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UNITED STATES OF AMERICA
BEFORE THE NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
	)	
Proposed Rule: Waste Confidence – Continued Storage of Spent Nuclear Fuel 10 C.F.R. Part 51	)	Docket No. 2012-0246
	)	
Draft Waste Confidence Generic Environmental Impact Statement	)	

Comments by Environmental Organizations
on Draft Waste Confidence Generic Environmental
Impact Statement and Proposed Waste Confidence Rule

And

Petition to Revise and Integrate All Safety and Environmental Regulations
Related to Spent Fuel Storage and Disposal

I. INTRODUCTION

The following Organizations hereby submit comments on the Draft Waste Confidence Generic Environmental Impact Statement ("DGEIS") and proposed revisions to NRC's regulations for implementation of the National Environmental Policy Act ("NEPA") regarding environmental impacts of spent fuel storage, 78 Fed. Reg. 56,776 (Sept. 13, 2013) ("proposed rule"): Alliance to Halt Fermi 3, Beyond Nuclear, Blue Ridge Environmental Defense League, Center for a Sustainable Coast, Citizens Allied for Safe Energy, Citizens' Environmental Coalition, Don't Waste Michigan, Ecology Party of Florida, Friends of the Coast, Friends of the Earth, Georgia Women's Action for New Directions, Green State Solutions, Hudson River Sloop Clearwater, Missouri Coalition for the Environment, NC WARN, Nevada Nuclear Waste Task Force, New England Coalition, No Nukes Pennsylvania, Northwest Environmental Advocates, Nuclear Energy Information Service, Nuclear Information and Resource Service, Nuclear Watch South, Physicians for Social Responsibility, Public Citizen, Promoting Health and Sustainable Energy, Radiation and Public Health Project, Riverkeeper, SEED Coalition, San Clemente Green, San Luis Obispo Mothers for Peace, Snake River Alliance, Southern Alliance for Clean Energy, and Vista 360.

These comments are supported by the Declaration of Dr. Arjun Makhijani (Dec. 20, 2013) (Exhibit A), the Declaration of David Lochbaum (Dec. 13, 2013) (Exhibit B), the Declaration of Dr. Gordon Thompson (Dec. 19, 2013) (Exhibit C), and the Declaration of Mark Cooper (Dec. 16, 2013) (Exhibit D).

This proceeding concerns the adequacy of NRC's response to the U.S. Court of Appeals' decision in *New York v. NRC*, 681 F.3d 471 (D.C. Cir. 2012), in which the Court vacated NRC safety findings regarding the availability of sufficient repository capacity for disposal of spent fuel and the safety of storing spent fuel in the interim. The Court concluded that the NRC lacked a lawful basis to rely on those safety findings to license and re-license nuclear reactors, because it had not analyzed, pursuant to NEPA, the reasonably foreseeable risk that sufficient repository capacity could not be found. 681 F.3d at 478.

Instead of supporting its reasonable assurance findings by conducting an appropriate environmental analysis of the probability of failing to site sufficient repository capacity and the consequences of such a failure, the NRC simply abandons those findings in the proposed rule. The words "reasonable assurance" — the key language of compliance with the Atomic Energy Act — do not appear in the proposed rule. Instead of predicting with "reasonable assurance" that spent fuel "will" be safely stored and disposed of, the NRC asserts — without any assurance — that it *can* be safely disposed of, *i.e.* that it is "feasible." These words confirm that, in the words of the Court of Appeals, "[t]he Commission apparently has no long-term plan other than hoping for a geologic repository."

But mere hope cannot satisfy the Atomic Energy Act. Under the Act and over thirty years of NRC and judicial interpretations, the proposed rule's failure to make reasonable assurance findings regarding the availability of a disposal solution for spent fuel deprives the NRC of any authority to license or re-license reactors. *See* 42 Fed. Reg. 34,391, 34,393 (July 5, 1977) ("The Commission would not continue to license reactors if it did not have reasonable confidence that the wastes can and will in due course be disposed of safely"); *Natural Resources Defense Council v. NRC*, 582 F.2d 166 (2nd Cir. 1978); *New York*, 681 F.3d at 474 (citing *Minnesota v. NRC*, 602 F.2d 412, 418 (D.C. Cir. 1979)); *Calvert Cliffs Nuclear Project, L.L.C. and Unistar Nuclear Operating Services, L.L.C.* (Calvert Cliffs Nuclear Power Plant, Unit 3), CLI-12-16, 76 NRC 63 , 66 (2012).

Moreover, even if the NRC were to attempt to make reasonable assurance findings, it lacks any technical basis for such findings. The DGEIS contains no analysis of the probability that sufficient repository capacity will be available or unavailable when needed. Such an analysis would require an evaluation of the likelihood that spent fuel repositories could be found that meet the U.S. Environmental Protection Agency's standards for a repository and the capacity of various geologic sites to accommodate the quantity of spent fuel to be generated. The last study the NRC did of that issue was in the mid-1970s, and it is severely outdated. Similarly, in order to provide sufficient support for a reasonable assurance finding regarding the safety of storing spent fuel for many decades if a repository is delayed, the NRC would have to catch up on long-delayed research regarding the long-term behavior of spent fuel in dry storage conditions. But the NRC is years away from obtaining adequate research results to make informed judgments about the safety of storing spent fuel for lengthy periods.

Without "reasonable assurance" safety findings regarding the availability of sufficient repository capacity or means of safely storing spent fuel for lengthy time periods -- or a technical basis for such findings -- the NRC has no authority under the Atomic Energy Act to continue licensing reactors to generate spent fuel. This failure to satisfy the Atomic Energy Act cannot be cured by the DGEIS, because a NEPA analysis cannot substitute for the safety findings that are independently required by the Atomic Energy Act.

Nor does the DGEIS satisfy NEPA. Even if the NRC could have made the reasonable assurance findings required by the Atomic Energy Act, the DGEIS is completely inadequate to support the licensing or re-licensing of reactors to generate spent fuel. In fact, the DGEIS flouts both NEPA and the Court's application of NEPA in *New York,* 681 F.3d 481 (D.C. Cir. 2012) in multiple ways:

- In blatant violation of NEPA and the Court's decision in *New York,* the DGEIS fails to examine the probability and consequences of failure to site a repository. Instead of examining the risk of failing to site a repository, the DGEIS rationalizes the risk away, by arbitrarily assuming that spent fuel will be protected by "institutional controls" for an infinite period of time at reactor sites. This assumption is not only absurd and inconsistent with the Nuclear Waste Policy Act ("NWPA"), but it also defeats the Court's purpose of forcing NRC to reckon with the environmental consequences of its failure to site a repository.

- The DGEIS fails to acknowledge that the proposed rule is a licensing action, and therefore it distorts the statement of purpose and need for the proposed rule as relating to administrative rather than environmental concerns. As a result, the DGEIS also mischaracterizes the alternatives that must be considered. Instead of evaluating alternatives related to storage and disposal of spent fuel, the DGEIS examines alternatives related to the administrative question of how to prepare an EIS. The result is a farcical cost-benefit analysis that utterly fails to address alternatives for avoiding or mitigating the environmental impacts of storing spent fuel or siting a repository.

- The DGEIS' analysis of the environmental impacts of extended spent fuel storage ignores the fact that NRC knows very little about the behavior of spent fuel in long-term or indefinite storage conditions, especially the potentially significant effects of long-term dry cask storage on high burnup fuel integrity. In violation of NEPA, the NRC makes no attempt to quantify these uncertainties.

- The DGEIS violates the Court's decision in *New York* by failing to analyze the significance of past spent fuel leaks for future risks, by making unsupported assumptions about its future ability to detect leaks, and by relying on inapplicable or nonexistent regulatory requirements for future prevention of leaks.

- The DGEIS asserts that the environmental impact of pool fires is "SMALL," *i.e.*, insignificant. In reaching this conclusion, the NRC uses a flawed concept of risk that is inappropriate to the consideration of potentially catastrophic environmental impacts. The DGEIS also ignores a range of pool fire causes, including the potential for an attack, the substantial cumulative frequency of fires, and the possibility that the risk environment will become more adverse in the future. If these factors are considered, the environmental impact of accident-induced pool fires is not SMALL, but LARGE.

- In violation of NEPA, the DGEIS makes no attempt to show how the environmental impacts associated with the proposed rule will be quantified and incorporated into cost-benefit analyses for nuclear reactors. Although spent fuel disposal and long-term storage costs are high enough to tip the balance of a cost-benefit analysis for reactor licensing away from licensing, nowhere does the NRC explain how it will take these costs into account in reactor licensing decisions.

- The NRC has splintered the analysis of environmental impacts associated with storage and disposal of spent fuel into an array of safety findings and environmental analyses. While the issues covered by these separate findings and analyses overlap and involve cumulative impacts, the NRC refuses to integrate them. The NRC also refuses to correct inconsistencies between them.

In order to comply with NEPA, the NRC must show that it has made a thorough assessment of the environmental risks of siting a repository and storing spent fuel for lengthy and perhaps indefinite periods. As discussed in the attached declarations by Dr. Arjun Makhijani, Dr. Gordon Thompson, and David Lochbaum, these impacts are significant. In addition, the DGEIS must show that it has quantified the risks and costs associated with siting a repository or failing to do so, including the risks and costs of maintaining spent fuel at reactor sites or away-from-reactor storage facilities for an indefinite period. The attached declaration of Mark Cooper shows that these costs are not only significant, but they may tip the balance of a cost-benefit analysis away from licensing or re-licensing reactors to energy efficiency and other energy alternatives.

Finally, the DGEIS must show how the significant risks and costs of siting a reactor or failing to do so, plus the risks and costs of spent fuel storage, will be integrated into the cost-benefit analyses for individual reactors. The proposed rule and DGEIS come at a critical juncture for the U.S. energy future. The costs of clean energy alternatives such as wind and solar are declining at the same time that costs of building new reactors and maintaining aging existing reactors are going up. Spent reactor fuel inventories, along with their storage costs and environmental risks, are also mounting at every U.S. reactor site -- and the prospect of a permanent repository grows more distant and costly with each passing decade. Under the circumstances, as demonstrated in the attached Declaration of Mark Cooper, the costs of spent fuel management could tip the balance away from new or re-licensed nuclear reactors toward energy efficiency or clean alternative energy sources. Thus it is important for the NRC to ensure that these energy choices are well-informed by full consideration of environmental risks and a weighing of reasonable alternatives, as required by NEPA. But the NRC has not even acknowledged its obligation to make that analysis, let alone shown how it plans to carry it out.

In *Calvert Cliffs,* CLI-12-16, the NRC suspended all reactor licensing and re-licensing while it responded to the Court's order in *New York.* 76 NRC 63 (2012). As the Commission recognized, "[w]aste confidence undergirds certain agency licensing decisions, in particular new reactor licensing and license renewal." *Id.* at 66. The NRC has not satisfied the Court's order, NEPA, or the Atomic Energy Act. Therefore, licensing and re-licensing of reactors must remain suspended unless and until the NRC complies with the law.

Petition to Revise and Integrate All Safety and Environmental Regulations Related to Spent Fuel Storage and Disposal

The Organizations respectfully request the NRC to revise and integrate all regulations that relate to the environmental impacts of spent fuel storage and disposal. Issues related to spent fuel storage impacts are now balkanized into separate rulemakings for spent fuel disposal impacts (Table S-3), safety and impacts of spent fuel storage and disposal from fuel generated during the license renewal period (Table B-1), safety and impacts of spent fuel storage after license termination (proposed 10 C.F.R. § 51.23), and safety and feasibility of siting a spent fuel repository (proposed 10 C.F.R. § 51.23).

While the NRC has divided consideration of environmental impacts into piecemeal decision-making, they are in fact related. By considering them separately, the NRC ignores the interaction of impacts, cumulative impacts, and inconsistencies in safety and environmental analyses conducted in the separate decision-making processes. In order to comply with NEPA, the NRC should conduct a comprehensive review of these regulations and environmental studies, revise them to be consistent with the current state of knowledge, and integrate them into one cohesive regulatory framework.

II. DESCRIPTION OF ORGANIZATIONS

The following is a description of the commenter organizations. All of the organizations are neighbors of existing or proposed nuclear power plants, and most have either intervened or plan to intervene in NRC proceedings for the licensing or re-licensing of nuclear power plants.

The Alliance to Halt Fermi 3 ("ATHF3") is a union of concerned individuals and organizations dedicated to halting Detroit Edison from building Fermi 3, a proposed new nuclear reactor near Monroe, Michigan. ATHF3 is also committed to the shutdown of the existing Fermi 2 as soon as possible.

Beyond Nuclear is a national watchdog organization on the nuclear power and radioactive waste industries, as well as on the federal government agencies which are supposed to protect the public and the environment from the risks of radiation and radioactive waste to human health and ecosystems. Beyond Nuclear aims to educate and activate the public about the connections between nuclear power and nuclear weapons and the need to abandon both to safeguard our future, including on the risks associated with the inevitable generation of radioactive waste by the nuclear industry. Beyond Nuclear advocates for an energy future that is sustainable, benign, and democratic. It is headquartered in Takoma Park, Maryland, a Nuclear-Free Zone.

The Blue Ridge Environmental Defense League ("BREDL") is a 25-year-old regional, community-based non-profit environmental organization in the southeastern United States, whose founding principles are earth stewardship, environmental democracy, social justice, and community empowerment. BREDL encourages government agencies and citizens to take responsibility for conserving and protecting our natural resources. BREDL advocates grassroots involvement to empower whole communities in environmental issues. BREDL also functions as a "watchdog" of the environment, monitoring issues and holding government officials accountable for their actions.

The Center for a Sustainable Coast was established in 1997 to improve the responsible use, protection, and conservation of Georgia's coastal resources – natural, historic, and economic. The Center for a Sustainable Coast works toward this objective by educating community members, collaborating with other groups, advising decision-makers and stakeholders, advocating legislation and scientific research, and taking legal action to prevent and control unwise activities that threaten to impair the quality, capacity, or diversity of the region's resources.

Citizens Allied for Safe Energy ("CASE") seeks to promote safe and sustainable energy production for Florida's communities and to oppose energy production that is harmful to Florida's communities' economic well-being, public health, and the environment. CASE seeks to carry out this mission by educating and mobilizing the public.

Citizens' Environmental Coalition ("CEC") is a 35-year-old grassroots organization dedicated to eliminating toxic pollution and cleaning up hazardous sites. CEC advocates closure of New York State's nuclear reactors and cleanup of the West Valley radioactive waste site. CEC also promotes clean sustainable energy and efforts to deal with climate change.

Don't Waste Michigan is a state-based organization formed to stop Michigan from becoming a nuclear waste dumpsite.

Ecology Party of Florida is an independent party setting out to transform politics in the State of Florida, in part through environmental issue-oriented advocacy. The Ecology Party focuses on environmental issues concerning nuclear power in Florida.

Friends of the Coast is a Maine-based organization advocating for nuclear safety, safe storage of nuclear waste, and protection of the human environment from nuclear pollution. Friends of the Coast was the only environmental advocacy organization actively engaged in the decommissioning of Maine Yankee Atomic Power Station (1997-2005) and the only non-governmental organization involved in oversight of the Maine Yankee Independent Spent Fuel Storage Installation.

Friends of the Earth is a leader in climate and energy solutions and in protecting human communities from environmental harm. It is the U.S. voice of an influential international network that operates in 70 countries. In South Carolina, Friends of the Earth has intervened in the NRC's licensing proceeding and the state regulatory proceeding for the V.C. Summer nuclear power plant.

Georgia Women's Action for New Directions ("WAND") is an independent grassroots, woman-led organization that seeks to direct women's voices into a powerful movement for social change. Georgia WAND promotes clean air, clean water, and a carbon-free, nuclear-free future through its environmental justice work. Georgia WAND monitors activities and policy decisions that affect the Savannah River Site and nuclear power plants.

Green States Solutions is an Iowa-based consulting firm specializing in advocacy, outreach, and campaign organization around climate change, renewable energy, energy efficiency, sustainability, and other environmental issues.

Hudson River Sloop Clearwater is a member-supported non-profit corporation whose mission is to preserve and protect the Hudson River, its tributaries, and related bodies of water. To achieve this, Clearwater works to provide innovative environmental programs, advocacy, and celebrations to inspire, educate, and activate the next generation of environmental leaders. Clearwater advocates for the closing of the Indian Point nuclear reactors in New York.

The Missouri Coalition for the Environment is an environmental advocacy organization, working on a variety of issues that affect human and environmental health. Missouri Coalition for the Environment focuses on issues surrounding clean water, clean air, clean energy and a healthy environment and uses education, public engagement, and legal action to achieve its goals.

Nevada Nuclear Waste Task Force was formed in the late 1980s and focuses its work on national nuclear waste policy and issues surrounding Yucca Mountain.

Since 1971, the New England Coalition ("NEC") has advocated for safe energy in New England and has provided education and resources for alternatives to nuclear power. NEC has also intervened in numerous NRC licensing proceedings involving the safety and environmental impacts of spent fuel storage at New England nuclear power plants.

No Nukes Pennsylvania is a Pennsylvania organization dedicated to fighting nuclear power.

North Carolina Waste Awareness and Reduction Network ("NC WARN") is a member-based non-profit tackling the accelerating crisis posed by climate change – along with the various risks of nuclear power – by watch-dogging Duke Energy practices and working for a swift North Carolina transition to energy efficiency and clean power generation. NC WARN partners with other citizen groups and uses sound scientific research to inform and involve the public on important environmental issues.

Northwest Environmental Advocates ("NWEA") promotes human health and environmental restoration in Oregon and Washington and on a national level. NWEA was founded in 1969 by citizens who were concerned about the imminent operation of the Trojan Nuclear Power Plant, located along the Columbia River at Rainier, Oregon. NWEA fought the Trojan plant throughout its inception until its eventual closure in 1993. NWEA has also been active in challenging a number of other nuclear reactors.

Nuclear Energy Information Service ("NEIS") is a non-profit organization committed to ending nuclear power. NEIS works to achieve this mission through educating, activating, and organizing the public on energy issues, building and mobilizing grass roots power and nonviolent opposition to nuclear power, and advocating for sustainable and ecologically-sound energy alternatives.

Nuclear Information and Resource Service ("NIRS") is a non-profit corporation with over 12,000 members across the United States. NIRS has a mission to promote a nonnuclear energy policy and a concern for the health and safety of the people and ecosphere.

Nuclear Watch South (formerly Georgians Against Nuclear Energy) is a grassroots, direct-action environmental group dedicated to phasing out nuclear power plants, abolishing nuclear weapons, safeguarding nuclear materials; and establishing ethical social policies for nuclear waste management.

Physicians for Social Responsibility ("PSR") has been working for over 50 years to create a healthy, just, and peaceful world for present and future generations. PSR uses its medical and public health expertise to prevent nuclear war and proliferation; slow, stop, and reverse global warming; protect the public from toxic chemicals; and eliminate the use of nuclear power.

Promoting Health and Sustainable Energy ("PHASE") is a nonprofit organization that provides the public with information regarding safety, health impacts and sustainable energy.

Public Citizen is a national, nonprofit consumer advocacy organization with over 70,000 members nationwide. Public Citizen's mission is to protect openness and democratic accountability in government and the health, safety, and financial interests of consumers. Public Citizen advocates for policies that will lead to safe, affordable and environmentally sustainable energy.

The Radiation and Public Health Project is the only U.S. organization whose mission is to conduct research and education on the health hazards posed by nuclear reactors. Group members have published 32 medical journal articles, 8 books, and 53 newspaper op-eds; have participated in 27 press conferences on findings; and testified to 19 government panels.

Riverkeeper is a non-profit, membership-supported environmental organization. Its mission is to protect the environmental, recreational and commercial integrity of the Hudson River and its tributaries, and safeguard the drinking water of nine million New York City and Hudson Valley residents.

San Clemente Green ("SCG") is an informal group of over 5,000 citizens dedicated to sustainable living. SCG's members are deeply concerned about the risks of living near the San Onofre Nuclear Generating Station ("SONGS"). SCG opposed the restart of SONGS and supports the safe decommissioning of the nuclear plant.

San Luis Obispo Mothers for Peace ("SLOMFP") is a non-profit organization concerned with the risks and hazards connected with the Diablo Canyon Nuclear Power Plant and with the dangers of nuclear power, weapons and waste on national and global levels. An all-volunteer non-profit group, SLOMFP has challenged NRC licensing decisions within the NRC and in Federal Courts since 1973.

Sierra Club Nuclear Free Campaign works to promote an energy efficient world, powered by clean, renewable technologies, free from dirty, dangerous, costly nuclear power and its legacy of toxic waste. Sierra Club Nuclear Free Campaign works to stop proposed new nuclear power and license extensions of existing plants and to address the mounting problems associated with nuclear radioactive waste.

The Snake River Alliance is an Idaho-based grassroots group working through research, education, and community advocacy for peace and justice, the end to nuclear weapons, responsible solutions to nuclear waste and contamination, and sustainable alternatives to nuclear power. The Snake River Alliance is Idaho's only grassroots nuclear watchdog and its leading advocate for clean energy.

The Southern Alliance for Clean Energy ("SACE") is a coalition of environmental and citizen organizations promoting green energy in the southeastern United States. SACE has intervened in several NRC proceedings for the licensing of new nuclear power plants.

The Sustainable Energy and Economic Development ("SEED") Coalition is a project of Texas Fund for Energy and Environmental Education, Inc., a statewide nonprofit organization with 5,000 members working for clean air and clean energy in Texas. The organization advocates for sustainable energy, including energy efficiency, renewable energy, and conservation.

Vista 360 is an independent Public Interest Leadership group of scientists, engineers, and business executives who engage in issues that potentially impact the public. Vista 360 is currently engaged in the Zion Decommissioning & Site Restoration Project (Zion Illinois 2010-2020) which is the largest decommissioning project in U.S. nuclear history.

III. BACKGROUND

A. Proposed Rule

Proposed Section 51.23(a) makes the following predictions:

> 1. It is "feasible to safely store spent nuclear fuel following the licensed life for operation of a reactor" and
> 2. It is "feasible to have a mined geologic repository within 60 years following the licensed life for operation of a reactor."

78 Fed. Reg. 56776, 56804 (September 13, 2013). The NRC states that these predictions are based on the Draft GEIS. *Id.*

Proposed Table B-1 makes the following findings regarding spent fuel storage and disposal impacts in license renewal cases:

> The expected increase in the volume of spent fuel from an additional 20 years of operation can be safely accommodated onsite with small environmental effects through dry or pool storage at all plants, if a permanent repository or monitored retrievable storage is not available.
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> * * *
>
> For the high-level waste and spent-fuel disposal component of the fuel cycle, the EPA established a dose limit of 15 millirem (0.15 mSv) per year for the first 10,000 years and 100 millirem (1.0 mSv) per year between 10,000 years and 1 million years for offsite releases of radionuclides at the proposed repository at Yucca Mountain, Nevada.
>
> The Commission concludes that the impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR Part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the impacts of spent fuel and high level waste disposal, this issue is considered Category 1.

78 Fed. Reg. at 56,805.

B. Draft GEIS

1. Description and characterization of federal action

On September 13, 2013, along with its proposed rule, the NRC also issued its Draft Waste Confidence Generic Environmental Impact Statement (DGEIS), NUREG-2157. *See* 78 Fed. Reg. 56621 (Sept. 13, 2013). The DGEIS purports to analyze "the environmental impacts of continued storage of spent fuel." DGEIS at xxv.

The DGEIS describes the federal action to be evaluated as follows:

> The Commission proposes to issue a revised Rule, 10 CFR 51.23, that generically addresses the environmental impacts of continued storage. This revision would adopt into regulation the environmental impact analyses in this draft GEIS. Further, the revision would state that because the impacts of continued storage have been generically assessed in this draft GEIS and codified in a Rule, NEPA analyses for future reactor and spent fuel storage facility licensing actions would not need to separately consider the environmental impacts of continued storage.

DGEIS at 1-5. The DGEIS acknowledges that the proposed rule is a major federal action. *Id.* at 1-3. But NRC denies that by generically resolving environmental issues with respect to reactor licensing, the proposed rule constitutes a licensing action:

> **The Waste Confidence rulemaking is not a licensing action**. It does not permit a nuclear power plant or any other facility to operate or store spent fuel. Every nuclear power plant or specifically licensed spent fuel storage facility must undergo an environmental review as part of its site-specific licensing process.

DGEIS at xxvi (emphasis in original).

2. Description of purpose and need

The DGEIS describe the purpose and need for the proposed action of codifying the environmental impacts of spent fuel storage and excusing their consideration in individual licensing cases as follows:

> The purpose and need for the proposed action are threefold: (1) to improve the efficiency of the NRC's licensing process by generically addressing the environmental impacts of continued storage; (2) to prepare a single document that reflects the NRC's current understanding of these environmental impacts; and (3) to respond to the issues identified in the remand by the Court in the *New York v. NRC* decision. The NRC intends to codify the results of its analyses in this draft GEIS at 10 CFR 51.23. NRC licensing proceedings for nuclear reactors and ISFSIs will continue to rely on the generic determination in 10 CFR 51.23 to satisfy obligations under NEPA with respect to the environmental impacts of continued storage.

DGEIS at 1-6. In other words, the purpose and need for the proposed action, as described in the DGEIS, is to justify a generic approach to the analysis of the environmental impacts of spent fuel storage, in lieu of a reactor-specific analysis.

3. Identification and weighing of alternatives

Guided by the DGEIS' methodology-focused definition of the purpose and need for the federal action, Chapter 7 sets forth an array of methodological alternatives for analyzing the environmental impacts of spent fuel storage. Instead of avoiding or diminishing physical environmental impacts of spent fuel, the alternatives considered in the DGEIS "provide different approaches that the NRC could apply to future licensing activities that can satisfy the agency's responsibility to consider the potential environmental impacts of continued storage in deciding whether to issue certain licenses." DGEIS at 7-1.

Thus, the DGEIS purports to analyze three methodological alternatives for evaluating environmental impacts of spent fuel storage and applying them in licensing decisions:

- First, the NRC could take no action and address the environmental impacts from continued storage in each of its nuclear power plant and ISFSI initial licensing and license renewal proceedings.
- Second, the NRC could develop a GEIS without incorporating the results into a rule. This approach would allow the NRC to adopt these draft GEIS

> findings into environmental reviews for future licensing activities, but without the binding effect of a rule.
>
> • Third, the Commission could issue a policy statement. The policy statement would not bind licensees and applicants like a rule, but it would provide notice of the Commission's intent to incorporate the findings of the GEIS into environmental reviews for future licensing activities.

DGEIS at 1-6.

The cost-benefit analysis in the DGEIS follows suit, comparing the administrative costs of preparing an EIS generically or on a site-specific basis. DGEIS at 7-2. Not surprisingly, given that none of these alternatives involves actual changes to the way nuclear reactors are operated or spent fuel is handled, the NRC reaches the conclusion that "[t]he alternatives considered in this chapter do not noticeably alter the environmental impacts from continued storage that the NRC addressed in Chapters 4, 5, and 6." DGEIS at 7-1. The rationale offered by the DGEIS for failing to evaluate the costs of continued spent fuel storage is that this activity "will occur regardless of the alternative that the NRC selects to consider its impacts." DGEIS at 7-1.

NRC analyzes the costs and benefits of NEPA review for the proposed action and each of its alternatives in terms of the actual cost of environmental review—i.e., site-specific review costs versus generic review costs. *See* DGEIS at 7-7–7-13. For example, the DGEIS asserts:

> While the no-action alternative avoids the costs associated with a GEIS and rulemaking, site specific review costs are significantly higher than the avoided costs of the GEIS and rulemaking. The GEIS-only and policy-statement alternatives avoid the costs of rulemaking, but result in higher costs than the no action alternative because of their respective up-front costs.

DGEIS at 7-14. As a result, the DGEIS concludes that:

> The primary benefit of the proposed action is that it eliminates the costs associated with site specific licensing reviews of issues related to the environmental impacts of continued storage.

DGEIS at 7-8.

4. Evaluation of environmental impacts

In Chapters 4, 5, and 6 and Appendices B, E, and F, the DGEIS evaluates the environmental impacts of spent fuel storage. Chapter 4 evaluates the environmental impacts of at-reactor spent fuel storage. Chapter 5 evaluates the environmental impacts of away-from-reactor storage. Chapter 6 evaluates cumulative environmental impacts. The appendices provide more detailed analyses of the technical feasibility of continued spent fuel storage and repository availability (Appendix B), spent fuel pool leak risks (Appendix D), and spent fuel pool fire risks (Appendix E). In all cases, the NRC concludes that environmental impacts are insignificant.

The DGEIS analyzes environmental impacts in three separate time frames: short-term storage (60 years beyond a reactor's licensed life), long-term storage (160 years beyond a reactor's licensed life), and indefinite storage in the event a repository does not become available. DGEIS at xxix – xxx, 1-13. For the indefinite storage periods, the DGEIS assumes that institutional controls, *i.e.*, "the continued regulation of spent nuclear fuel," will remain in effect. DGEIS at 1-14. According to the DGEIS:

> This assumption avoids unreasonable speculation regarding what might happen in the future regarding Federal actions to provide for the safe storage of spent fuel. Although government agencies and regulatory safety approaches can be expected to change over long periods of time in the future, the history of radiation protection has generally been towards ensuring increased safety as knowledge of radiation and effectiveness of safety measures has improved. For the purpose of the analyses in this draft GEIS, the NRC assumes that regulatory control of radiation safety will remain at the same level of regulatory control as currently exists today.

DGEIS at 1-14 (emphasis added).

5. Rationale for refusing to consider alternatives that would avoid or mitigate environmental impacts of spent fuel storage

The DGEIS lists a set of alternatives, proposed for consideration by members of the public, that could avoid or mitigate the adverse environmental impacts of spent fuel storage, but the NRC refuses to analyze them in the DGEIS:

> During the scoping period for the draft GEIS, the NRC received many suggested alternatives to the Waste Confidence rulemaking, including calls for halting NRC licensing activities and shutting down operating reactors or imposing new requirements on nuclear power plants, such as storing spent fuel in special hardened onsite storage, reducing spent fuel pool density, and accelerating the transfer of spent fuel from pools to dry casks. The NRC determined that halting NRC licensing and closing nuclear reactors would not meet the purpose and need of the proposed rulemaking action. The NRC also determined that additional requirements on spent fuel storage would not meet the purpose and need. Further, the draft GEIS is a NEPA review and not a licensing action; therefore, this draft GEIS would not be the appropriate activity in which to mandate new spent fuel storage requirements.

DGEIS at xxvi. The DGEIS provides the additional rationale that:

> Although cessation of nuclear power plant licensing and operations would halt the future generation of spent fuel, other environmental impacts could result from the required development of replacement power sources or demand reductions. Even then, the environmental impacts of continued storage would not cease until sufficient repository capacity becomes available.

DGEIS at 1-9.

COMMENTS

IV. THE PROPOSED RULE FAILS TO SATISFY ATOMIC ENERGY ACT REQUIREMENTS FOR LICENSING AND RE-LICENSING REACTORS

A. The Proposed Rule Violates the Atomic Energy Act by Eliminating Previous Safety Findings That Are Essential to Atomic Energy Act Compliance

As the NRC conceded in its first waste confidence decision (Denial of Petition for Rulemaking, 42 Fed. Reg. 34,391 (July 5, 1977)) and as affirmed by the U.S. Court of Appeals in *Natural Resources Defense Council v. NRC,* 582 F.2d 166 (2nd Cir. 1978), in order to satisfy the Atomic Energy Act, NRC reactor licensing decisions must include predictive reasonable assurance findings regarding (a) the availability of sufficient and safe spent fuel disposal capacity when it is necessary and (b) the safety of spent fuel storage in the meantime. *See also Minnesota v. NRC*, 602 F.2d 412 (D.C. Cir. 1979). As the NRC explained in 1977, in its first pronouncement on the issue:

> The Commission would not continue to license reactors if it did not have reasonable confidence that the wastes can and will in due course be disposed of safely. The accumulating evidence as discussed below continues to support the Commission's implicit findings of reasonable assurance that methods of safe permanent disposal of high-level wastes can be available when they are needed. Given this, and the fact that at present safe storage methods are presently available and highly likely to remain so until a permanent disposal system can be demonstrated and licensed, the Commission sees no reason to cease licensing reactors.

42 Fed. Reg. at 34,393. While these reasonable assurance findings do not need to be as rigorous as other safety findings because they predict events far in the future, they must demonstrate a technical basis for a reasonable level of "confidence" that reactor fuel will be isolated from humans and the environment as long as it remains radioactive. 44 Fed. Reg. at 34,393.

Until the instant proposed rule, all NRC "waste confidence" decisions, since the first decision in 1984, have included "reasonable assurance" findings. For instance, Findings 2 and 4 of the 1984 waste confidence decision contained "reasonable assurance" findings regarding the same issues:

> (2) The Commission finds *reasonable assurance* that one or more mined geologic repositories for commercial high-level radioactive waste and spent fuel will be available by the years 2007-09, and that sufficient repository capacity will be available within 30 years beyond expiration of any reactor operating license to

> dispose of existing commercial high level radioactive waste and spent fuel originating in such reactor and generated up to that time.
>
> (4) The Commission finds *reasonable assurance* that, if necessary, spent fuel generated in any reactor can be stored safely and without significant environmental impacts for at least 30 years beyond the expiration of that reactor's operating license at that reactor's spent fuel storage basin, or at either onsite or offsite independent spent fuel storage installations.

49 Fed. Reg. 34,660 (Aug. 31, 1984) (emphasis added). Similarly, Findings 2 and 4 of the 1990 waste confidence decision contained "reasonable assurance" findings regarding the same issues:

> (2) The Commission finds *reasonable assurance* that at least one mined geologic repository will be available within the first quarter of the twenty-first century, and that sufficient repository capacity will be available within 30 years beyond the licensed life for operation (which may include the term of a revised or renewed license) of any reactor to dispose of the commercial HLW and SNF originating in such reactor and generated up to that time.
>
> (4) The Commission finds *reasonable assurance* that, if necessary, spent fuel generated in any reactor can be stored safely and without significant environmental impacts for at least 30 years beyond the licensed life for operation (which may include the term of a revised or renewed license) of that reactor at its spent fuel storage basin, or at either onsite or offsite ISFSIs.

55 Fed. Reg. 38,474 (Sept. 18, 1990) (emphasis added). Findings 2 and 4 of the 2010 waste confidence decision (subsequently vacated by the Court of Appeals on other grounds) also stated:

> (2) The Commission finds *reasonable assurance* that sufficient mined geologic repository capacity will be available to dispose of the commercial high-level radioactive waste and spent nuclear fuel generated by any reactor when necessary.
>
> (4) The Commission finds *reasonable assurance* that, if necessary, spent fuel generated in any reactor can be stored safely and without significant environmental impacts for at least 60 years beyond the licensed life for operation (which may include the term of a revised or renewed license) of that reactor in a combination of storage in its spent fuel storage basin and either onsite or offsite ISFSIs.

75 Fed. Reg. 81,037, 81,040 (Dec. 23, 2010) (emphasis added).

The proposed rule violates the Atomic Energy Act by completely eliminating any "reasonable assurance" safety findings regarding the safety of spent fuel storage or the availability of spent fuel disposal capacity. The only safety finding made in the proposed rule is a statement in the preamble that the NRC *lacks* confidence to make a reasonable assurance finding regarding the availability of a “disposal solution” at “the end of a reactor’s licensed life for operation.” 78 Fed. Reg. at 56,784.

While admitting in a footnote that “reasonable assurance” findings regarding an “offsite storage solution” and interim storage are required by law (78 Fed. Reg. at 56,778 n. 1 (citing *Minnesota*, 602 F.2d at 418)), the NRC asserts that the proposed rule’s only purpose is to codify the results of a NEPA analysis:

> *B. Waste Confidence Rulemaking*
> B1. What is the purpose of this Waste Confidence rulemaking? The NRC’s use of a rule to generically satisfy its NEPA obligations with respect to continued storage will enhance efficiency in individual licensing reviews by analyzing the environmental impacts of continued storage, which are the same or largely similar at each nuclear power reactor or storage site, and codifying the results of that analysis. Part of the environmental analysis for a nuclear power reactor or storage facility license includes a review of the impacts caused by the spent nuclear fuel generated in the reactor. That analysis must assess the impacts of the spent nuclear fuel from generation through disposal. If the Commission lacks reasonable assurance that a disposal solution will be available at the end of a reactor’s licensed life for operation, NEPA requires that the Commission assess the impacts of continued storage of the spent nuclear fuel pending disposal at a repository.

78 Fed Reg. 56,783-84. But the NRC’s complete substitution of NEPA findings for safety findings is unlawful. The NRC must comply with *both* the Atomic Energy Act *and* NEPA. *Limerick Ecology Action v. NRC,* 869 F.2d 719, 729 (3d Cir. 1989). The two statutes are independent and distinct in their requirements. The Atomic Energy Act establishes a minimum level of protection of public health and safety against radiological hazards. NEPA, on the other hand, requires disclosure and weighing of risks posed by licensing actions that are authorized by the NRC under the Atomic Energy Act; but it does not establish minimum standards. The two statutes do overlap. For example, NEPA requires the NRC to consider the reasonably foreseeable risk that siting sufficient repository capacity will not be feasible, and what would be the impacts if it is not feasible. But compliance with one statute does not excuse compliance with the other. *Limerick Ecology Action*, 869 F.2d at 729-30 (noting that case law “do[es] not suggest that NEPA can never require consideration of additional alternatives simply because there is some overlap in the considerations required by both statutes”). Moreover, while the Court of Appeals in *New York* focused on the NRC’s noncompliance with NEPA in promulgating the 2010 Waste Confidence Decision, nothing in the Court’s opinion could be read to reverse *Natural Resources Defense Council* or *Minnesota*’s holdings that the NRC must make waste confidence safety findings that comply with the Atomic Energy Act. In the absence of such reasonable assurance findings, the NRC has no lawful basis for issuing or re-issuing reactor licenses. 42 Fed. Reg. at 34,393; *Natural Resources Defense Council,* 582 F.2d at 170; *Minnesota v. NRC,* 602 F.2d at 418.

B. The Proposed Rule Violates the Atomic Energy Act by Removing the Previous Finding Regarding Sufficiency of Repository Capacity

As discussed above, until the instant proposed rule, all NRC "waste confidence" decisions have included "reasonable assurance" findings. In addition, until the proposed rule, all "waste confidence" decisions have specifically addressed the question of whether the NRC has reasonable assurance that sufficient repository capacity will be available to accommodate spent reactor fuel when it is needed. This change can be seen by comparing the proposed rule with all of the quotations from Findings 2 and 4 in Section A above.

In contrast to these previous findings, the proposed rule finds only that it is "feasible" to "safely store spent nuclear fuel following the licensed life for operation of a reactor" and that it is "feasible" to "have a mined geologic repository within 60 years following the licensed life for operation of a reactor." 78 Fed. Reg. at 56,804.[1] The NRC's previous reasonable assurance finding regarding the availability of sufficient repository capacity for disposal of spent fuel *has completely disappeared from the NRC's regulations.* Its disappearance is not explained. Neither the proposed rule nor the accompanying DGEIS gives any explanation as to why the proposed rule now fails to address the question of whether the NRC has a reasonable basis for confidence in the availability of sufficient repository capacity when it is needed. The closest the NRC comes to addressing the issue is by entitling a section in Appendix B "Repository Capacity will be Available to Dispose of Spent Fuel." *Id.* at B-2. But the heading makes no reference to reasonable assurance or the sufficiency of capacity, and the text that accompanies that heading makes no assertion that the NRC has a technical basis for a finding of reasonable assurance that sufficient repository capacity will be available when it is necessary. Nor does the DGEIS contain any analysis of the risk that sufficient repository capacity will not become available when it is needed.

Instead, the DGEIS analyzes "scenarios" which assume the unavailability of repository capacity. That is a far cry from analyzing the question of whether the NRC has a technical basis for a reasonable assurance finding regarding the availability of sufficient repository capacity or an environmental risk analysis of the uncertainty surrounding such a prediction. As the Court ruled in *New York*, the NRC must evaluate the "likelihood of nonavailability" of repository capacity unless it is "remote and speculative." 681 F.3d at 479. And a finding of technical feasibility is a far cry from a finding that sufficient repository capacity will actually be available.

The sufficiency of repository capacity is a crucially important consideration in determining whether it is safe for the NRC to continue to allow the generation of spent fuel in licensing decisions. Spent fuel is a highly radioactive substance that must be isolated for many thousands of years in order to protect public health and the environment. Generalizations about the technical feasibility of "a" repository do not answer the question of whether repository capacity will be sufficient to accommodate the spent fuel that will be generated in the future by reactors that have not yet been licensed or re-licensed. As discussed in the attached Makhijani

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[1] In previous waste confidence decisions, the NRC used the term "feasible" in reasonable assurance findings regarding high-level waste disposal. *See, e.g.,* Finding 1 of the 1990 waste confidence decision: "The Commission finds reasonable assurance that safe disposal of high-level radioactive waste and spent fuel in a mined geologic repository is technically feasible." 55 Fed. Reg. at 38,475 (1990).

Declaration (pars. 8.4 – 8.13), "[t]he proposed rule's assertion of the feasibility of a repository does not guarantee that there will be a repository with sufficient capacity to accommodate all the spent fuel envisioned."

In addition, the proposed rule's failure to address the sufficiency of repository capacity is inconsistent with Congressional policy that disposal of spent fuel in a repository is the only safe means of protecting public health and the environment from spent fuel in the long run. *See* Section 11 of the Nuclear Waste Policy Act ("NWPA"), which establishes a national policy of disposing of spent nuclear fuel in a deep geologic repository. 42 U.S.C. § 10131 (1982).[2] In the proposed rule, the NRC appears to assume that no reasonable assurance finding regarding repository capacity is needed because of its opinion that spent fuel can be stored safely for the long-term or perhaps indefinitely at reactor sites or away-from reactor storage facilities. Aside from the fact that NRC's opinion is essentially unsupported (*see* discussion in Section VI.A below), that assumption cannot be squared with the NWPA.

C. Lack of Sufficient Technical Support for Reasonable Assurance Findings

Even if the NRC were to attempt to make "reasonable assurance" findings about the availability of sufficient repository capacity or the safety of extended interim storage of spent fuel as required by the Atomic Energy Act, NRC has demonstrated by its own actions that it lacks sufficient information to support such findings. The question of feasibility of spent fuel disposal cannot be evaluated without considering the probability that a repository will safely contain radioactivity for the hundreds of thousands of years required. In order to evaluate that probability, it is necessary to evaluate the environmental impacts of disposing of spent fuel in a range of geologic media. NRC cannot simply presume that a repository is feasible. Disposal impacts are relevant because they are part of the waste confidence finding that a mined geologic repository is feasible. By definition, a "feasible" repository must meet reasonable health and safety standards. Further, sufficient capacity at one or more such sites meeting safety criteria must be available to accommodate spent fuel from any and all commercial light water reactors that may be built. The Draft GEIS sets no upper limit on the amount of spent fuel to be disposed of. By failing to evaluate spent fuel disposal impacts and the sufficiency of repository capacity (if necessary at more than one site), the NRC has excluded a major part of the picture regarding the feasibility of spent fuel disposal. *See* Makhijani Declaration, pars. 8.2-8.24.

Nor does the NRC have a sufficient technical understanding of the risks of extended spent fuel storage to support a reasonable assurance finding. As discussed in the Organizations' comments on the scope of the DGEIS, NRC's own documents show that existing information is grossly inadequate to support any reasonable predictive findings about the safety of such long-term spent

[2] The NWPA also clearly distinguishes between storage and disposal. Storage is the "retention of . . . spent nuclear fuel . . . with the intent to recover such waste or fuel for subsequent use, processing, or disposal." Section 2(25). Disposal is the "emplacement in a [deep geologic] repository . . . with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste." Section 2(9), (18).

fuel storage.[3] There is no existing environmental or other study that has even attempted to predict the environmental impacts of storing spent fuel on site for hundreds of years, or perhaps indefinitely. Indeed, all other studies have been premised on the opposite conclusion – that a repository will be available in the relatively near future. NRC has commenced a study of the issue: the "Long-Term Waste Confidence Update Project," in which the NRC proposes to assess the environmental impacts of storing spent fuel for 200 years after cessation of licensing. *See* 75 Fed. Reg. at 81,040.[4] But work on the Long-Term Waste Confidence Update Project had only just begun at the time of the D.C. Circuit's decision, and it is far from complete.

The NRC Staff has estimated that the Long-Term Waste Confidence Update Project EIS will take until 2019 to finish. COMSECY-12-0016, Memorandum from R.W. Borchardt to NRC Commissioners re: Approach for Addressing Policy Issues Resulting from Court Decision to Vacate Waste Confidence Decision and Rule at 3 (July 9, 2012) ("COMSECY-12-0016"). Two preliminary studies issued as part of the Project support the Staff's seven-year time estimate by demonstrating (a) the complexity of the issues raised by long-term and indefinite spent fuel storage and (b) the Commission's lack of knowledge on the subject. The first study, issued for comment in December 2011, sets forth a series of topics that must be addressed in the Long-Term Waste Confidence Update Project EIS, including the degree to which nuclear power will be used in the future, the nature of future dry cask storage and transportation technology, prospects for long-term maintenance of institutional and regulatory control, and accidents to be considered. Draft Report for Comment: Background and Preliminary Assumptions for an Environmental Impact Statement – Long-Term Waste Confidence Update (Dec. 2011) (the "Preliminary Assumptions Document"). While the NRC proposed, as a preliminary matter, to make assumptions about many of these topics, comments show that they may not be assumed and instead should be the *subject* of the EIS for the Long-Term Waste Confidence Update Project. *See* comments by Institute for Energy and Environmental Research, Blue Ridge Environmental Defense League, Natural Resources Defense Council, Riverkeeper, and Southern Alliance for Clean Energy on NRC Report Updating Preliminary Assumptions for an EIS on Long-Term Spent Fuel Storage Impacts (Feb. 17, 2012) (copy attached as Exhibit G).

The second study, issued for comment in May 2012, identifies an array of technical issues regarding dry storage and transportation impacts on which the NRC must collect additional data before it can evaluate dry cask long-term integrity and cask vulnerability to degradation and accidents. Draft Report for Comment: Identification and Prioritization of the Technical Information Needs Affecting Potential Regulation of Extended Storage and Transportation of Spent Nuclear Fuel (May 2012) ("Technical Needs Document").

Therefore, the NRC has years of research to do in order to gather sufficient data regarding spent fuel degradation and transportation and handling risks. It will take a long time, potentially well over a decade, to collect the data needed to make scientifically valid impact analyses for high

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[3] The Organizations' scoping comments and supporting declaration of Dr. Arjun Makhijani ("Makhijani Scoping Declaration") are attached to these comments as Exhibits E and F, respectively.

[4] As the Court observed in *State of New York*, that rulemaking may address "some or all of the problems" that it remanded to the agency. 681 F.3d at 483.

burnup fuel stored for long periods. Necessary research tasks include development of a sound database for a scientifically valid evaluation of the environmental impacts of prolonged storage of spent fuel, including high burnup spent fuel up to 62.5 GWd/MTU and MOX spent fuel. In addition, there are essentially no data available for high burnup spent fuel that has been stored in dry casks for extended periods of time. The deficiencies in the NRC's understanding of spent fuel characteristics and behavior under long-term storage conditions are further addressed in the attached Declaration of Dr. Arjun Makhijani, pars. 4.1-4.35.

The NRC attempts to rationalize its lack of support for a reasonable assurance finding about the safety of interim spent fuel storage by characterizing the finding as a "policy statement." 78 Fed. Reg. at 56,799. The characterization is fallacious and evasive of the NRC's responsibilities under the Atomic Energy Act. The Atomic Energy Act requires that safety must be assured by factual predictions that are based on technical evidence, not by policy statements. *Limerick Ecology Act*, 869 F.2d at 734-35.

Thus, the lack of reasonable assurance findings in the proposed rule renders them invalid as a matter of law for supporting the issuance of new reactor licenses or the re-issuance of existing licenses. The NRC cannot cure this fatal deficiency by inserting the "magic words" of "reasonable assurance." Instead, it must have a technical basis for such findings. As discussed above, it has no such basis. In light of the fatal deficiencies in the proposed rule, the NRC lacks lawful grounds for issuing or re-issuing any reactor licenses. *Calvert Cliffs Nuclear Project, L.L.C. and Unistar Nuclear Operating Services, L.L.C.* (Calvert Cliffs Nuclear Power Plant, Unit 3), CLI-12-16, 76 NRC 63, 66 ("Waste confidence undergirds certain agency licensing decisions, in particular new reactor licensing and license renewal.")

V. THE DGEIS VIOLATES NEPA BY MISSTATING THE PURPOSE AND NEED FOR THE PROPOSED RULE AND THEREBY PROVIDING A MEANINGLESS ALTERNATIVES AND COST-BENEFIT ANALYSIS

In the DGEIS, the NRC purports to fulfill the key preliminary requirements for structuring the DGEIS and ensuring the completion of a meaningful analysis: defining the proposed action, describing the purpose and need of the proposed action, and identifying a range of alternatives to the proposed action. But the NRC taints the process by beginning it with the same legally erroneous premise rejected by the Court of Appeals in *New York v. NRC*: that proposed 10 C.F.R. § 51.23 is not a licensing action.

Leading from this faulty premise, the DGEIS makes the absurdly circular assertion that the purpose and need for the DGEIS is to decide whether to address the environmental impacts of spent fuel storage generically or on a site-specific basis. The NRC then compounds its legal error to an even more absurd effect, by identifying a range of alternatives for *thinking about* the environmental impacts of spent fuel storage. The NRC conducts a comically detailed comparison of the costs and benefits of these alternative methods for analyzing environmental impacts of spent fuel storage, and finds that although none of these modes of thought have any adverse physical impacts on the environment, the generic mode of analysis is the "preferred alternative" for reasons of administrative efficiency. Thus, based on the NRC's grossly erroneous structuring of the DGEIS, the DGEIS de-couples the environmental impacts of spent fuel from reactor licensing decisions and ensures that concerns about spent fuel storage or disposal impacts will never stop the issuance of a reactor license or result in the alteration of its terms. In short, the DGEIS is rendered meaningless.

In order to comply with NEPA, the NRC must correctly define the proposed action and its purpose and need, and must conduct a meaningful analysis of a reasonable array of alternatives. *See* 10 C.F.R. Part 51, App'x A (in an EIS, the NRC must "briefly describe and specify the need for the proposed action"), 10 C.F.R. § 51.71(d) (an EIS must include an analysis of "alternatives available for reducing or avoiding adverse environmental effects," including "consideration of the economic, technical, and other benefits and costs of the proposed action and its alternatives"). *See also* 40 C.F.R. §§ 1502.13, 1502.14 (in an EIS, an agency must describe the "purpose and need for the proposed action" and "[r]igorously explore and objectively evaluate all reasonable alternatives"). These alternatives must include the option of denying new reactor license applications and license renewal applications for existing reactors, as well as alternatives for mitigating the adverse environmental impacts of spent fuel storage and disposal such as prohibition of the use of high burnup fuel. Whether the NRC performs this analysis in a GEIS or reactor-specific EISs is a matter for the NRC's discretion, but NEPA requires that it must be done. *Baltimore Gas & Elec. Co. v. NRDC*, 462 U.S. 87, 97-101 (1983).

A. NEPA Requirements for Identification of the Proposed Action, Statement of Purpose and Need, and Alternatives Analysis

As the courts have long recognized, the "linchpin" of an EIS is "the requirement for a thorough study and a detailed description of alternatives." *Monroe County Conservation Council, Inc. v. Volpe*, 472 F.2d 693, 697-98 (2nd Cir. 1972) (internal citations omitted). The alternatives analysis is the linchpin of an EIS because it "ensure[s] that each agency decision maker has before him and takes into proper account all possible approaches to a particular project . . . which would alter the environmental impact and the cost-benefit analysis." *Calvert Cliffs' Coordinating Comm., Inc. v Atomic Energy Comm'n*, 449 F.2d 1109 (D.C. Cir. 1971) (further noting this ensures "the most intelligent, optimally beneficial decision will ultimately be made"). The courts' emphatic characterization of the importance of alternatives in an EIS is rooted in the Council of Environmental Quality regulations, which describe the alternatives requirement as the "heart" of the EIS. 40 C.F.R. § 1502.14; *see also* 10 C.F.R. Part 51, Subpt. A, App. A § 5. As such, the alternatives analysis required by 10 C.F.R. § 51.71(d) is a crucial component of the DGEIS. Alternatives that must be considered include the "no-action" alternative, a reasonable range of action alternatives, and mitigation alternatives. 10 C.F.R. § 51.71(d), 10 C.F.R. Part 51, Subpt. A, App'x A, §§ 5, 7.

The statement of purpose and need for the proposed action is crucially important to the adequacy of an EIS because it "delimit[s] the universe of the action's reasonable alternatives." *Citizens Against Burlington v. Busey*, 938 F.2d 190, 195 (D.C. Cir. 1991). *See also Wyoming v. U.S. Dep't of Agric.*, 661 F.3d 1209, 1244 (10th Cir. 2011) ("how the agency defines the purpose of the proposed action sets the contours for its exploration of available alternatives."). As the Court observed in *Webster v. U.S. Department of Agriculture*, 685 F.3d 411, 422 (4th Cir. 2012), "[o]nly alternatives that accomplish the purposes of the proposed action are considered reasonable, and only reasonable alternatives require detailed study. . . ." Thus, in *Citizens Against Burlington*, the court warned that "[a]n agency may not define the objectives of its action in terms so unreasonably narrow that only one alternative from among the environmentally benign ones in the agency's power would accomplish the goals of the agency's action, and the EIS would become a foreordained formality." 938 F.2d at 195.

B. The DGEIS's Description of the Proposed Action is Incomplete and Fails to Acknowledge that Proposed 10 C.F.R. § 51.23 is a Licensing Action

The DGEIS provides only a partial description of the proposed regulatory action in 10 C.F.R. § 51.23. The DGEIS defines the proposed action as:

> issu[ing] a revised Rule, 10 CFR 51.23, that generically addresses the environmental impacts of continued storage. . . . Further, the revision would state that *because the impacts of continued storage have been generically assessed in this draft GEIS and codified in a Rule, NEPA analyses for future reactor and spent fuel storage facility licensing actions would not need to separately consider the environmental impacts of continued storage.*

DGEIS at 1-5 (emphasis added). In other words, proposed Section 51.23 generically resolves, for individual reactor licensing and re-licensing decisions and spent fuel storage facility licensing decisions, the question of whether storage of spent fuel would have significant impacts on the environment.

While this definition of the proposed action is correct as far as it goes, it is incomplete. The DGEIS fails to acknowledge that the proposed rule makes other environmental findings generically applicable to all individual reactor licensing and re-licensing decisions and spent fuel storage facility licensing decisions. These findings are the following:

- Proposed 10 C.F.R. § 51.23 makes generic safety findings with respect to the feasibility of safely storing spent fuel for an indefinite period and the feasibility of siting a repository for spent fuel disposal within 60 years.
- Proposed Table B-1 makes an environmental impact finding that spent fuel disposal impacts are not large enough to require "that the option of extended operation under 10 CFR part 54 should be eliminated."
- Proposed Table B-1 makes an environmental finding that the NRC "has not assigned a single level of significance for the impacts of spent fuel and high level waste disposal."

Equally important, the DGEIS fails to acknowledge that all of the provisions of proposed 10 C.F.R. § 51.23 and proposed Table B-1 listed above constitute licensing actions, because they enable the creation of spent fuel by resolving safety and environmental issues that are necessary to the licensing and re-licensing of reactors. As was true of the 2010 Waste Confidence Decision that was vacated by the U.S. Court of Appeals, the "action" of the 2013 proposed rule is to "allow the licensing of nuclear plants." *New York v. NRC*, 681 F.3d 471, 478 (D.C. Cir. 2012). *See also id.* at 476 (finding that the waste confidence decision is a "pre-determined 'stage' of each licensing decision"). There is no doubt that if carried out, these proposed actions will result in adverse impacts to the environment through the creation of spent reactor fuel.

Not only does the DGEIS fail to acknowledge the fact that the proposed regulations constitute licensing actions, it denies that fact:

> **The Waste Confidence rulemaking is not a licensing action**. It does not permit a nuclear power plant or any other facility to operate or store spent fuel. Every nuclear power plant or specifically licensed spent fuel storage facility must undergo an environmental review as part of its site-specific licensing process.

DGEIS at xxvi (emphasis in original).

C. The DGEIS' Statement of Purpose Violates NEPA Because it Bears No Relationship to the Environmental Harm Caused by the Proposed Action

Compounding the NEPA violation caused by the DGEIS' defective description of the proposed action, the DGEIS' description of the "purpose and need for the proposed action" strays even further off course into the realm of the utterly fallacious. The statement of purpose and need bears no relationship to any physical effects on the environment and absurdly contemplates the relative merits of *thinking and writing about* environmental impacts in different ways. According to the DGEIS:

> The purpose and need for the proposed action are threefold: (1) to improve the efficiency of the NRC's licensing process by generically addressing the environmental impacts of continued storage; (2) to prepare a single document that reflects the NRC's current understanding of these environmental impacts; and (3) to respond to the issues identified in the remand by the Court in the *New York v. NRC* decision.

DGEIS at 1-6. Thus, instead of addressing the purpose and need for licensing decisions that allow harm to the environment through the generation of spent fuel, the DGEIS addresses the purpose and need for making a licensing decision generically instead of on a reactor-specific basis. But the question of how to prepare an EIS has no bearing on what will be the physical environmental impacts of the NRC's decisions to allow reactors to generate spent fuel. Thus, the statement of purpose and need blatantly violates NEPA.

The DGEIS' additional statement that the purpose and need for the proposed action is "to respond to the issues identified in the remand by the Court" does not bring the NRC any closer to complying with NEPA, because elsewhere the DGEIS clearly rejects the Court's decision that the safety and environmental findings in 10 C.F.R. § 51.23 constitute a licensing decision. As discussed above, the DGEIS asserts that "the Waste Confidence Rulemaking is not a licensing action." DGEIS at xxvi. Indeed, this repudiation of the Court of Appeals' decision is written in bold and placed in a text box for emphasis.

Thus, the DGEIS' statement of purpose and need is impermissible under NEPA, because it fails to address the purpose or need for NRC to allow the environmental harm that would be permitted by the proposed action. *See Baltimore Gas & Elec. Co. v. NRDC*, 462 U.S. 87, 96 (1983) ("The key requirement of NEPA . . . is that the agency consider and disclose the actual environmental effects in a manner that will ensure that the overall process . . . brings those effects to bear on decisions to take particular actions that significantly affect the environment."). As a result, as further discussed below, the environmental harm caused by generation of spent fuel is "foreordained" and the GEIS becomes a mere "formality." *Citizens Against Burlington*, 938 F.2d at 195.

D. The DGEIS Violates NEPA by Failing to Identify or Compare the Costs and Benefits of Reasonable Alternatives to Avoid or Mitigate the Adverse Environmental Impacts of Spent Fuel Generation

Not surprisingly, because the DGEIS' purpose and need statement bears no relationship to the actual physical environmental impacts of the proposed action, the range of alternatives identified in the DGEIS also bears no relationship to the physical impacts of the proposed action or their avoidance or mitigation. The NRC's failure to identify a meaningful array of alternatives violates NEPA. *Calvert Cliffs*, 449 F.2d at 1128 ("NEPA requires that an agency must -- to the fullest extent possible . . . consider alternatives to its actions which would reduce environmental damage.").

Instead of considering alternatives for avoiding or mitigating the environmental impacts of spent fuel that will be generated as a result of future licensing decisions, the NRC presumes that spent fuel production will continue and then considers alternative methods for analyzing the impacts of this spent fuel production. *See* DGEIS at 7-1 (each alternative "provides a means for the NRC to address, in its environmental review documents, the environmental impacts of continued spent fuel storage (continued storage) at a reactor site or at an away-from-reactor storage facility."). Thus, the two main alternatives considered in the DGEIS are whether to prepare a generic impact analysis or a set of reactor-specific impact analyses. DGEIS at 1-6. The NRC observes, without irony, that neither of these alternatives "noticeably alter the environmental impacts from continued storage." DGEIS at 7-1. In fact, the NRC's failure to identify any actual physical environmental effects from these alternatives is just the "foregone conclusion" of the NRC's faulty analysis. *Citizens Against Burlington*, 938 F.2d at 195.

The NRC admits that commenters demanded consideration of actual alternatives to the proposed action, but the NRC refused, relying on its misplaced purpose and need statement:

> During the scoping period for the draft GEIS, the NRC received many suggested alternatives to the Waste Confidence rulemaking, including calls for halting NRC licensing activities and shutting down operating reactors or imposing new requirements on nuclear power plants, such as storing spent fuel in special hardened onsite storage, reducing spent fuel pool density, and accelerating the transfer of spent fuel from pools to dry casks. *The NRC determined that halting NRC licensing and closing nuclear reactors would not meet the purpose and need of the proposed rulemaking action.* The NRC also determined that additional requirements on spent fuel storage would not meet the purpose and need. Further, the draft GEIS is a NEPA review and not a licensing action; therefore, this draft GEIS would not be the appropriate activity in which to mandate new spent fuel storage requirements.

DGEIS at xxvi (emphasis added).[5] And further, the NRC admitted that not licensing and re-licensing nuclear power would stop the production of waste. However, NRC shied away from consideration of a no-action alternative that would stop licensing, by stating:

> Although cessation of nuclear power plant licensing and operations would halt the future generation of spent fuel, other environmental impacts could result from the required development of replacement power sources or demand reductions. Even then, the environmental impacts of continued storage would not cease until sufficient repository capacity becomes available.

DGEIS at 1-9. This statement is simply irrational, and reflects a complete lack of analysis. The fact that other energy sources may have environmental impacts does not render them unworthy of consideration. NEPA requires that the entire array of reasonable alternatives must be analyzed. *Calvert Cliffs*, 449 F.2d at 1128. In addition, consideration of the no-action alternative of not licensing and re-licensing reactors that would generate spent fuel is explicitly required under NEPA and NRC implementing regulations. *See* 10 C.F.R. § 51.71(d), 10 C.F.R. Part 51, Subpt. A, App'x A, §§ 5, 7; *see also* 40 C.F.R. § 1502.14.

Compounding the absurdity of the DGEIS' identification of alternatives as a choice among analytical methods, the DGEIS' cost-benefit analysis consists of meticulous cost estimates and comparisons of the human hours and quantity of paper required for each method. DGEIS at 7-3, H-2. The results are absurd, giving no information whatsoever about the relative costs and benefits of measures to avoid or mitigate the environmental impacts of the spent fuel that will be generated through future licensing decisions. These impacts are potentially significant and the costs of mitigating them are potentially great, as discussed in Sections V.F, VI.E, and VII below.

E. In Violation of NEPA and *New York v. NRC*, the DGEIS Assumes that NRC Will Continue to License Reactors to Generate Spent Fuel, and that the Proposed Rule is Unrelated to Those Decisions

The DGEIS also indicates that the NRC has made a pre-conceived determination that reactors *will* be licensed and re-licensed, and that the DGEIS is a mere formality. In Section 7, the NRC claims to have considered whether to include one set of physical impacts in its cost-benefit analysis, *i.e.*, the costs and benefits related to "the environmental impacts of continued storage." DGEIS at 7-2. But the NRC explains that the DGEIS omits such an analysis because "continued storage [is] an activity that will occur regardless of the alternative that the NRC selects to consider its impacts." DGEIS at 7-1. This assertion can only be true if the decision to allow the future generation of spent fuel is "foreordained." *Citizens Against Burlington*, 938 F.2d at 195. Thus, the DGEIS effectively confirms that consideration of the environmental impacts of spent fuel generation will not affect reactor licensing or re-licensing decisions in any way. This is a blatant violation of NEPA and the Court's decision in *New York v. NRC* that the NRC's

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[5] This quotation also falsely suggests that NRC could apply 10 C.F.R. § 51.23 to order the shutdown of licensed operating reactors. Section 51.23 is, on its own terms, a licensing regulation. The NRC should have clarified that the proposed rule would not allow the shutdown of operating reactors and therefore it is not a viable alternative for consideration under NEPA.

evaluation of the environmental impacts of spent fuel generation is "not separate" from licensing decisions for nuclear reactors. 681 F.3d at 476.

F. The NRC Must Evaluate a Reasonable Array of Alternatives for the Avoidance or Mitigation of Spent Fuel-Related Environmental Impacts, Either in the DGEIS or Reactor-Specific EISs

NEPA requires that the NRC must analyze a reasonable set of alternatives for the avoidance or mitigation of the significant impacts of generation of spent fuel, and integrate those considerations into individual licensing decisions. *See Robertson v. Methow Valley Citizens Council,* 490 U.S. 332, 351 (1989) (explaining that the "requirement that an EIS contain a detailed discussion of possible mitigation measures flows both from the language of the Act and, more expressly, from CEQ's implementing regulations"); *see also* 10 C.F.R. § 51.71(d) (an EIS must include an analysis of "alternatives available for reducing or avoiding adverse environmental effects"). Whether the NRC performs that analysis generically or on a reactor-specific basis is entirely up to the NRC's discretion. *Baltimore Gas & Electric,* 462 U.S. at 96. But NEPA requires that it must be done.

First and foremost, the NRC must consider the no-action alternative, *i.e.,* the alternative of not permitting further generation of spent fuel through the licensing of new reactors and the re-licensing of existing reactors. *Calvert Cliffs*, 449 F.2d at 114 (the alternatives requirement "seeks to ensure that each agency decision maker has before him and takes into proper account all possible approaches to a particular project (including total abandonment of the project) which would alter the environmental impact and the cost-benefit analysis"). As demonstrated in the attached declarations of Dr. Arjun Makhjani (Exhibit A), Dr. Gordon Thompson (Exhibit C), and David Lochbaum (Exhibit B), spent fuel storage and disposal have significant environmental impacts, and measures for mitigation of those impacts involve significant costs. As further demonstrated in the attached declaration of Mark Cooper (Exhibit D), the costs of managing spent fuel could be great enough to tip the balance against reactor licensing or re-licensing. NEPA requires a full analysis of the environmental impacts of spent fuel generation, as well as a weighing of the relative costs and benefits of alternative energy sources in relation to the significant costs associated with nuclear power generation and spent fuel management. NEPA requires such an analysis before the NRC can promulgate a final version of 10 C.F.R. § 51.23.

The NRC must also consider the relative costs and benefits of mitigation alternatives to reduce adverse environmental impacts. For instance, numerous options are available to reduce the radiological risk arising from management of spent fuel, including options for providing enhanced protection of ISFSIs from attacks. Thompson Declaration, par. XI-8. Use of such options at ISFSIs across the United States would also support a national strategy of protective deterrence. *Id.* Whether these alternatives are considered generically or in individual licensing cases, they must be carried out under NEPA.

VI. THE DGEIS VIOLATES NEPA BECAUSE IT DOES NOT FULLY CONSIDER THE REASONABLY FORESEEABLE IMPACTS OF THE PROPOSED RULE

A. The Proposed Rule's Finding Regarding the Technical Feasibility of a Repository Is Not Supported by the DGEIS

In *New York*, the Court concluded that the NRC's "reasonable assurance" finding that a repository will be available is insufficient to satisfy NEPA because it does not show that the "likelihood of nonavailability" is "remote and speculative." 681 F.3d at 479. Therefore the Court ordered NRC to conduct a "full analysis" of "the potential environmental effects" of storing spent fuel onsite at nuclear plants "on a permanent basis." 681 F.3d at 479. The Court stated quite clearly that the EIS must address the impacts of a "failure to secure permanent storage." *Id.*

Under NEPA's rule of reason standard, the analysis of the risk of failure to secure permanent storage for spent fuel must include the following: the risk that sufficient repository capacity that meets NRC's Part 63 standards for containment will not be found; the risk that even if sufficient repository capacity is found it will not be licensed before substantial environmental harm has occurred; and the nature of the harm that could occur if interim measures to protect spent fuel from exposure to the environment fail. But the DGEIS contains no such analysis. The DGEIS completely ignores the issue of the probability that sufficient repository capacity will be available in a timely way. *See* Makhijani Declaration, pars. 8.1-8.24. Moreover, instead of analyzing the environmental impacts that could occur if spent fuel remains undisposed of for many decades and escapes to the environment, the NRC assumes those impacts will not happen because they will be prevented by the indefinite maintenance of "institutional controls." *See* DGEIS at 1-14 (stating the assumption that "[i]nstitutional controls, i.e., the continued regulation of spent nuclear fuel, will continue").

B. The DGEIS' Assumption of Indefinitely Effective Institutional Controls Violates NEPA

Instead of complying with NEPA and the Court's decision in *New York* by examining the risk of failing to site a repository, the DGEIS rationalizes the risk away by arbitrarily assuming that spent fuel will be protected by "institutional controls" for an infinite period of time at reactor sites or away-from-reactor storage sites. This assumption is not only absurd and inconsistent with the NWPA, but it flouts the Court's requirement to reckon with the environmental consequences of its failure to site a repository.

1. NRC's assumption of indefinitely effective institutional controls violates NEPA because it is inconsistent with the NWPA and NRC regulations

NRC's determination that spent fuel can be safely stored for an indefinite amount of time above-ground is inconsistent with the NWPA and NRC's own regulations. As discussed above in Section V, the NWPA establishes a national policy of disposing of spent nuclear fuel in a deep geologic repository. By labeling the consideration of permanent on-site storage of spent nuclear fuel as "indefinite storage" the NRC seeks to avoid the necessary conclusion that when on-site storage becomes permanent it becomes disposal. This assumption of de facto above-ground disposal directly violates the NWPA.

The Draft GEIS' assumption of indefinite institutional controls is also inconsistent with the NRC's own regulations. For instance, the NRC's low-level waste disposal regulations assume that active controls will fail after 100 years, and intruder barriers will fail around 500 years. 10 CFR § 61.7 (b)(4) & (b)(5). To state that institutional controls are likely to fail in the NRC's regulations, and then assume throughout this draft GEIS that institutional controls will last forever is inconsistent and irrational.

And the NRC's assumption is inconsistent with general federal policy regarding containment of hazardous materials. When reviewing the Department of Energy's (DOE) cleanup plans for legacy waste sites, the NRC required the DOE to assume that "contamination isolation barriers and stewardship measures at sites where wastes are left in place will eventually fail." National Research Council, Board on Radioactive Waste Management, Commission on Geosciences, Environment, and Resources. *Long-Term Institutional Management of U.S. Department of Energy Legacy Waste Sites* (Washington, DC: National Academy Press, 2000), available at http://www.nap.edu/catalog.php?record id=9949. This directly contradicts the assumption of forever continuing institutional controls relied upon by the NRC in the draft GEIS.

Finally, as a matter of law, the NRC may not assume the effectiveness of institutional controls to prevent radiological releases to the environment during the extended period of spent fuel storage. As the Court held in *New York*, "merely pointing to [a] compliance program is in no way sufficient to support a scientific finding." 481 F.3d at 481. The question of whether institutional controls will remain in place for hundreds or thousands of years must be addressed as an element of risk.

2. NRC's assumption of indefinitely effective institutional controls violates NEPA and *New York v. NRC* because it arbitrarily assumes the nonexistence of an impact instead of analyzing it

The NRC asserts that a loss of institutional controls is so remote and speculative that its consideration is outside the requirements of the National Environmental Policy Act (NEPA). *Id.* at 1-15, fn. 2. Given the many examples in history of loss of institutional controls, it is the NRC's assumption that institutions will remain intact and capable of caring effectively for spent fuel over an indefinite period of time that is more fairly characterized as remote and speculative. Makhijani Declaration, pars. 6.3, 10.3. As Dr. Makhijani discusses in Section 6, this assumption in the DGEIS flies in the face of facts, history and common sense. For instance, the U.S. has been in two world wars in less than 100 years. Just over a decade ago, the financial capital of the U.S. suffered a devastating attack that could have targeted a nuclear power plant. There have been a dozen government shutdowns since 1981. In the most recent shutdown, in October 2013, some waste management functions – even for "visible" facilities – almost came to a halt. For instance, the Fernald Preserve, which includes a large visible mound of radioactive waste from the Fernald uranium plant that was part of the nuclear weapons complex was closed. Had the government shutdown lasted much longer, the pump and treat operations that are a mandated part of water quality objectives, would have come to a halt. Makhijani Declaration, par. 6.6 – 6.7.

The NRC asserts that the purpose of its assumption of continued institutional controls is to "avoid unreasonable speculation regarding what might happen in the future regarding Federal actions to provide for the safe storage of spent fuel." DGEIS at 1-14. Admitting a lack of information satisfies the first obligation for agencies faced with uncertainties in an EIS, but the NRC fails to complete any of the remaining three obligations under the CEQ regulation for incomplete or unavailable information. 40 C.F.R. § 1502.22(b). After admitting uncertainty, under section 1502.22(b) the agency must include within the EIS:

> (2) [A] statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment; (3) a summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment, and (4) the agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community.[6]

40 C.F.R. § 1502.22(b).

C. The Proposed Rule's Determination that it is Feasible to Safely Store Spent Fuel for an Indefinite Period Violates NEPA Because it is Devoid of Valid Technical Support and Fails to Consider a Range of Factors Affecting the Long-Term Safety of Spent Fuel Storage

The DGEIS asserts that spent fuel can be stored safely and without significant impacts for an indefinite period of time. DGEIS at xliv-xlv, lv, 8-2 – 8-3. But the NRC's findings on this issue are almost devoid of valid technical support. Makhijani Declaration, par. 4.1 et seq. The studies cited by the NRC do not support the broad generalizations in the DGEIS. For instance, the Draft GEIS relies on a pilot study that was never intended to be used for regulatory purposes; and it relies on other studies that are limited to short time frames. Makhijani Declaration, pars. 4.2–4.5. But even the short-term studies show evidence of spent fuel degradation during storage. Makhijani Declaration, par. 4.5.

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[6] The Supreme Court has held that Council on Environmental Quality regulations for the implementation of NEPA "impose a duty on all federal agencies." *Marsh v. Oregon Natural Res. Council*, 490 U.S. 360, 372 (1989). The NRC is a federal agency and therefore must answer this call to duty. "Reasonable forecasting and speculation is thus implicit in NEPA, and we must reject any attempt by agencies to shirk their responsibilities under NEPA by labeling any and all discussion of future environmental effects as 'crystal ball inquiry'." *Scientists' Inst. For Pub. Info. v. Atomic Energy Comm'n*, 481 F.2d 1079, 1086 (D.C. Cir. 1973).

As discussed in Dr. Makhijani's declaration, the Draft GEIS assumes that spent fuel bundles can be stored for millennia and repeatedly transferred hundreds of times from one cask to another without large releases of radioactivity. But the Draft GEIS contains almost no information about spent fuel characteristics that could cause adverse safety risks and environmental impacts in case of long-term or indefinite storage, both during storage and during the many transfers that must take place. Makhijani Declaration, par. 4.6. The Draft GEIS contains no analysis of how spent fuel characteristics may contribute to the risk of an accidental release of radioactivity during extended storage of dry casks; or how these factors may contribute to accident risks during the many transfers that would take place over an extended period of time, *i.e.*, transfers between pools and casks, transfers between storage casks, transfers between storage and transportation casks, and transfers between transportation casks and casks used for ultimate disposal of spent fuel. *Id.*

The DGEIS cites just one study (Billone et al. 2013) that has evidence about the deterioration of high burnup spent fuel during drying and subsequent storage. DGEIS at B-13. Even so, the lessons contained in this study, such as the implications of degradation for accident consequences or the differences between risks of various zirconium alloys used as cladding material are not discussed in the Draft GEIS. Makhijani Declaration, par. 4.7.

The DGEIS omits any mention of the fact that elsewhere, the NRC has acknowledged that it has a serious lack of information about the behavior of spent fuel stored for long periods. Makhijani Declaration, par. 4.8. In May 2012, the NRC published a *Draft Report for Comment: Identification and Prioritization of the Technical Information Needs Affecting Potential Regulation of Extended Storage and Transportation of Spent Nuclear Fuel* (Draft Report on Technical Information Needs). This report catalogs what is known, as well as the gaps in knowledge, of spent fuel degradation mechanisms. Some of the gaps will require extensive new data and a considerable amount of time to fill.

The Draft Report on Technical Information Needs was based on a number of prior reports, data from physical examination of some "lower burnup" spent fuel, and extrapolation from this data to 80 years. Based on this data, the Draft Report concluded:

> ….The current regulatory framework supports at least the first 80 years of dry cask storage (i.e., a 40-year initial licensing term, followed by a license renewal for a term of up to 40 years, although many of the existing facilities were licensed for an initial term of 20 years under the regulations in place at the time).
>
> The technical basis for the initial licensing and renewal period is supported by the results of a cask demonstration project *that examined a cask loaded with lower burnup fuel* (approximately 30 GWd/MTU [gigawatt-days per metric ton uranium] average; all fuel burnup in this paper is given as peak rod average value). Following 15 years of storage, the cask internals and fuel did not show any significant degradation (Einziger et al., 2003). The data from this study can be extrapolated to maintain a licensing safety finding that *low burnup SNF* can be safely stored in a dry storage mode for at least 80 years with an appropriate aging

management program that considers the effects of aging on systems, structures, and components (SSCs).

Makhijani Declaration, par. 4.8 (emphasis added). Note that the existing licensing and license extension procedures are based on examination of a single cask of relatively low burnup uranium dioxide spent fuel that had been in dry storage for only 15 years. The paper lists data extensive requirements for extending this analysis to:

- high burnup spent fuel that would be stored from 120 years to 300 years;
- spent fuel burnups up to about 62.5 GWd/MTU;
- mixed oxide (MOX) spent fuel (which has plutonium-239 instead of uranium-235 as the fissile material that sustains the chain reaction); and
- new cladding, fuel compositions, and assembly designs that have been and will continue to be put into use.

Makhijani Declaration, par. 4.9 & Table 6-1. In the Draft Study, the NRC proposed to undertake a seven-year study of the phenomena identified in the Draft Report; but the plan was deferred when resources were diverted to the preparation of the Waste Confidence DGEIS. Makhijani Declaration, par. 4.12.

As Dr. Makhijani observes, the NRC's failure to mention in the Draft GEIS the agency's own previously expressed concerns about the data gaps essential to understanding high burnup and MOX spent fuel and spent fuel with new cladding materials is an egregious technical omission. The missing data are critical to assessing the health and environmental impacts of spent fuel; gathering the data will need extensive additional research. Whenever a scientist lacks sufficient information to evaluate an issue, it is essential to identify the missing information and, at the very least, conduct an uncertainty analysis. Neither of those steps was taken by the NRC in the DGEIS. On the contrary, the one study that the NRC cited to justify its conclusion that impact accident consequences would be low explicitly did *not* consider uncertainties. The NRC's failure to mention its own documented concerns about spent fuel characteristics seriously compromises the scientific integrity of the Draft GEIS. Makhijani Declaration, par. 4.12.

The NRC's failure to acknowledge the amount of information that is lacking regarding spent fuel behavior over the long-term is all the more disturbing in light of the fact that the Nuclear Waste Technical Review Board (NWTRB) has expressly acknowledged the dearth of information regarding spent fuel integrity and degradation. Makhijani Declaration, par. 4.13. NWTRB confirms that at present no U.S. data are available for high burnups (up to 62.5 GWd/MTU) for any of the NRC's storage scenarios, or for periods of storage anywhere comparable to the long timeframe of hundreds of years that the NRC will have to consider in its EIS in one or more scenarios. Predictions, estimates or projections that the NRC may make of the effects of high burnup spent fuel storage, particularly over long-term periods, in its GEIS cannot be validated with scientific data or observations with presently available information. Such validation is essential for reliable and scientifically acceptable estimates of the environmental and health impacts of long-term storage and transportation. Makhijani Declaration, par. 4.13.

The NWTRB also commented on the lack of information about interactions between different degradation mechanisms as well as the possible effect of high burnup on those interactions:

> These [degradation] mechanisms and their interactions are not well understood. New research suggests that the effects of hydrogen absorption and migration, hydride precipitation and reorientation, and delayed hydride cracking may degrade the fuel cladding over long periods at low temperatures, affecting its ductility, strength, and fracture toughness. *High-burnup fuels tend to swell and close the pellet-cladding gap, which increases the cladding stresses and can lead to creep and stress corrosion cracking of cladding in extended storage.* Fuel temperatures will decrease in extended storage, and cladding can become brittle at low temperatures.[7]

Makhijani Declaration, par. 4.14 (quoting NWTRB Report, p. 11, italics added). Hence, high burnup could possibly combine with other factors to create conditions that would result in severe, if not catastrophic, releases of radioactivity. This possibility must be studied. *Id.*

Besides the NRC staff's 2012 proposal, the NWRTB has also proposed an extended research program to address the problem of the lack of data. The NWTRB research and development recommendations include:

- Understanding the ultimate mechanical cladding behavior and fuel-cladding degradation mechanisms potentially active during extended dry storage, including those that will act on the materials introduced in the last few years for fabrication of high-burnup fuels
- Understanding and modeling the time-dependent conditions that affect aging and degradation processes, such as temperature profiles, in situ material stresses, quantity of residual water, and quantity of helium gas
- Modeling of age-related degradation of metal canisters, casks, and internal components during extended dry storage
- Inspection and monitoring of fuel and dry-storage systems to verify the actual conditions and degradation behavior over time, including techniques for ensuring the presence of helium cover gas
- Verification of the predicted mechanical performance of fuel after extended dry storage during cask and container handling, normal transportation operations, fuel removal from casks and containers, off-normal occurrences, and accident events
- Design and demonstration of dry-transfer fuel systems for removing fuel from casks and canisters following extended dry storage

Makhijani Declaration, par. 4.15.

[7] NWTRB 2010, p. 11, italics added.

Dr. Makhijani also points out that other institutions have also analyzed the critical data gaps regarding high burnup degradation and its implications for storage, transport and disposal. For instance, a 2012 paper published by the National Academy of Engineering noted the following:

> Based on its assessment, the study board concluded that the technical basis for the spent fuel currently being discharged (high utilization, burnup fuels) is not well established and that the possibility of degradation mechanisms, such as hydriding, will require more study. The NWTRB recommended periodic examinations of representative amounts of spent fuel to ensure that degradation mechanisms are not in evidence.

Makhijani Declaration, par. 4.16 (quoting Kadak 2012). Of equal concern as the serious data gaps identified by the National Academy of Engineering is the fact that as recently as 2012, neither the NRC nor the nuclear power industry had implemented the periodic examinations of spent fuel recommended by the NWTRB in 2010. *Id.*

Without this basic information, the NRC has an inadequate foundation for any predictive safety finding regarding the behavior of spent fuel in long-term storage conditions. And any EIS that is prepared to discuss these matters should acknowledge and analyze the considerable uncertainty that exists.

In his declaration, Dr. Makhijani lists a number of spent fuel degradation phenomena that could affect the safety of spent fuel during long-term storage. Safety parameters that could be compromised include confinement, criticality, retrievability, shielding, structural, and thermal. Makhijani Declaration, par. 4.18. Impacts of spent fuel degradation could be serious enough to result in environmental releases during spent fuel inter-cask transfer and could result in more severe impacts in cases of accidents. *Id.*

For instance, little is known about the extent to which microbiologically induced corrosion could corrode seals and/or the cask body that affect containment. Laboratory work and examination of spent fuel of different levels of burnup stored for long periods in spent fuel pools followed by long-term storage in dry casks is needed. Makhijani Declaration, par. 4.19. Other phenomena that may cause degradation include stress corrosion cracking, delayed hydride cracking, and low temperature creep. The NRC Draft Report on Technical Information Needs notes that "All three mechanisms depend on a source of stress that would come from pellet swelling. If the stress is not present, the mechanisms become benign. If operative, these mechanisms could increase the source term and increase cladding stress. The latter could affect containment, especially if other degradation processes have compromised the canister." Makhijani Declaration (quoting Draft Report at 6-2).

In other words, the NRC does not know at present whether corrosion of seals or the canister body may occur to an extent that compromises containment. Damage to canisters could set the stage for severe releases either during inter-cask transfer or because the canister itself degrades. Makhijani Declaration, par. 4.20.

Dr. Makhijani also observes that high burnup fuels tend to build up much thicker levels of oxide during the in-reactor period as well as much higher levels of hydrogen in the cladding. Figure 2 below shows that the typical increase in outer oxide layer thickness increases from about 20 microns at 30 GWd/MTU to about 100 microns at about 62 or 63 GWd/MTU at discharge from the reactor. Moreover, the spread in the oxide layer thickness increases with burnup, indicating that some fraction of fuel rods may be at a much greater risk of failure. Makhijani Declaration par. 4.21 (citing NWTRB 2010, Figure 20).

The NWTRB has issued the following caution about prolonged spent fuel pool storage:

> Cladding may already have some small defects like tiny holes or hairline cracks, internal and external corrosion that has decreased the original metal wall-thickness, absorbed hydrogen, and hydride precipitation; however, it is very rare that new defects are detected while in the pool. Significant cladding defects can be detected during wet storage by monitoring stack off-gas for fission product gas leaks; if leaks are found, then assemblies are further inspected and breached fuel-rods are canned if necessary. Generally, a visual inspection is made of assemblies to identify fuel assemblies that may need to be classified as damaged and require special handling. If the cladding is functionally undamaged, there is an insignificant risk of expected fuel oxidation [at the time of transfer to dry storage]. Given undamaged cladding and the visible transfer of assemblies into and out of wet storage, the fuel-assembly containment criterion is deemed satisfied. Thus, during wet pool storage, used fuel is not expected to experience significant deterioration before dry storage. *If pool storage of fuel is continued for an extended period, it will be necessary to assess and evaluate the effects on intact or damaged fuel.*[8]

Makhijani Declaration, par. 4.23 (citing NWTRB 2010, p. 60). Although the Draft GEIS assumes that pool storage could continue for periods approaching 140 years (the first spent fuel discharged during 80 years of licensed operation, plus 60 years of post-operating license storage), it has not included any uncertainty analysis relating to impacts of damage that may occur in some fraction of the spent fuel during such prolonged storage. *Id.*

The NWTRB has identified hydriding, creep and stress corrosion cracking to be "[t]he most significant potential degradation mechanisms affecting the fuel cladding during extended storage." Makhijani Declaration, par. 4.25 (quoting NWTRB 2010, p. 10). These phenomena can lead to "failed fuel" under certain conditions. Fuel failure occurs when there is a rupture in the fuel cladding, allowing fuel pellets direct contact with the environment around the fuel, the reactor coolant, spent fuel pool water, the canister environment, or the general environment during inter-cask transfer of failed fuel. If detected during cask loading, failed fuel is normally put in a "can," which is a special sleeve, prior to loading into the cask. But if failure occurs after dry storage commences, some fuel pellets could be exposed to the environment during transfer. The NRC has refused to state how it would transfer failed spent fuel. It plans to figure it out when the problem arises. Makhijani Declaration, Par. 4.24.

[8] NWTRB 2010, p. 60, italics in the original.

The Draft GEIS concludes that the phenomena leading to failed fuel (*i.e.*, hydriding, creep and stress corrosion cracking) are unlikely to cause significant problems in the "short-term." DGEIS at B-13. With respect to long-term storage, the NRC claims to be ignorant of any studies "that would cause it to question the technical feasibility of continued safe storage of spent fuel in dry casks." *Id.* But the Draft Study of Technical Needs admits that the level of knowledge regarding galvanic corrosion, stress corrosion cracking, low-temperature creep and propagation of existing flaws is "low"; and that knowledge of delayed hydride cracking is only "medium." The NRC's amnesia regarding its own study undermines the credibility and integrity of the Draft GEIS. Makhijani Declaration, par. 4.25.

Incredibly, the only explicit mention of failed fuel in the Draft GEIS is in the context of spent fuel pool leaks:

> Impacts from spent fuel pool leakage occur from radionuclide contaminants present in spent fuel pool water. The sources of radionuclide contaminants in spent fuel pool water are activation products and fission products. Activation products are elements formed from the neutron bombardment of a stable element and fission products are elements formed as a byproduct of a nuclear reaction and radioactive decay of other fission products. *The sources of activation products are corrosion and wear deposits (including corrosion films on the fuel bundle surfaces)*. Fission products come from bundles with rods that failed in-reactor or from intact bundles that adsorbed circulating fission products.[9]

DGEIS at E10 (emphasis added). The NRC's limitation of its consideration of failed fuel to short-term storage conditions is grossly insufficient, given that the principal long-term risks are likely to arise after prolonged storage has resulted in serious fuel degradation of some fraction of the fuel rods, notably in the case of high burnup spent fuel. Makhijani Declaration, par. 4.26.

The NRC's failure to address the effects of failed fuel on safety and environmental risk is all the more remarkable in the context of the NRC's own admission that it does not yet know how it will transfer such failed spent fuel. The NRC has no experience in transferring failed fuel from one cask to another. By NRC's own admission, it has not even developed the procedures to do so. Makhijani Declaration, par. 4.27.

The NRC also has no basis in data or experience in estimating how much additional damage could be done to failed fuel by transferring it between casks. This would apply even to damaged medium burnup fuel stored for short or moderate periods of time (up to two or three decades) in dry casks. It is *a fortiori* true of high burnup spent fuel that has been stored for many decades or even a few hundred years, given the considerations about such spent fuel discussed in the rest of this section. Makhijani Declaration, par. 4.28.

Indeed, in this context, Dr. Makhijani observes that no spent fuel bundle, damaged or not, has ever been transferred from one dry cask to another. Further, while the Draft GEIS postulates a

[9] DGEIS at E-10 (emphasis added).

Dry Transfer System for fuel inspection, repackaging and transfer, such a facility has never been built in the United States. The NRC even refuses to say how it would handle and repackage failed fuel. This makes the lack of discussion of the impacts of the transfer of failed spent fuel bundles even more problematic since the NRC lacks sufficient empirical basis for estimating the probabilities and consequences of the spread of radioactivity during transfers in the normal case. Makhijani Declaration, par. 4.29.

In failing to address the issue of failed spent fuel inter-cask transfers, the NRC also has ignored the fact that failed spent fuel bundles are already stored in dry casks, but have never had to undergo inter-cask transfers. For instance, there are 95 failed spent fuel bundles stored in 15 dry casks at San Onofre Nuclear Generating Station alone. Makhijani Declaration, par. 4.30.

As discussed above, NWTRB has proposed an extended research program to address the lack of data regarding spent fuel characteristics. It is also important to have dry storage performance data on the newer cladding materials that have been developed to enable high fuel burnup, which is a relatively recent practice (since about the turn of the century). There are practically no such data. Indeed, even the research has been focused mainly on in-reactor behavior of high burnup fuels rather than on degradation during prolonged storage. Makhijani Declaration, par. 4.31.

Safety and environmental risks of storing other forms of spent fuel are ignored or tossed off with scant attention in the DEIS. For instance, the U.S. is building a MOX plant to convert weapons grade plutonium into commercial reactor fuel. There is no significant experience with irradiation of such MOX fuel in a commercial reactor in the United States. Only lead test assemblies have been irradiated. Therefore there is essentially no experience with storage of commercial MOX spent fuel in the United States in wet or dry storage for any length of time. France, which has the most experience with MOX spent fuel, stores it in pools and has no dry storage. The draft GEIS simply assumes away the problem of MOX spent fuel with the following statement:

> Because the MOX fuel that would be generated at the Mixed Oxide Fuel Fabrication Facility is substantially similar to existing light water reactor fuel and is, in fact, intended for use in existing light water reactors in the United States, MOX fuel from this project is within the scope of this draft GEIS.[10]

Contrary to the claim in the Draft GEIS MOX fuel is decidedly *not* "substantially similar to existing light water reactor fuel." In the former the fissile material is plutonium, which has different nuclear characteristics (a smaller delayed neutron fraction, for instance) than current low-enriched uranium reactor fuel. Even more importantly for the present purposes, the characteristics of the spent fuel will be different. For instance, uranium spent fuel from a PWR with initial 4.25 percent enrichment and burnup of 50 GWd per metric ton would have about 1 percent plutonium isotopes in it at discharge, including about half-a-percent plutonium-239. For the same burnup MOX fuel would typically have 8.46 percent total plutonium to start with. The spent fuel from a PWR would have about five times as much total plutonium, and about three-and-half-times as much plutonium-239. Makhijani Declaration, par. 4.32.

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[10] DGEIS at 2-8.

In the example provided (50 GWd per metric ton burnup in a PWR), the MOX spent fuel would have about six-and-half-times the amount of plutonium-241 as the uranium spent fuel. Plutonium-241 decays into americium-241 relatively rapidly with a half-life of just 14.4 years. Amercium-241 has a half-life of 432 years.[11] Unlike plutonium-239 and plutonium-241, americium-241 is a powerful gamma radiation emitter; it would pose special problems during spent fuel transfer, long after the main gamma-emitting fission product, cesium-137 (half-life about 30 years), would have decayed away. These problems associated with americium-241 gamma radiation dose would extend to post-accident recovery in case of release of radionuclides from the spent fuel. Makhijani Declaration, par. 4.33.

It stretches credulity that the NRC staff is not aware of these critical differences that would make a significant difference between impacts of MOX spent fuel and uranium spent fuel. In any case, the Draft GEIS assertion that there the two are substantially similar is wrong. A specific impact analysis is needed for MOX spent fuel. Makhijani Declaration, par. 4.34.

Similarly, the GEIS pays little heed to the environmental impacts of extended storage of stainless steel fuel cladding. As Dr. Makhijani points out, stainless steel was used as fuel cladding early in the history of U.S. commercial reactors. By 1994, only one reactor had any stainless steel clad fuel in its core. By 1992, a total of 679 metric tons of spent fuel (uranium heavy metal content) had been generated from the stainless steel clad fuel. Further, the use of stainless steel cladding was discontinued partly because of in-reactor degradation of stainless steel cladding. For instance, the stainless steel cladding in the Connecticut Yankee reactor "experienced a number of fuel element failures" between 1977 and 1980, even though it had performed well in this regard prior to that time. The degradation characteristics of stainless steel fuel are different than zircaloy fuel and needed to be explicitly considered in the Draft GEIS. The Draft GEIS catalogs the amount of stainless steel spent fuel but does not discuss the failed fuel or its transfer from one dry cask to another. It does not discuss whether accidents involving such failed fuel would have more or less severe consequences than failed zircaloy-clad fuel. Makhijani Declaration, par. 4.35.

Thus, the DGEIS fails to provide an adequate technical basis for a reasonable assurance finding regarding the safety of long-term or indefinite spent fuel storage. Worse, the DGEIS ignores a wealth of studies concluding that much more study of spent fuel behavior is required before it is possible to reach informed conclusions about its behavior under extended storage conditions. Finally, the DGEIS ignores the safety and environmental risks posed by variations in spent fuel about which it has little knowledge. Not only has the NRC failed to obtain the information it needs to make a safety finding, but it has not even analyzed the uncertainty created by the lack of information.

[11] Properties of radionuclides, including half-lives and dose conversion factors can be found in FGR 13 CD 2002.

D. The Proposed Rule's Determination That Spent Fuel Can Be Safely Stored in Pools for an Indefinite Period is Not Based on an Adequate Environmental Analysis of Spent Fuel Pool Leaks

NRC's analysis of spent fuel pool (SFP) leaks in the DGEIS violates NEPA. NEPA requires agencies to take a "hard look" at all reasonably foreseeable impacts of the proposed action. 42 U.S.C. 4332(2)(C); *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 350 (1989) (quoting *Kleppe v. Sierra Club*, 427 U.S. 390, 410 n. 21 (1976)); *see also* 40 C.F.R. §§ 1502.1, 1502.8 (agencies must include a "full and fair discussion" of direct, indirect, and cumulative environmental impacts). As the Court concluded in *New York v. NRC*, this means "[u]nder NEPA, an agency must look at both the probabilities of potentially harmful events and the consequences if those events come to pass." 681 F.3d at 478-79 (citing *Carolina Envtl. Study Grp. v. U.S.*, 510 F.2d 796, 799 (D.C. Cir. 1975)). Only if the probability of an environmental impact is so low as to be "remote and speculative," can an agency avoid analyzing the impacts of an action. *Id.* (citing *City of New York v. Dep't of Transp.*, 715 F.2d 732, 738 (2d Cir. 1983) ("The concept of overall risk incorporates the significance of possible adverse consequences discounted by the improbability of their occurrence.")). Thus, the Court held that the NRC must evaluate both the probability and the consequences of environmental impacts resulting from SFP leaks before finalizing the Waste Confidence Decision.

In reaching this conclusion, the Court in *New York v. NRC* found NRC's previous analysis of SFP leaks underlying the 2010 waste confidence decision lacking. The Court faulted the NRC for failing to "look *forward* to examine the effects of the additional time [spent fuel will be held] in storage [pools]," and failing to "examin[e] past leaks in a manner that would allow the Commission to rule out the possibility that those leaks were only harmless because of site-specific factors or even sheer luck." 681 F.3d at 481. The Court went on to fault the NRC for relying on untested improvements to SFPs to conclude leak impacts would be insignificant and relying entirely on monitoring and compliance programs as a buffer against pool degradation. *Id.* The Court then reached the seemingly obvious conclusion, that "[a] study of the impact of thirty additional years of SNF storage must actually concern itself with the extra years of storage." *Id.*

Regrettably, the NRC's new SFP leaks analysis in the DGEIS suffers from the same flaws as the vacated 2010 waste confidence decision. Seemingly without regard to NEPA or the *New York v. NRC* Court's decision, the NRC concludes SFP leaks will not have significant impacts without conducting the requisite analyses required by the remand and NEPA.

First, the NRC again fails to evaluate the relevance of past leaks to future risks, other than to say past leaks were not large enough to adversely impact public health. This is exactly the kind of backward-looking thinking the Court disapproved in *New York v. NRC*. As the Court unequivocally provided, "the harm of past leaks—without more—tells us very little about the potential for future leaks or the harm such leaks might portend." *See id.*

Second, the NRC again inappropriately relies almost exclusively on compliance programs to support its scientific finding that significant impacts will not occur. *See* DGEIS at E-9, 4-26 (The NRC states that "stainless-steel liners and leakage-collection systems . . . and . . .

monitoring and surveillance of SFP water levels[,] make it unlikely that a leak will remain undetected long enough to exceed any regulatory requirement . . .” and further asserts that required groundwater monitoring provides an additional layer of protection.). As the Court warned the agency in *New York v. NRC,* “merely pointing to the compliance program is in no way sufficient to support a scientific finding that spent-fuel pools will not cause a significant environmental impact during the extended storage time.” *See* 681 F.3d at 481 (The NRC cannot merely assert that “leaks will not occur because the NRC is ‘on duty.’”).

Third, the NRC again fails to consider the impacts of additional storage time, as required by the Court. *See id.* (The NRC “must actually concern itself with the extra years of storage.”). This shortfall is even more concerning because the DGEIS contemplates indefinite storage – and not merely storage for an additional 30 years. The proposed rule also lacks any time limit for environmental and safety findings regarding pool storage of spent fuel.

The DGEIS also violates NEPA. It fails to consider many reasonably foreseeable impacts, including off-site impacts that do not exceed the NRC’s radiological exposure limits, on-site impacts, and certain social and economic factors including licensee longevity, property devaluations, and cleanup costs. It also fails to fully evaluate cumulative impacts. *See generally Robertson*, 490 U.S. at 350. In addition, the NRC conducts a generic analysis using bounding parameters that are not broad enough to cover a number of site-specific concerns. *See New York v. NRC*, 681 F.3d at 480-81 (NRC must conduct a “thorough and comprehensive” analysis using “conservative bounding parameters.”). And, it fails to consider impacts of storage of spent fuel in pools for longer than 60 years, although such storage is reasonably foreseeable and indeed contemplated by certain NRC regulations, including the proposed rule 10 C.F.R. § 51.23 (which has no time limit on extended storage) and existing rule 10 C.F.R. § 50.82 (which allows for decommissioning beyond 60 years under certain circumstances). *See Robertson*, 490 U.S. at 350; *see also Potomac Alliance*, 682 F.2d at 1035-36 (J. Bazelon, concurring) (noting that NRC may not simply ignore reasonably foreseeable possibilities).

For all these reasons, which are discussed more fully below and in the accompanying declaration of David Lochbaum (incorporated herein by reference), the analysis of SFP leak impacts in the DGEIS fails to satisfy NEPA.

1. The NRC’s SFP leaks impact analysis violates NEPA and the Court’s decision in *New York v. NRC* because it does not evaluate the relevance of past leak events to the probability and consequences of future leaks

In its SFP leak impacts analysis, the NRC must “examin[e] past leaks in a manner that would allow the Commission to rule out the possibility that those leaks were only harmless because of site-specific factors or even sheer luck.” *New York v. NRC* 681 F.3d at 481. Without such an examination, the NRC cannot rely on “a finding that past leaks have been harmless [to reach] a conclusion that future leaks at all sites will be harmless as well.” *Id.* But this is exactly what the NRC attempts to do in its DGEIS – it provides a list of past leaks without meaningfully evaluating the circumstances surrounding leak detection or the leak impacts. And, the list is incomplete: the NRC fails to mention significant past SFP leaks at the Yankee Rowe nuclear plant and Brookhaven National Laboratories (BNL) that grossly exceeded the U.S. Environmental Protection Agency (EPA) drinking water standard of 20,000 picocuries per liter (pCi/l) for tritium. Lochbaum Declaration, pars. 4.3-4.6, 4.7-4.17. The occurrence of these leaks not only undermines the NRC's conclusion that past SFP leaks were "harmless," but the fact that such large leaks progressed undetected for years undermines the NRC's assurances that all future SFP leaks will be detected before causing harm, based on the assumption that existing regulatory requirements are sufficient to meet this goal. NEPA requires a more complete evaluation of the relevance of past leak events to the probability and consequences of future leaks.

a. NRC's analysis of past leaks in Tables E-4 and E-5 is incomplete

As discussed above, the NRC must look at both the probability and consequences of SFP leaks. *New York v. NRC*, 681 F.3d at 478-79 (citing *Carolina Envtl. Study Grp. v. U.S.*, 510 F.2d 796, 799 (D.C. Cir. 1975)). To do this, the NRC claims to have looked at past leaks to "establish a baseline for the analysis of future impacts and provide context to those impacts." DGEIS at E-19. Information about the occurrence of past leaks is contained entirely within Table E-4 in the DGEIS, which lists 16 past leaks at 13 reactors sites. DGEIS at E-20. However, this table is incomplete, and fails to discuss the BNL and Yankee Rowe nuclear plant SFP leaks. Without assessing these leaks, the DGEIS underestimates the prevalence of past leaks and thus the likelihood of future leaks. *See* Lochbaum Declaration, par. 4.2. These omitted leaks have important implications (discussed below) and must be considered.

NRC also fails to discuss the actual probability of past leaks in its analysis of future leaks. NRC asserts that SFP leaks "seldom occur due to stringent design features and operational controls." DGEIS at E-9. This is blatantly false. SFP leaks occur often, as demonstrated by NRC's own chart acknowledging that at least 16 leaks have occurred at 13 reactor sites (out of approximately 100), and also by the above discussion of several leaks that NRC failed to consider. *See* DGEIS at E-20. Basic math tells us that more than 10-15% of SFPs in the United States have already leaked. And those are just the leaks that have been detected. As discussed in the following subsection it is clear that many leaks go undetected for long periods of time and as such, it is reasonably likely that additional leaks are occurring or have occurred at operating reactors that are currently unknown to the NRC.

b. NRC does not discuss the circumstances and implications of past leaks

Not only does the NRC fail to fully consider the probability of future SFP leaks as noted above, but the NRC also fails to properly assess the circumstances within which past leaks were detected, and the environmental and economic impacts of past SFP leaks (including those leaks listed in Table E-4, the BNL leak, and the Yankee Rowe leak). NEPA requires such consideration. *See New York v. NRC*, 681 F.3d at 478-79 (citing *Carolina Envtl. Study Grp. v. U.S.*, 510 F.2d 796, 799 (D.C. Cir. 1975)). "Only if the harm in question is so 'remote and speculative' as to reduce the effective probability of its occurrence to zero may the agency dispense with the consequences portion of the analysis." *New York v. NRC*, 681 F.3d at 482 (citing *Limerick Ecology Action, Inc. v. NRC*, 869 F.2d 719, 739 (3d Cir. 1989)).

As is more fully set forth in the accompanying Lochbaum Declaration, many past leaks directly refute the NRC's underlying conclusion in the DGEIS that leaks will be detected promptly and not cause significant harm. For example, the Yankee Rowe and Salem nuclear plant leaks demonstrate how a leak of over 100 gallons per day (gpd) can occur for long periods of time without detection. Lochbaum Declaration, pars. 4.3-4.7, 4.18-4.23. Each of these leaks caused harm. Lochbaum Declaration, pars. 4.3-4.7, 4.18-4.23 (at Yankee Rowe "approximately two million gallons of radioactively contaminated water leaked for perhaps as long as three years before [the leak] was detected," with nearby surface water having tritium concentrations of over 1,000,000 pCi/L) (the Salem leak leached into surrounding soil and groundwater below the reactor site, causing the need for a massive cleanup in which, so far, "over 28 million gallons of groundwater have been recovered and processed"). Leaks at BNL and Indian Point demonstrate that smaller leaks can likewise go undetected and contaminate the environment. Lochbaum Declaration, pars. 4.7-4.17, pars. 4.24-4.31 (the BNL leak went undetected for 12 years and contaminated groundwater, causing tritium levels between 2 and 32 times the federal drinking water standard) (at Indian Point, a leak went undetected, leaching into the soil and groundwater for about 2 years and resulting in exceedances of drinking water standards for tritium and strontium-90). The NRC failed to consider the consequences of these, or any other leaks listed in Table E-4, in its SFP leaks analysis.

Moreover, the NRC does not describe how the leakage was ultimately detected for any of the SFP leak events listed on Table E-4 in the DGEIS. Lochbaum Declaration, pars. 4.3-4.17. As noted in the Lochbaum Declaration, several of the SFP leaks (including Salem, BNL, and Indian Point) were detected by "sheer luck." Lochbaum Declaration, pars. 4.7-4.17, 4.18-4.23, 4.24-4.31 (at Salem, because of a clog in the leak detection system, a 100 gpd leak went undetected until water from the leak seeped through concrete and formed a puddle on the floor of an adjacent building at the reactor site) (at BNL, despite discovering contamination in the groundwater in the 1980s, a SFP leak was not detected in four inspections or through water level monitoring for 12 years; eventually, during a fifth test in 1997, the leak was discovered) (at Indian Point, a SFP leak that started in the 1990s went undetected for years until it was discovered during the investigation of a subsequent leak in 2005; the 2005 leak was only discovered when workers noticed moisture forming on a concrete wall during construction related excavation).

Before concluding that future leaks will not cause significant environmental impacts, the NRC was required to consider the impacts of past leaks and describe how past leaks were detected. It failed to do so. And, because of that failure it could not then assess whether past detection methods can ensure that future leaks will likewise be detected. In fact, as described above, many past leaks were discovered literally by accident, or due to random occurrences that were entirely unconnected to NRC regulatory requirements and controls in place at the time. Common sense dictates that the thorough, careful analysis of past leaks required by NEPA must necessarily examine how the past leaks were detected, in order to determine whether existing and future controls are sufficient. Because the NRC cannot reasonably rely on luck, NEPA requires it to analyze impacts of future leaks that go undetected. Without such an analysis, the DGEIS violates NEPA and the Court's order in *New York v. NRC*.

2. The NRC's SFP leak impacts analysis violates NEPA and the Court's decision in *New York v. NRC* because it inappropriately relies almost entirely on compliance programs to support its scientific finding that significant impacts will not occur

In the DGEIS, the NRC concludes that leaks will be prevented and detected before causing significant impacts. DGEIS at xxxvii, 4-26, E-9–10, E-15–16. To reach this conclusion, (a) the NRC claims that all leaks of greater than 100 gallons per day will be promptly detected, and (b) the NRC relies on inapplicable leak detection regulations, voluntary programs, and programs that are substantially reduced in scope after reactors shut down.

NRC cannot, without more, simply assert that "leaks will not occur because the NRC is 'on duty.'" *New York v. NRC*, 681 F.3d at 481. Relying almost entirely on monitoring and regulatory compliance programs, many of which are inapplicable once a reactor shuts down, to conclude that future leaks will be detected before causing significant impacts is not sufficient. *See id.* (Despite NRC's enforcement and inspection efforts, "merely pointing to the compliance program is in no way sufficient to support a scientific finding that SFPs will not cause a significant environment[al] impact during the extended storage period." This is especially true when the NRC's predictions span nearly a century at certain facilities.). NEPA requires the NRC to consider the reasonably foreseeable impacts that could result if these monitoring and regulatory compliance programs fail to detect a significant leak.

a. The NRC fails to explain the importance and usefulness of its 100 gallon per day leak detection threshold

In the DGEIS, the NRC claims that leaks equal to or greater than the average evaporation rate, 100 gallons per day (gpd), will be promptly detected—100 gpd is the average SFP evaporation rate. DGEIS at E-10 (According to the DGEIS, "[t]o go undetected, a leak would need to be less than the fluctuations in water level of a SFP lost to evaporation."). This assumption, however, is simply not true. As noted above in Section VI.D.1.B, leaks great than 100 gpd have gone undetected by monitoring systems in the past for long periods of time (e.g., the Yankee Rowe leak, which went undetected for somewhere between 1 and 3 years, and released 2 million gallons of contaminated SFP water; the Salem leak which went undetected for a long period of time due to a clog in the telltale drain of the leak detection system). Lochbaum Declaration, pars. 4.4-4.5, 4.21. And, the NRC did not even evaluate leaks less than 100 gpd. As described above, past leaks of less than 100 gpd have also gone undetected for long periods of time (e.g., the Indian Point leaks went undetected for long periods of time, including one for over 2 years in the 1990s; the BNL leak went undetected for 12 years despite abnormally high tritium levels in the groundwater and repeated SFP tests). Lochbaum Declaration, pars. 4.17, 4.25.

The NRC's claim that it is on duty and that it will promptly detect leaks of over 100 gpd and that lesser leaks will not cause significant impacts is unsupported. Because past leaks have occurred both above and below the threshold, it is reasonably foreseeable that similar leaks could occur in the future. NEPA requires the NRC to analyze the impacts of such future leaks in its DGEIS.

b. The NRC improperly relies on inapplicable regulations, voluntary programs, and programs that are greatly reduced in scope after reactors shut down

In concluding that all leaks will be detected before causing significant impacts, the NRC repeatedly relies on inapplicable and voluntary compliance and monitoring programs. *See* Lochbaum Declaration at Sections VI and VII.

For example, the NRC claims SFP water levels are being "constantly measured by instrumentation." DGEIS at E-10. This is false. Water level instrumentation is not required to be in pools at all times; rather, it is required only during the short time when spent fuel is being moved. Lochbaum Declaration, par. 6.19. The NRC also claims that licensees are required to perform groundwater monitoring at reactor sites for support of its conclusion that leaks are unlikely to migrate off site. DGEIS at E-10. This is also false. The NRC has no general groundwater monitoring requirements, either for operating reactors or decommissioning reactors. Lochbaum Declaration, par. 6.40. To support its claim, the NRC relies on the Decommissioning Planning Rule (DGEIS at E-5, E-8); however, that rule allows licensees to choose whether or not to conduct groundwater monitoring. Lochbaum Declaration, Section VI.D, par. 6.41. And the NRC relies on the Groundwater Protection Initiative as support for its conclusions about SFP leaks. DGEIS at E-6. Unfortunately, the Groundwater Protection Initiative is voluntary and as such, cannot be relied upon to ensure future leaks will be promptly detected. Lochbaum Declaration, pars. 6.42-6.44 (noting further that this voluntary program has only been audited at operating reactors, never at shutdown reactors). Further, there is no requirement that licensees analyze a postulated leak of any magnitude of contaminated water from a SFP, even though that type of NRC requirement exists in other contexts (e.g., during the licensing process for the liquid waste management system).[12] Lochbaum Declaration, pars. 6.25-6.30. Because these programs are voluntary or inapplicable, NRC has no basis for relying on them to conclude that leaks will be detected before causing significant impacts.

In support of its conclusion, NRC also assumes that current monitoring requirements, oversight procedures, and other programs will remain effective after reactors shut down. DGEIS at 1-15, 1-17, E-4. This assumption is unsound because the scope of many of these requirements, procedures, and programs will be greatly reduced. Lochbaum Declaration, par. 7.2. For example, shut down reactor licensees do not receive important safety communications and enforcement orders that are issued to operating reactor licensees. Lochbaum Declaration, Pars. 7.3-7.10 (e.g., after the March 2011 Fukushima disaster in Japan, an order requiring installation of monitoring equipment at SFPs was sent to reactor licensees, but no record of the order exits for the shutdown Zion nuclear power reactors). Similarly, NRC relies upon the Maintenance Rule to ensure leak detection. DGEIS at E-5. However, it is greatly reduced in scope after reactors shut down. Lochbaum Declaration, pars. 7.20-7.21 (Under the Maintenance Rule, "licensees can and do legally omit structures, systems, and components needed to detect and

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[12] Not only should the NRC have included a postulated leak analysis, it should have quantified that analysis. The NRC must conduct a quantitative analysis to the extent practicable. *See* 10 C.F.R. § 51.71(d). A discussion of how a quantitative analysis could have been conducted can be found in the Lochbaum Declaration, pars. 6.32 to 6.34.

mitigate SFP leaks . . . from the scope of their maintenance programs.”). NRC also relies on its aging management program to ensure SFPs remain structurally sound during storage. DGEIS at E-5. However, that program, like so many others, is reduced in scope after reactors shut down. Lochbaum Declaration, pars. 7.37-7.43 (explaining that aging management is only required during the period of extended operation, not throughout the entire 60-year storage period). The NRC’s analysis fails to evaluate how this reduction in aging management protects against the bathtub curve effect—demonstrating an increase in failure rate over time. Lochbaum Declaration, par. 7.42.

In conducting a sufficient NEPA analysis, the NRC should have analyzed examples of shut down reactors and the regulatory scheme that applies to them. For example, the Zion and Dresden Unit 1 nuclear plants are shut down and have greatly reduced regulatory programs. Lochbaum Declaration, pars. 7.22-7.36 (At the shutdown Zion nuclear plant, works or inspectors “seeking to ascertain whether ‘spent fuel in a safe condition’ is reasonably assured . . . need only evaluate whether protections against a fuel handling accident and a significant reduction in SFP water inventory are adequate.”) (At the shutdown Dresden reactor the licensee turned off the SFP cooling and cleanup system in 1983 and the owner had no leak detection program or water level inventory program.).

The NRC’s claims that leaks will be detected before significant impacts are caused because it is “on duty” not only violate NEPA and the Court’s decision, but they are also untrue. The NRC should have conducted an analysis that discussed regulations and programs that are in place throughout the storage period. And, the NRC should have analyzed the impacts of SFP leaks should these limited regulations and programs not result in prompt leak detection.

3. NRC’s SFP leaks impact analysis violates NEPA and the Court’s decision in *New York v. NRC* because it fails to meaningfully consider the impacts of additional storage time

“[A] proper analysis of the risks [of SFP leaks] would necessarily look forward to examine the effects of the additional time in storage . . .” because the “WCD . . . seeks to extend the period of time for which pools are considered safe for storage.” *New York v. NRC*, 681 F.3d at 481. In vacating the 2010 waste confidence decision, the court held that “[a] study of the impact of thirty additional years of SNF storage must actually concern itself with the extra years of storage.” *Id.* An analysis of the extra storage time is especially relevant, “when the period of time covered by the Commission’s predictions may extend to nearly a century for some facilities.” *Id.* In the proposed rule 10 C.F.R. § 51.23, there is no delineated time frame for storage (“it is feasible to safely store spent nuclear fuel following the licensed life for operation of a reactor”), and as such, it could be indefinite. Regardless of whether NRC claims fuel will only be in pools for 60 years or indefinitely, NRC has not considered the impacts of the additional time in pool storage.

While implementation of aging management programs is required by the NRC during a facility’s operating life, and period of extended operation, there is no such requirement during the 60 year post –shutdown period, or beyond. Lochbaum Declaration, pars. 7.37-7.43. As a result, further aging degradation in the absence of such programs will eventually cause an increase in the failure rate of certain plant structures or systems, including SFPs, based on the use of the "bathtub curve." *See* Lochbaum Declaration, pars. 7.37, 7.42. The NRC's SFP leaks analysis fails to explain the increase in failure rate or provide support for its conclusion that extra time in storage will not cause significant impacts if and when future leaks occur. As such, it flies in the face of NEPA and the Court's decision.

4. NRC's analysis violates NEPA because it fails to consider certain reasonably foreseeable significant impacts altogether

As discussed at the outset of this Section, the NRC must take a "hard look" at all reasonably foreseeable impacts of the proposed action. 42 U.S.C. 4332(2)(C); *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 350 (1989) (quoting *Kleppe v. Sierra Club*, 427 U.S. 390, 410 n. 21 (1976)). Further, as the *New York v. NRC* Court noted, this goes beyond merely looking at human health impacts. 681 F.3d at 481 (noting that "near-term health effects are not the only type of environmental impacts"). NRC's analysis violates NEPA because it fails to evaluate certain significant impacts altogether and fails to fully consider cumulative impacts related to SFP leaks.

As explained in greater detail in the Lochbaum Declaration, the NRC fails to evaluate offsite impacts from leaks when the contamination does not exceed federal radiological standards, onsite leak impacts, and social and economic impacts related to property devaluation and licensee longevity. *See generally* Lochbaum Declaration, Section VIII. For example, in the DGEIS, the NRC considers radiological impacts "small" if releases do not exceed standards in NRC's regulations. DGEIS at 4-64, E-18. However, significant environmental impacts can and do occur even with contamination below NRC's radiological standards. *See* Lochbaum Declaration, pars. 8.2-8.7 (explaining that while the contamination from the Salem nuclear plant SFP leak has not violated federal standards for drinking water, it resulted in a sizable cleanup cost; and noting an effluent pipe leak at Braidwood nuclear plant in Illinois had significant consequences even though it did not exceed offsite radiological standards—e.g., bottled water was provided to about 420 homeowners and the licensee purchased contaminated property and reimbursed some 14 property owners for devaluations from the leak). The NRC also excludes any analysis of onsite impacts from SFP leaks. DGEIS at E-8 (asserting that onsite impacts are outside the scope of the DGEIS). But significant impacts, such as costly cleanups, could occur onsite for SFP leaks, and should be analyzed in the DGEIS. Lochbaum Declaration, pars. 8.2-8.7 (e.g., an underground pipe leak at New Jersey's Oyster Creek nuclear plant cost millions of dollars to cleanup even though it remained onsite).

SFP leaks, and the extensive cleanups associated with them, also may cause property devaluation. *See* Lochbaum Declaration, pars. 8.6, 8.9 (noting that a pipe leak at Braidwood caused property devaluation for at least 15 property owners and the licensee either purchased the contaminated property outright or reimbursed landowners for their losses). The NRC fails to consider this impact. And, it also fails to consider the likelihood of increased impacts that will occur over time. From a socioeconomic perspective, given the typical lifespan of a corporation, an owner no longer receiving revenue from a permanently retired nuclear plant may not survive for six decades to clean up the leaks from its SFPs. Lochbaum Declaration, par. 8.10.

NRC's narrow framework for assessing SFP leak impacts has resulted in an "analysis" which fails to adequately consider other relevant environmental impacts as well. Particularly, NRC's consideration of the impacts posed by SFP leaks on surface water resources is severely wanting and inadequate under NEPA as well as the court's decision. NRC acknowledges that SFP leaks can discharge to offsite surface waters, but then indicates that "dilution ensures that radionuclides" would be "diluted well below EPA safe drinking-water limits." DGEIS at E-17. This limited focus on drinking water-related impacts boils down to a consideration from a public health aspect, and ignores other relevant potential environmental impacts to surface waters, namely impacts to aquatic ecology. Importantly, NRC's restricted consideration of impacts to surface waters is precisely what was deemed by the Circuit Court as insufficient. 681 F.3d at 481. Yet, the DGEIS contains no meaningful analysis of how SFP leaks may impact nearby aquatic habitats and organisms.[13]

NRC must fully analyze the extent to which SFP leaks may contaminate surface waters and the foreseeable impact of such contamination on the aquatic ecology of such waters. Such an assessment cannot be limited to NRC dose calculation methodology, but rather must focus more broadly on impacts to aquatic organisms, with regard for other Federal, State, and/or local standards and requirements. The DGEIS must consider the length of time surface waters will be contaminated by, and thus, aquatic ecology exposed to, radiological contamination (with due consideration for the fact that SFP leaks may admittedly occur for long periods of time undetected) and the various ways in which different radionuclides have the potential to bioaccumulate in the environment, e.g. in river sediments, sub-aquatic vegetation, shellfish, and finfish. NRC must determine the extent to which aquatic organisms may be impacted over long-periods of time. An evaluation of the impacts of bioaccumulation and long-term exposure to low levels of radioactivity should be conducted by the NRC. NRC should focus attention on long-term exposure impacts to varying fish populations, as well as impacts to individuals within populations. NRC should not assume that a lack of impacts to date (at plants where SFP leaks have already contaminated surface waters) means that no future impacts will occur. *See New York v. NRC*, 681 F.3d at 481. Rather, NRC must fully evaluate the foreseeable future impacts to aquatic organisms that may occur as a result of SFP leaks. In addition, an assessment of the foreseeable impacts of SFP leaks on surface waters must also consider the potential for such leaks to interfere with recreational enjoyment of such waters (such as swimming, fishing, boating, etc.), with regard to the fact that such waters may be legally designated as suitable for such purposes by State agencies.

Moreover, NRC's assessment of the impacts of SFP leaks on public health is likewise improperly narrow. That is, NRC focuses only on whether releases would "exceed permissible levels set by the NRC and the EPA." DGEIS at E-18. However, it is appropriate and necessary under NEPA to assess all *foreseeable* impacts, and not to only focus on certain narrow standards. Thus, given the court's directive to NRC to assess potential future harm to the public and "the effect of the *additional* time in [pool] storage," (*New York*, 681 F.3d at 481 (emphasis added)),

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[13] In fact, despite the fact that one of the purported focuses of the DGEIS is SFP leaks, the NRC's only consideration of impacts to aquatic ecology focuses on cooling water intake structure impacts, with no meaningful discussion of impacts of radioactive waste storage on such resources. *See* DGEIS at § 4.10, at pages 4-35-4-41.

NRC's DGEIS must include a comprehensive evaluation of the risks to public health posed by potential future SFP leaks and long-term exposure to such leaks, and in this regard, NRC should examine the long-term impacts from low-level exposure to SFP leaks in light of the conclusion of the Biological Effects of Ionizing Radiation VII report that every exposure to radiation, regardless of how small, and no matter what pathway, produces a corresponding increase in the likelihood of cancer.[14]

Further, the NRC fails to fully evaluate cumulative impacts in its DGEIS. The Court of Appeals explained that "a proper analysis of the risks [of SFP leaks] would necessarily look *forward* to examine the effects of the additional time in storage, *as well as examining past leaks*." *New York*, 681 F.3d at 481 (first emphasis in original; second emphasis added). Under NEPA, the NRC must consider the "impact on the environment that results from the incremental impact of [its] action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or non-federal) or person undertakes such other actions." 40 C.F.R. § 1508.7; *see also* 10 C.F.R. §51.45(c); *see also* 10 C.F.R. § 51.75, 10 C.F.R. § 51.45. This is because cumulative impacts "can result from individually minor but collectively significant actions taking place over a period of time." *See* 40 C.F.R. § 1508.7. As numerous courts have explained, a meaningful cumulative impact assessment must therefore identify (1) the affected area, (2) the expected impacts of the project, (3) other past, present, proposed, and reasonably foreseeable actions that are expected to have impacts in the same area, (4) the impacts or expected impacts from such other actions, and (5) the overall expected impact in light of the accumulation of the individual impacts. *See Grand Canyon Trust v. FAA*, 290 F.3d 339, 345-46 (D.C. Cir. 2002). In other words, the agency "cannot treat the identified environmental concern in a vacuum." *Id.* at 346.

However, NRC has demonstrably failed to fully assess cumulative impacts in relation to SFP leaks. To begin with, the NRC does not consider impacts from multiple SFP leaks in close proximity (e.g., sites such as Turkey Point where there are multiple SFPs) or impacts from combined contamination of groundwater in areas where other waste sites are nearby (e.g., Plant Vogtle is located just across the Savannah River from the Savannah River Site, which contains a large amount of nuclear waste).

In addition, NRC has failed to analyze the cumulative impacts that may result from past, present, and reasonably foreseeable future radiological leaks from *non*-SFP systems, structures, and components. It can logically be expected that future (and/or existing) leaks and contamination from SFPs will interact with and cause cumulative impacts with any past, current, and likely future leaks from other, non-SFP components. As one NRC licensing board has aptly explained, "if releases from SFP leaks encounter groundwater, then the radionuclides would co-mingle and coalesce with any impacts that might be present from other sources" and "it is unlikely" that "concentration levels" in groundwater "can be parsed into relative contributions from the separate sources that contribute to the overall groundwater contamination at the site, and that

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[14] National Research Council, Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII – Phase 2 (2006), *available at*, https://download.nap.edu/catalog.php?record_id=11340 (finding that the risk of cancer is linear with dose and that there is no level of exposure below which there is no proportional risk).

"[b]y necessity", "the impacts to groundwater from SFP leaks and the subsequent discharges into" adjacent surface waters must be considered "on a site-wide basis." In the Matter of Entergy Nuclear Operations, Inc. (Indian Point Nuclear Generating Units 2 and 3), Docket Nos. 50-0247-LR and 50-286-LR, ASLBP No. 07-858-03-LR-BD01, Order (Granting in Part and Denying in Part Applicant's Motions *in Limine*) (March 6, 2012), at 29, ADAMS Accession No. ML12066A170. Thus, such cumulative radiological leakage impacts must be fully assessed in NRC's DGEIS.

Non-SFP leaking plant components at facilities around the country have already contaminated on-site and off-site groundwater and public waterways.[15] As of June 2011, NRC reported that 42 of 65 reactor sites, i.e., 65%, have experienced problems with radiological leaks.[16] The trend of accidental radiological leaking can be expected to continue and even increase as America's original nuclear fleet continues to age. Indeed, the basic engineering principle of the "bathtub" curve (*see* Lochbaum Declaration, pars. 7.37-7.43) indicates that as these aging nuclear plants reach the end of their operating lives, problems, such as component degradation and resulting leaks, can be expected to sharply increase. Historically, U.S. nuclear power plants have had leakage problems with difficult to inspect buried pipes and components. The U.S. GAO conducted a study that concluded in 2011 that, "[t]he occurrence of leaks at nuclear power plants from underground piping systems is *expected to continue* as nuclear power plants age and their piping systems corrode."[17] GAO confirmed that because "underground piping systems tend to corrode" and are "largely inaccessible and difficult to inspect," the "*severity of leaks could increase* without mitigating actions."[18] Plant owners' aging management programs and more recent industry initiatives that allegedly are designed to "handle" leaks from the miles and miles of buried and inaccessible buried components fall far short of providing the necessary assurances the radiological leaks will be properly detected and prevented in the future.[19] The NRC must

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[15] *See generally* Liquid Radioactive Release Lessons Learned Task Force Final Report, September 1, 2006, *available at*, ADAMS Accession No. ML062650312 ; *see also* Riverkeeper and Hudson River Sloop Clearwater Initial Statement of Position Regarding Consolidated Contention RK-EC-3/CW-EC-1 (Spent Fuel Pool Leaks) (December 22, 2011), at 41-43, *available at* ADAMS Accession No. ML12335A617 (describing various non-SFP component leaks that have occurred at Indian Point).

[16] *See* Leaks and Spills of Tritium at U.S. Commercial Nuclear Power Plants, Rev 9 (June 7, 2012), ADAMS Accession No. ML101270439; *see also* Union of Concerned Scientists, *Groundwater Events Sorted by Date*, September 27, 2010, *available at*, http://www.ucsusa.org/assets/documents/nuclear_power/Groundwater-Events-Sorted-by-Date.pdf; Jeff Donn, Radioactive tritium leaks found at 48 US nuke sites (June 21, 2011), *available at*, http://www.msnbc.msn.com/id/43475479/ns/us_news-environment/t/radioactive-tritium-leaks-found-us-nuke-sites/ (last visited Dec. 13, 2012).

[17] Liquid Radioactive Release Lessons Learned Task Force Final Report, September 1, 2006, at 22 *available at*, ADAMS Accession No. ML062650312 (emphasis added).

[18] *Id.* at 1.

[19] Plant programs and industry initiatives are simply not designed to identify or stop *all* potential radiological leaks; alleged "enhanced" inspection commitments still only cover a small fraction of total amounts of onsite buried piping. *See, e.g.*, In the Matter of Entergy Nuclear Operations, Inc. (Indian Point Nuclear Generating Units 2 and 3), ASLBP # 07-858-03-LR-BD01, Docket #

consider and account for this in its DGEIS. In addition, accidental spills and releases caused by human error have also resulted in releases of radioactivity to the environment at nuclear power plants.[20] Such incidents will likely continue to occur, and NRC must consider cumulative impacts that may result from such accidental spills and releases.

It is reasonably foreseeable that non-SFP components will continue to contaminate the environment around U.S. nuclear power plants prior to as well as during post-operation timeframes, and it is patent that such other radiological leaks may affect the nature and impact of any future SFP leak, i.e., result in cumulative impacts. NRC must fully analyze such cumulative impacts.

Because the NRC's analysis fails to consider several reasonably foreseeable impacts, it directly violates NEPA.

5. NRC's analysis violates NEPA because it fails to consider relevant measures to mitigate adverse environmental consequences of SFP leaks

NEPA mandates that in undertaking environmental reviews, agencies must "discuss the extent to which adverse effects can be avoided" so that "the agency [and] other interested groups and individuals can properly evaluate the severity of the adverse effects." *Robertson v. Methow Valley Citizens Council,* 490 U.S. 332, 351-52 (1989) (citations omitted).[21] Without such a

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05000247, 05000286, Exhibit # NYS000164-00-BD01, Pre-Filed Written Testimony of Dr. David J. Duquette, Ph.D Regarding Contention NYS-5, ADAMS Accession No. ML12334A699 (explaining deficiencies in the "aging management program" at Indian Point for preventing and detecting corrosion of buried pipes and components).

[20] Liquid Radioactive Release Lessons Learned Task Force Final Report, September 1, 2006, at 34, *available at*, ADAMS Accession No. ML062650312; Riverkeeper and Hudson River Sloop Clearwater Initial Statement of Position Regarding Consolidated Contention RK-EC-3/CW-EC-1 (Spent Fuel Pool Leaks) (December 22, 2011) at 42, 53, *available at* ADAMS Accession No. ML12335A617; GZA, GeoEnvironmental, Inc. Final IPEC Quarterly Long-Term Groundwater Monitoring Report, Quarter Two 2010 (Report No. 10) (February 15, 2011), IPEC00227561, at p.1-2, ADAMS Accession No. ML12275A555 (hereinafter "GZA IPEC Quarter 2 Groundwater Report") (Entergy's vendor describing a spill from a Reactor Waste Storage Tank ("RWST"), that resulted in a marked increase in the tritium plume present at the Indian Point site that Entergy attributes to the Unit 2 SFP leaks; this spill resulted in an increase in radionuclide levels in the groundwater that lasted for many months).

[21] *See also id.* ("One important ingredient of an EIS is the discussion of steps that can be taken to mitigate adverse environmental consequences. . . Implicit in NEPA's demand that an agency prepare a detailed statement on 'any adverse environmental effects which cannot be avoided should the proposal be implemented,' is an understanding that the EIS will discuss the extent to which adverse effects can be avoided. More generally, omission of a reasonably complete discussion of possible mitigation measures would undermine the 'action forcing' function of NEPA. Without such a discussion, neither the agency nor other interested groups and individuals can properly evaluate the severity of the adverse effects. . . Recognizing the

discussion, it is patent that the agency has failed to take the requisite "hard look" at the environmental consequences of a proposed action. *See id.* Regulations implementing NEPA are likewise instructive. In particular, federal regulations require that reviewing agencies consider and assess mitigation measures in an EIS. 40 C.F.R. § 1508.25(b)(3); *see also* 10 CFR Part 51, Subpart A, App. A ("appropriate mitigating measures of the alternatives will be discussed"). These regulations define mitigation as:

> (a) Avoiding the impact altogether by not taking a certain action or parts of an action.
> (b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.
> (c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.
> (d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
> (e) Compensating for the impact by replacing or providing substitute resources or environments.

40 C.F.R. § 1508.20; *see also* 10 C.F.R. § 51.71 (requiring consideration of "alternatives available for reducing or avoiding adverse environmental effects").

Yet, the DGEIS fails to include an assessment of all relevant measures that may mitigate adverse environmental consequences of future SFP leaks and any contamination of the environment resulting therefrom. Various feasible measures are available that could avoid, minimize, rectify, reduce, or eliminate the environmental impacts of future radiological SFP leaks and contamination associated with such leaks. The EIS should include an assessment of the feasibility and efficacy of all reasonable measures to mitigate the impacts of future SFP leaks on the environment, including, but not limited to, the following:

- *<u>Immediate clean-up activities associated with groundwater contamination resulting from SFP leakage</u>*. NRC must fully consider the degree and extent to which immediate clean-up activities may reduce environmental impacts of future SFP leakage. In particular, NRC must assess the feasibility and efficacy of extracting (via extraction wells) any contaminated groundwater, treating and/or excavating any contaminated soil, and any other remedial clean-up measures that could address contamination resulting from future SFP leaks. For example, NRC must analyze the degree to which groundwater extraction may prevent the migration of radiological contamination into adjacent surface waters and thereby avoid impacts to aquatic ecologies. Notably, NRC should not simply accept, or draw conclusions based upon, activities licensees may have (or have not) already taken in response to previous radiological leakage and groundwater

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importance of such a discussion in guaranteeing that the agency has taken a 'hard look' at the environmental consequences of proposed federal action, CEQ regulations require that the agency discuss possible mitigation measures in defining the scope of the EIS, in discussing alternatives to the proposed action, and consequences of that action, and in explaining its ultimate decision.")

contamination circumstances. Instead, NRC should evaluate the efficacy of groundwater extraction, soil remediation, and other clean-up measures on an independent basis.

- *Mandatory comprehensive groundwater monitoring*. NRC must assess the efficacy of *mandatory* groundwater monitoring for minimizing the environmental harm of any future SFP leaks. NRC currently has no plans to impose any such mandatory requirements, but instead continues to rely on a purely voluntary industry program.[22] The benefits of mandatory monitoring are patent. Mandatory, as opposed to voluntary, monitoring can potentially assist in minimizing the impacts of potential future SFP leaks, and, therefore, must be fully considered in the DGEIS.

- *Preventative measures to proactively find SFP leaks before they occur and potentially cause measureable environmental impacts*. The degree to which licensees are currently committed to, or will be required to, inspect SFPs is suspect. *See* Lochbaum Declaration at Paragraphs 6.38-6.44, 7.13-7.25, 7.33-7.35, 9.6. NRC must assess the feasibility and efficacy of mandatory regular inspections of SFPs during the post-operation pool storage timeframes. NRC should consider the practicality and usefulness of physical/mechanical inspections of SFP liners, walls, floors, transfer canals, and other portions, at recurring frequencies. To the extent spent fuel is too densely packed to allow for full inspection, NRC must assess the feasibility and efficacy of reducing the density of pools to allow for such full inspections.

- *Measures to prevent initiation or exacerbation of future SFP leaks*. NRC should analyze the feasibility and efficacy of measures that could be undertaken to enhance the integrity or robustness of SFP structures and prevent the initiation or exacerbation of SFP leaks. NRC should consider newer technologies, materials, or "upgrades" that may minimize the potential for SFP leaks and environmental contamination as a result thereof. For example, NRC should consider whether existing SFPs have "tell-tale" drain collection systems that prevent environmental harm, and, to the extent SFPs do not have such systems, the efficacy of retrofitting SFPs with such systems. NRC should also consider the impacts of new seismological information on the integrity of SFPs in the event of earthquakes in the future and available "upgrades" to account for such circumstances.

- *Preventative measures to proactively prevent future leaks from leaking non-SFP components*. NRC must assess the steps that it could take to prevent or reduce future leaks from non-SFP components (e.g., other plant systems, structures, and components such as buried pipes), which, if not addressed are likely to result in cumulative environmental impacts in conjunction with future SFP leaks. NRC should also consider all reasonable measures that licensees could take to reduce or minimize the likelihood of future component leaks and impacts to groundwater, such as the feasibility and efficacy of moving buried pipes and structures above-ground so as to be able to better monitor

[22] SECY-11-0019, Policy Issue, Senior Management Review of Overall Regulatory Approach to Groundwater Protection, (February 9, 2011), *available at*, http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2011/2011-0019scy.pdf, at 3-4.

such components, and substantially increasing the number of inspections of components that are known to be prone to leakage.

- *Measures to mitigate impacts to aquatic ecologies in adjacent affected waterways*. NRC must give due consideration to the fact that aquatic ecosystems may be exposed to contamination from SFP leaks for centuries. Even low levels of any such contamination may result in impacts over time. Therefore, NRC must fully assess all measures that will minimize environmental harm to aquatic ecologies resulting from radiological SFP leaks. This includes, but is not limited to, an assessment of the feasibility and efficacy of enhanced/robust environmental monitoring of the impacts of future SFP leaks to these ecosystems. NRC cannot simply assume that existing NRC radiological effluent and environmental monitoring programs are adequate to capture all environmental impacts that may occur as a result of future SFP leaks. NRC should consider the degree to which enhanced programs will be able to more accurately detect any impacts, and, therefore assist in minimizing environmental harm. NRC should consider a wide portfolio of monitoring measures that licensees may not currently undertake, including, but certainly not limited to, the analysis of fish bone and shellfish shells in order to monitor for certain "bone seeking" radionuclides such as strontium-90, the sampling of benthic organisms, sampling at additional control locations, sampling of specific species as opposed to only opportunistic sampling, sampling more frequently, and sampling of additional analyses to ensure detection of particular radionuclides.

- *Measures to increase public access to information concerning future SFP leaks and groundwater contamination that occurs as a result.* NRC must fully analyze the extent to which more openness and transparency regarding SFP leaks and groundwater contamination will reduce environmental impacts. That is, an assessment of the significance of an environmental impact includes the degree to which it is highly controversial. 40 C.F.R. § 1508.27(b). To the extent SFP leaks may be considered controversial,[23] they are "significant" as contemplated by NEPA. Thus, measures to alleviate public concern would assist in minimizing the overall impacts of any future SFP leaks. Accordingly, NRC should consider mitigation measures related to openness and transparency in relation to SFP leaks. For example, NRC should consider the feasibility and efficacy of full and regular public disclosure and publication of licensee radiological groundwater monitoring results to keep the public fully informed of existing circumstances. This is in relation to any results that are not already currently made publicly available via NRC's ADAMS. NRC should contemplate the usefulness of such disclosures as results are generated, i.e., on a monthly or quarterly basis, depending on specific circumstances. In addition, measures to provide the public with easier access to site-specific annual radiological monitoring reports, which are available in NRC's document system, ADAMS, should also be considered.

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[23] For example, since leaks at Indian Point were "discovered," there has been a high level of public concern, which continues today. *See* Liquid Radioactive Release Lessons Learned Task Force Final Report, September 1, 2006, at ii, *available at*, ADAMS Accession No. ML062650312.

NRC has the unequivocal obligation to *consider and discuss* relevant mitigation options that are available, and to weigh the costs and benefits of such options. *See Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 351-52 (1989). Thus, pursuant to the basic tenets of NEPA, NRC must assess the foregoing measures, as well as any and all other relevant potential mitigation measures.

6. NRC's SFP leaks impact analysis violates NEPA and the Court's decision in *New York v. NRC* because the bounding parameters used by NRC are not broad enough to cover a number of site-specific concerns

Although the Court in *New York v. NRC* found that a generic analysis of environmental impacts of spent fuel storage may be appropriate, whether generic or site-specific, the analysis must be "thorough and comprehensive." *New York v. NRC*, 681 F.3d 471, 481 (D.C. Cir. 2012). The Court accepted the NRC's bounding assumptions in the 2010 waste confidence rule, considering them to be "conservative" and finding the risks associated with the waste confidence decision to be "essentially common." *Id.* at 480. However, in the DGEIS, the NRC fails to use conservative bounding assumptions and as a result, the NRC fails to fully consider several site-specific concerns.[24]

NRC's generic analysis of radioactive contamination in groundwater from spent fuel pool leaks is deficient because that issue is most appropriately addressed in a site-specific manner as explained in the recently finalized update to the License Renewal Generic Environmental Impact Statement. There, the NRC determined that impacts surrounding "radionuclides in groundwater" should be addressed as a *site-specific*, rather than generic basis because:

> This new Category 2 issue evaluates the potential contamination and degradation of groundwater resources resulting from inadvertent discharges of radionuclides into groundwater from nuclear power plants. Within the past several years, there have been numerous events at power reactor sites which involved unknown, uncontrolled, and unmonitored releases of radionuclides into the groundwater. The number of these events and the high level of public controversy have made this issue one that the NRC believes needs a "hard look" as required by NEPA.
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> *As a voluntary action, NEI 07–07 [Industry Ground Water Protection Initiative—Final Guidance Document; NEI 2007] cannot be enforced by the NRC.* As such, no violations can be issued against a licensee who fails to comply with the guidance in NEI 07-07. Furthermore, *the NRC cannot rely on a voluntary initiative as a basis to ensure that the nuclear power industry will have adequate*

[24] Bounding estimates are especially important here, where in its proposed rule, NRC states that site-specific concerns regarding future reactor and SFP storage facilities cannot be brought up during individual licensing actions. *See* Waste Confidence- Continued Storage of Spent Nuclear Fuel 78 Fed. Reg. 56804 (Sept. 13, 2013) (amending 10 C.F.R. pt. 51); *see also* Proposed Regulation 10 C.F.R. § 51.23(b).

> *information available for the NRC to determine whether a documented leak or spill does or does not have an adverse impact on groundwater resources.* Regarding the magnitude of impact, the NRC bases its determination of SMALL to MODERATE impact on a review of existing plants have had inadvertent releases of radioactive liquids. Even though the NRC expects impacts for all plants to be within this range, a conclusion of LARGE impact would not be precluded for a future license renewal review based on new and significant information if the data support such a conclusion. As reflected in the final GEIS and rule, "Radionuclides released to groundwater" remains a Category 2 issue.

Generic Environmental Impact Statement for License Renewal of Nuclear Plants, at 1-24, NUREG-1437, Volume 1, Revision 1 (June 2013) (emphasis added).[25] But here, in the DGEIS, NRC relies on that same voluntary initiative in support of its generic determination that SFP leaks will not cause significant impacts. DGEIS at E-5-E-7. NRC provides no explanation of why it deems the issue of radionuclides in groundwater site-specific in the license renewal context, but not in the waste confidence assessment of spent fuel pool leaks into groundwater and its generic treatment here is inconsistent with its recent License Renewal GEIS and illogical.

And further, the NRC should have considered a number of other site-specific concerns that fall outside of its current bounding estimates. For example, it should consider SFP sites where multiple reactors and SFPs exist (e.g., Turkey Point nuclear plant in Florida). The NRC should have also considered SFP sites where other nuclear facilities or waste sites are in close proximity, such as Plant Vogtle and its proximity to the Savannah River Site. In addition, the NRC should have considered sites that are particularly vulnerable to flooding, such as the Oconee and Fort Calhoun nuclear plants. Dam Failures and Flooding at U.S. Nuclear Plants, Union of Concerned Scientists (October 2012); Perkins, Richard, et al., Screening Analysis Report for the Proposed Generic Issue on Flooding of Nuclear Power Plant Sites Following Upstream Dam Failures (July 2011).

Generally, in order to assess the probability of future SFP leaks, a consideration of site-specific factors is critical. For example, particular sites' susceptibility to natural disasters including earthquakes, hurricanes, floods, etc., may affect the integrity of SFPs, and the probability that such events may occur can lead to or exacerbate existing SFP degradation and leaks. That is, NRC must take into account current information regarding seismicity in regions where nuclear power plants are located,[26] as well as the most current scientific knowledge regarding sea level

[25] Additionally, this provides another example of how NRC's reliance on inappropriate, inapplicable, and voluntary programs fails to satisfy NEPA as discussed in Section VI.D.2.b of these comments. While in its June 2013 License Renewal GEIS, NRC found that reliance on a voluntary program could not serve as a basis for ensuring information will be available for NRC to determine whether a leak did or did not have significant impacts, here, in its waste confidence DGEIS, NRC relied on that exact same document to support the conclusion that leaks will not have significant impacts. *See* DGEIS at E-5–E-6. This is completely illogical and at a minimum, NRC must explain this discrepancy.

[26] In 2007, the NRC began examining new earthquake hazard information and found that various seismic hazard estimates have increased and required further analysis; NRC is currently

rise and other impacts of climate change, including the increased frequency of severe weather events that result in storm surges, flooding, and extended power outages that could compromise safe storage of spent fuel at reactor sites.[27] Site-specific review related to these kinds of external circumstances is necessary since new information reveals such issues can be problematic and since different regions in the U.S. face different geological conditions and weather patterns.

Moreover, in relation to foreseeable impacts to surface waters from SFP leaks NRC should consider the following: the nature of the affected surface water (that is, is it an estuary that flows back and forth versus a static man-made pond?); the presence of nearby significant habitats and endangered species in surface waters affected by SFP leaks; the relevant status of the aquatic ecology in a given waterway, such as whether the waterway is already degraded or contains stressed fish populations, such as the Hudson River;[28] the degree to which already existing

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continuing to update earthquake risk hazard estimates for U.S. nuclear power plants in light of newer information and seismic models. *See* Generic Issue 199 (GI-199), Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants: Safety/Risk Assessments, August 2010, ADAMS Accession No. ML100270639; Memo from P. Hiland to B. Sheron Re: Results of Safety/Risk Assessment of Generic Issue 199, September 2, 2010, ADAMS Accession No. ML100270598. Site-specific consideration of such new information and analyses concerning regional seismology and hazards posed therefrom is necessary for determining risks of future SFP leaks at particular nuclear power plants. For example, a study by Columbia University seismologists in 2008 concluded that the area surrounding the Indian Point nuclear plant was not, as previously thought, an area of low seismic activity, and that, in fact, it was "quite possible" the region could experience upwards of a 7.0 magnitude earthquake, which the owner of the plant has admitted Indian Point is not designed to withstand. *See* Lynn R. Sykes, John G. Armbruster, Won-Young Kim, & Leonardo Seeber, Observations and Tectonic Setting of Historic and Instrumentally Located Earthquakes in the Greater New York City–Philadelphia Area, Bulletin of the Seismological Society of America, Vol. 98, No. 4, pp. 1696–1719, August 2008; The Earth Institute, Columbia University, "Earthquakes May Endanger New York More than Thought, Says Study: Indian Point Nuclear Power Plant Seen as Particular Risk," Press Release Posted on The Earth Institute website, August 21, 2008, *available at*, http://www.earth.columbia.edu/articles/view/2235 (last visited December 13, 2012). Any such new information must be considered in relation to the risk of future SFP leaks at particular plants as waste is stored in such pools during post-operation timeframes.

[27] *See, e.g.*, NRC Event Notification Report #48452 for Oyster Creek (October 29, 2012), *available at*, http://www.nrc.gov/reading-rm/doc-collections/event-status/event/2012/20121030en.html (Notice of unusual event declared due to high intake structure water level).

[28] For example, in the Hudson River, which is adjacent to the Indian Point nuclear facility, study has shown that 10 out of 13 critical fish species are in long-term decline, largely as a result of entrainment, impingement, and thermal impacts from power plant cooling water intake structures. *See* The Status of Fish Populations and the Ecology of the Hudson, Pisces Conservation Ltd., April 2008, *available at*, http://www.riverkeeper.org/wp-content/uploads/2009/06/Status-of-Fish-in-the-Hudson-Pisces.pdf; NYSDEC Hudson River Power Plants FEIS (June 25, 2003), Public Comment Summary at 57,

radiological contamination of surface waters resulting from prior SFP leaks may affect the level and degree of exposure to future SFP leaks; how site-specific susceptibility to severe weather events and earthquakes, may affect the behavior, fate, and effect of radiological contamination in surface waters resulting from future SFP leaks; and the degree to which radiological contamination of surface waters "threatens a violation of Federal, State, or local law or requirements," (40 C.F.R. § 1508.27(b); 10 C.F.R. § 51.71(d)) such as whether and the extent to which radiological contamination of surface waters results in violations of applicable state water quality standards adopted pursuant to the Clean Water Act or state environmental protection laws (including prohibitions and limitations on the discharge of radiological materials to State surface waters,[29] designated best usages of surface waters, and other established surface water standards.)[30]

In relation to foreseeable impacts to groundwater resources, NRC should consider site-specific factors as they bear upon the likely behavior, fate, and effect of radiological contamination plumes resulting from future SFP leaks, including the following: the varying geological landscapes underlying reactors and SFPs at different sites (e.g., the nature of the bedrock and the hydraulic gradient underneath and surrounding the site); the nature of nearby resources (including the presence of significant habitats and endangered resources); the degree to which already existing groundwater contamination resulting from past radiological leaks may affect the behavior, fate, and effect of any new groundwater contamination resulting from new SFP leaks; and how site-specific susceptibility to severe weather events and earthquakes, may affect the behavior, fate, and effect of radiological contamination plumes resulting from future SFP leaks. In addition, NRC must consider whether and the extent to which radiological groundwater

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http://www.dec.ny.gov/docs/permits_ej_operations_pdf/FEISHRPP5.pdf. NRC must consider how long-term exposure to radiological contamination from SFP leaks may impact already troubled fish populations.

[29] For example, New York State law contains a provision that prohibits discharges of high-level radioactive waste as well as any discharges not permitted by NYS rules and regulations. *See* New York State Environmental Conservation Law § 17-0807(1), (4).

[30] For example, it is common for designated best usages established pursuant to the CWA to include recreational activities such as swimming, fishing, boating, etc.; in New York, the Hudson River directly adjacent to the Indian Point nuclear power plant has been designated as suitable for recreational activities, including swimming and boating; State standards require that the discharge of deleterious substances shall not impair the waters for such best uses. 6 NYCRR § 701.11; 6 NYCRR § 700.1(a)(49); 6 NYCRR 700.1(a)(56); 6 NYCRR § 703.2. NRC must consider the degree and extent to which future SFP leaks may interfere with such designated uses of impacted surface waters. In this regard, NRC cannot narrowly examine compliance with NRC dose limits; as such limits do not necessarily reflect the pathways of exposure contemplated by water protection standards. For example, at Indian Point, the plant owner only considers one exposure pathway, i.e., the consumption of fish and invertebrates from the Hudson River, when calculating NRC-doses. Entergy Nuclear Operations, Inc. (Indian Point Unit 1, 2, and 3 Nuclear Power Plants Docket Nos. 50-03, 50-247, and 50-286), Radioactive Effluent Release Report: 2010, at page 33 of 49, *available at*, ADAMS Accession No. ML11124A031 ("Liquid offsite dose calculations involve fish and invertebrate consumption pathways *only*") (emphasis added). This fails to capture exposure resulting from recreational uses of the waterway.

contamination results in violations of applicable state water quality standards adopted pursuant to the Clean Water Act ("CWA") or state environmental protection laws. *See* 40 C.F.R. § 1508.27(b); 10 C.F.R. § 51.71(d). This includes designated best usages of state groundwaters,[31] and any other established groundwater standards.

Because NRC's bounding parameters are not broad enough to encompass a number of site-specific concerns NRC's generic waste confidence EIS is insufficient.

7. NRC's SFP leaks impact analysis violates NEPA because it does not consider impacts from SFP storage beyond 60 years, even though longer storage in SFPs is contemplated by the proposed regulation 10 C.F.R. § 51.23 and by 10 C.F.R. § 50.82

NRC assumes that spent fuel will be stored in pools for no more than 60 years after the licensed life of a reactor, and thus, only looks at SFP impacts in the 60-year short-term timeframe. DGEIS at 1-14. NRC bases its assumption on one of its decommissioning regulations which states that "[d]ecommissioning will be completed within 60 years of permanent cessation of operations." 10 C.F.R. § 50.82(a)(3); *see also* DGEIS at xxix. This assumption is problematic in at least three ways.

First, the language of the proposed rule itself is not limited to 60 years of storage in pools. The new proposed 10 C.F.R. § 51.23(a)(2) puts no time limit on the NRC's finding that it is feasible to safely store spent fuel. (*Compare* the proposed 10 C.F.R. § 51.23(a)(2) "it is feasible to safely store spent nuclear fuel following the licensed life for operation of a reactor" *with* the 2010 regulation, "spent fuel generated in any reactor can be stored safely and without significant environmental impacts for at least 60 years beyond the licensed life for operation."). The time period for storage contemplated by the proposed regulation is therefore indefinite. Given the indefinite time period of the safety finding in proposed 10 C.F.R. § 51.23(a)(2), the DGEIS wrongly assumes that spent fuel will be stored in pools for only 60 years.

Second, the decommissioning regulation contemplates storage beyond 60 years in certain circumstances. 10 C.F.R. § 50.82(a)(3). In determining whether decommissioning beyond 60 years is appropriate, NRC considers several factors, including the "unavailability of waste disposal capacity." 10 C.F.R. § 50.82(a)(3). In light of the current unavailability of a repository or disposal site, it is reasonably likely that some licensees could seek Commission approval to extend the decommissioning time period, including wet storage of spent fuel, beyond the 60 year timeframe. In order to comply with NEPA, the NRC must assess the potential impacts of wet storage beyond 60 years.

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[31] For example, the State of New York has designated the best use of the groundwater beneath the Indian Point nuclear power plant to be "as a source of potable water supply," and requires that the discharge of deleterious substances shall not impair the groundwaters for such best uses. *See* 6 NYCRR § 701.18; 6 NYCRR § 701.15; 6 NYCRR § 703.2. This is regardless of whether such groundwaters are *actually* used for potable purposes.

Third, the NRC's Decommissioning GEIS contemplates pool storage for more than 60 years in the ENTOMB alternative. Decommissioning GEIS, Supplement 1, NUREG-0586 (2002). The Decommissioning GEIS presents three decommissioning alternatives: SAFSTORE, DECON, and ENTOMB. As the NRC explains: "During the short-term storage timeframe, the pools will be used to store fuel until a licensee decides to remove the spent fuel as part of implementing either the SAFSTOR or DECON decommissioning option." DGEIS at 2-25. The ENTOMB scenario, however, contemplates storage of spent fuel in pools for up to 100 years. *Id.* at 3-25–26. However, the NRC ignores the third option for decommissioning, the ENTOMB scenario. *See* Decommissioning GEIS, Supplement 1, NUREG-0586 at 3-21.

Therefore, NRC's own documents demonstrate that there is a reasonably foreseeable potential that spent fuel will be stored in reactor pools for more than 60 years. The DGEIS should account for this potentially extended time frame for pool storage. If it does not, the proposed rule should be changed to limit the prediction of environmental impacts to only 60 years.

E. The Proposed Rule's Determination That Spent Fuel Can Be Safely Stored in Pools for an Indefinite Period is Not Based on an Adequate Environmental Analysis of Spent Fuel Pool Fire Risks

Under NEPA, the NRC is required to "examine both the probability of a given harm occurring *and* the consequences of that harm if it does occur." *New York v. NRC*, 681 F.3d at 482 (emphasis in original). "Only if the harm in question is so 'remote and speculative' as to reduce the effective probability of its occurrence to zero may the agency dispense with the consequences portion of the analysis." *Id.* (citing *Limerick Ecology Action, Inc. v. NRC*, 869 F.2d at 739). In its 2010 waste confidence update, the NRC did not look at the consequences of spent fuel pool fires. Instead, it asserted that "it did not need to examine the consequences of fires because the "risk of fires [is] very low." But the Court rejected the NRC's analysis holding that NRC must look at the consequences of spent fuel pool fires. *Id.* (NRC "must put the weights on both sides of the scale before it can make a determination.").

To determine risk, NRC purports to "combine[ ] the probability of an accident with the consequences of that accident." DGEIS at xxx, 4-68, 4-69. Using this method to determine risk, the DGEIS asserts that the environmental impact of pool fires is "SMALL," *i.e.,* insignificant. DGEIS at F-12. NRC admits however, that "the consequences of a severe accident, should one occur, would be significant and destabilizing." DGEIS at F-7.

Dr. Thompson's declaration provides a detailed analysis of the reasons for his opinion that the NRC has seriously understated both the probability and consequences of pool fires, and that in fact their environmental impacts are significant.

A fundamental problem with the draft GEIS is its method of assessing risk. The draft GEIS defines radiological risk as the numerical product of the probability and the consequences of an event, and further argues that a high-consequence, low-probability event, such as a severe accident, could be determined to have a small environmental impact if the risk is sufficiently low. In the context of the draft GEIS, that definition of radiological risk, and the associated determination of environmental impact, are fundamentally flawed from at least four overlapping perspectives:

- First, numerical estimates of consequences and probability are typically incomplete and highly uncertain.
- Second, significant aspects of consequences and probability are not susceptible to numerical estimation.
- Third, larger consequences can be qualitatively different than smaller consequences.
- Fourth, devotees of this definition of risk typically argue, as does the draft GEIS, that equal levels of "risk", as they define it, should be equally acceptable to citizens. That argument may be given a scientific gloss, but is actually a statement laden with subjective values and interests. An informed citizen could reject the argument on reasonable grounds.

Thompson Declaration, Section IV. The qualitative difference between large and small consequences is not a well-known factor in the United States, but is recognized in Europe. For example, analysts at the French government's Institut de Radioprotection et de Surete Nucleaire (IRSN) have found a qualitative difference between larger and smaller radiological consequences. The IRSN analysts estimated the costs (i.e., economic damage) that would arise from an accidental, atmospheric release of radioactive material from the Dampierre nuclear generating station in France. They considered two types of release – a "controlled" (smaller) and a "massive" (larger) release. A paper summarizing their findings was presented at the 2012 Eurosafe conference. Thompson Declaration, par. IV-11.

The IRSN analysts concluded that the costs arising from a massive release would differ "profoundly" from the costs arising from a controlled release, in terms of both qualitative and quantitative factors. Indeed, they described the massive release as "an unmanageable European catastrophe." Their paper concluded with the statement:

> "Safety decisions may also be informed by this picture, in particular if it is realized that the most severe cases actually carry huge stakes for the nation and therefore that their lower probability may not balance their catastrophic potential."

Thompson Declaration, par. IV-13 (quoting Ludivine Pascucci-Cahen and Momal Patrick (IRSN), "Massive radiological releases profoundly differ from controlled releases", paper for presentation at the Eurosafe conference, Brussels, 5-6 November 2012).

Dr. Thompson also reports that there is strong evidence that the 1986 Chernobyl accident was a principal cause of the dissolution of the Soviet Union. Political unrest related to the accident was noted in a 1987 paper by the US Central Intelligence Agency.

> As public dissatisfaction grows, the Chernobyl' accident may provide a focal point around which disgruntled citizens can organize, and Moscow may discover that Chernobyl' is a continuing irritant with a potential for social and ethnic tensions for years to come.

Thompson Declaration, par. IV-14 (quoting *The Chernobyl' Accident: Social and Political Implications* (Washington, DC: CIA, December 1987). Public dissatisfaction did indeed grow, and the Warsaw Pact and the Soviet Union dissolved in 1991. Mikhail Gorbachev, the last head of state of the Soviet Union, confirmed in a 2006 essay that the Chernobyl accident was a principal cause of the Union's dissolution. Thompson Declaration, par. IV-IV-15.

As Dr. Thompson observes, the full array of consequences of a large, atmospheric release of radioactive material from a nuclear facility in the United States is difficult to predict. The nature and scale of those consequences would vary according to the characteristics of the release and other factors. It is clear, however, that there are unresolved socio-political tensions in this country. Thus, the consequences of a large release could include substantial political stress. It is unlikely that aggrieved citizens would be comforted if they learned that NRC had determined, at a prior time, that the release was a low-risk event. Thompson Declaration, par. IV-16.

The draft GEIS relies on PRA-type studies for its estimation of radiological risk. Studies of this type can provide useful information about radiological risk, for certain purposes. However, these studies cannot provide a credible estimate of the probability of a radiological event such as a pool fire. Thompson Declaration, pars. X-31–X-39.

The draft GEIS sets forth a highly optimistic view of the future conditions that will affect stored spent fuel. It assumes that institutional controls will remain operative into the indefinite future, arguing that this assumption "avoids unreasonable speculation regarding what might happen in the future". This assumption, like other optimistic assumptions in the draft GEIS, is neither reasonable nor prudent. Moreover, assuming static conditions is speculative in the extreme, and shows a profound ignorance of human history. Given the long timeframes envisioned in the draft GEIS, the only reasonable approach is to consider a broad range of scenarios. Those scenarios would encompass substantial changes in the risk environment over time. The changes could be non-uniform across the United States. Thompson Declaration, par. VII-2.

The draft GEIS significantly under-estimates the probability of an attack-induced pool fire. That probability cannot be determined quantitatively. In light of human history, observation of the contemporary world, and consideration of possible societal trends, a prudent decision maker would conclude that a successful attack on a reactor or spent-fuel-storage facility in the United States over the coming decades is as likely to occur as are major national challenges that are planned for, such as severe natural disasters or engagement in wars. Thompson Declaration, pars. VI-10, X-35.

Another significant deficiency in the DGEIS' risk analysis is its failure to consider the relationship between pool fires and operating reactors. Pool storage of spent fuel, as considered in the draft GEIS, could occur, and probably will occur, at locations near operational reactors. Risk linkages among spent-fuel pools and operational reactors at a site could be manifested in a cascading sequence of incidents that preclude mitigating actions needed to maintain pools in a safe state. Mitigating actions could be precluded by, for example, a radiation field arising from the release of radioactive material. NRC has never, to Dr. Thompson's knowledge, published a credible technical analysis of a cascading sequence of incidents of this type, or publicly stated that it has performed such analysis in secret. The present state of knowledge suggests that risk linkage among pools and operational reactors leads to an under-estimate of risk by at least one order of magnitude (i.e., factor of 10). Accordingly, the draft GEIS should have carefully considered the potential linkage of radiological risk among pools and operational reactors at each site. The draft GEIS has not considered this matter. Thompson Declaration, Section X.

Importantly, the draft GEIS substantially underestimates the consequences of a pool fire. Those consequences could include the long-term displacement of millions of people, economic damage measured in trillions of dollars, and adverse social and political outcomes. A pool fire yielding these consequences would be a national disaster of historic dimensions. Thompson Declaration, Section X. And as discussed above, very large consequences are qualitatively different than smaller ones.

As Dr. Thompson's declaration shows, the nature of pool fire risks is such that a meaningful environmental impact estimate cannot be yielded by simply multiplying probability times consequences. First, some of the key factors are not easily quantifiable; for instance, it is difficult to quantify the probability of an attack, which is easily the greatest threat to a spent fuel pool. As Dr. Thompson suggests, the element of prudence should pay a significant role where a facility is as attractive a target as a fully laden fuel pool.

Second, the NRC does not have a full picture of all the factors that could cause a pool fire. For instance, in footnote 5 on page F-9, the NRC admits that the seismic risk analysis on which it based its consequence analysis did not include reactors in the western United States, presumably because of the fact that they have been studied less than eastern earthquakes. Third, the NRC has not aggressively pursued research or open public debate about the behavior of spent fuel in pools. As a result, there is not a significant body of rigorous scientific research that can be relied upon, as is more the case with reactor studies. And finally, the consequences of an accident or successful attack on a fuel pool could be catastrophic on a massive scale. Measuring potential damages in billions of dollars is not sufficient to account for the social, economic and political upheaval that such an event may cause. Thus, the NRC's estimate that spent fuel pool fires have insignificant impact is not defensible. In fact, a reasonable assessment of pool fire impacts would conclude they are significant.

VII. THE PROPOSED RULE HAS SIGNIFICANT ENVIRONMENTAL IMPACTS THAT MUST BE PLUGGED INTO INDIVIDUAL REACTOR LICENSING DECISIONS

As the Supreme Court observed in *Baltimore Gas and Electric Co.:*

> Congress did not enact NEPA . . . so that an agency would contemplate the environmental impact of an action as an abstract exercise. Rather, Congress intended that the 'hard look' be incorporated as part of the agency's process of deciding whether to pursue a particular federal action. It was on this ground that the Court of Appeals faulted the Commission's action, for failing to allow the uncertainties potentially to 'tip the balance' in a particular licensing decision. As a general proposition, we can agree with the Court of Appeals' determination that an agency must allow all significant

> environmental risks to be factored into the decision whether to undertake a proposed action.

462 U.S. at 101. Here, the environmental impacts of the spent fuel to be generated by new or re-licensed reactors, and the costs of avoiding or mitigating those impacts, are potentially enormous. Yet, in violation of NEPA, the DGEIS provides no mechanism for integrating those costs and impacts back into individual licensing decisions.

A. The Impacts and Costs Related to Spent Fuel Storage and Disposal Are Significant

As demonstrated in the attached expert declarations by Dr. Arjun Makhijani, David Lochbaum, and Dr. Gordon Thompson, the environmental impacts of storing spent fuel are significant.

Environmental impacts of indefinite storage of spent fuel may be catastrophic, as discussed in the Declaration of Dr. Arjun Makhijani, Section 7. In the Yucca Mountain EIS, for instance, the DOE found that loss of institutional controls would result in the "unchecked deterioration and dissolution of the materials" in storage, with "catastrophic" effects. And the DOE conservatively underestimated those impacts. Makhijani Declaration, pars. 7.3 and 7.4. Dr. Thompson also testified that the cumulative frequency of successful attacks on ISFSIs could be substantial and that the consequences of a successful attack could be severe. Thompson Declaration, Section XI.

David Lochbaum's declaration shows that NRC relies on nonexistent or inapplicable regulatory requirements to prevent or detect future leaks at decommissioned reactors. Given the large volume and radioactivity of some undiscovered pool leaks in the past, and given NRC's failure to show that they will be detected and prevented in the future, environmental impacts of pool leaks are significant.

Dr. Gordon Thompson's declaration shows that NRC has significantly underestimated the environmental impacts of pool fires. *See* discussion above in Section VI.F.

In addition, the costs of avoiding or mitigating those impacts are significant. For instance, the NRC's finding that it is feasible to have a geologic repository raises questions of cost. What will it cost to isolate spent fuel for many thousands of years? Is the cost affordable when compared with the profit that a nuclear reactor will yield? As discussed in the Declaration of Mark Cooper, these costs are so large they must be considered. Conservatively estimating the costs of spent fuel storage and disposal, Mr. Cooper estimates total costs in the range of $210 to $350 billion, in real, undiscounted dollars. Cooper Declaration, p. 10. That is a figure that is certainly large enough to demand consideration by the Nuclear Regulatory Commission. Moreover, converting those costs to costs per unit of output, he concludes that the costs would be in the range of $10 to $20 per megawatt hour ($0.01 to $0.02/ kWh) of electricity generated by the rectors that produce the waste. Cooper Declaration, p. 4. This is equal to 10 to 20 percent of the cost of nuclear power from newly constructed reactors as calculated by the Energy Information Administration. Compared to the cost of the other resources included in the Energy Information Administration analysis, the cost of waste management would make nuclear power much less attractive as a resource.

The Cooper Declaration also shows that the cost of nuclear waste management is often larger compared to the operating costs and margins of existing reactors. Several operating reactors have recently been abandoned because their operating margins can be as low as $9/MWh, which is insufficient to cover their costs and meet the revenue requirements that their owners demand and others may face a similar fate. Cooper Declaration, pp. 20-21. Waste management costs of $10 to $20 per MWh must be considered very significant in evaluating the economics of aging reactors. The majority of the license renewals that are pending at the NRC, or expected to come before the NRC in the next few years, involve reactors whose operating costs and margins are no better than the margins for reactors that were recently retired before their licenses expired.

B. Costs of Spent Fuel Storage and Disposal Could Tip the Balance Of Reactor Licensing Decisions

As demonstrated by the Cooper Declaration, the costs of spent fuel storage and disposal could tip the balance of reactor licensing decisions away from licensing and in the direction of renewables and energy efficiency. As discussed above, spent fuel costs are equal to 10 to 20 percent of the cost of nuclear power from newly constructed reactors. These costs are also significant for existing reactors, which face increasing operating costs as a result of aging. Cooper cites estimates of the cost of electricity resources prepared by the mid-Atlantic grid operator PJM and Lazard, a Wall Street analysis firm, which show that a significant amount of energy efficiency can be achieved at a cost that is lower than the cost of waste management alone. Cooper Declaration, p. 17.

VIII. THE PROPOSED RULE AND DRAFT WASTE CONFIDENCE EIS VIOLATE NEPA BECAUSE THEY SEGMENT THE ANALYSIS OF ENVIRONMENTAL IMPACTS OF SPENT FUEL STORAGE AND DISPOSAL

The NRC has splintered the analysis of safety and environmental issues associated with management of spent fuel into myriad of separate subparts. This hodgepodge of regulatory provisions and environmental findings is characterized by inconsistencies, internal deficiencies, and huge analytical gaps. Although all of them are related, the NRC refuses to consider their relationship or to reform any of them. The result is that any decisions NRC makes about licensing of reactors are utterly uninformed about the environmental impacts of spent fuel storage or disposal. For instance:

- In the proposed waste confidence rule, the NRC makes a finding that spent fuel disposal is feasible, but it fails to make any reasonable assurance finding regarding the availability of sufficient repository capacity to accommodate the spent fuel that will be generated as a result of future NRC licensing decisions. While the Court directed the NRC to analyze the uncertainty associated with failure to site a repository, the NRC simply dropped the safety finding from its regulations. *See* Section IV above.

- In order to comply with the Court's order to analyze the uncertainty associated with its prediction of sufficient spent fuel disposal capacity, the NRC would need to analyze the environmental impacts of spent fuel disposal in an array of geologic media, with an analysis of the uncertainty regarding whether the repositories could meet federal limits for containing radioactivity and how much spent fuel they could accommodate. Makhijani Declaration, pars. 8.2-8.24. The DGEIS does not provide any information about spent fuel disposal impacts, however. Instead, the DGEIS declares spent fuel disposal impacts irrelevant to its analysis and refers the reader to Table S-3. DGEIS at 1-18.

- Table S-3 is clearly related to the NRC's findings regarding feasibility of spent fuel disposal, because the NRC has stated that it will not revisit the conclusions in Table S-3 unless it has reason to doubt its waste confidence conclusion regarding the feasibility of spent fuel disposal. 55 Fed. Reg. at 38,491.

- As discussed in the Makhijani Declaration, Table S-3 assumes that spent fuel will be disposed of in a bedded salt repository. Based on that assumption, Table S-3 states that the environmental impacts of a spent fuel repository are zero. But Table S-3 is no longer technically valid, because the NRC has ruled out the assumption underlying Table S-3 that spent fuel can be safely disposed of in a bedded-salt repository. Makhijani Declaration, par. 8.20. However, NRC has refused to re-evaluate Table S-3, because – as discussed above – only a change in the allegedly waste confidence determination would cause NRC to revisit Table S-3.

- In its license renewal rule (Table B-1 of Appendix A to 10 C.F.R. Part 51), the NRC treats the environmental impacts of spent fuel disposal as insignificant for purposes of making license renewal decisions, based on the existence of EPA repository standards, but does not relate this decision to Table S-3, which concludes that spent fuel impacts are insignificant on completely different grounds. The NRC does not explain the inconsistency between Table B-1 and Table S-3.

- The Draft GEIS claims that environmental impacts of spent fuel disposal are irrelevant to the waste confidence DGEIS. But when the NRC promulgated its final license renewal rule in 2013, it did not include any conclusions regarding the environmental impacts of spent fuel disposal, stating that "[t]he generic conclusion on offsite radiological impacts of spent nuclear fuel and high-level waste is not being finalized pending the completion of a generic environmental impact statement on waste confidence." 78 Fed. Reg. 37,282 37,322 (June 20, 2013). In a footnote, the NRC further explained:

  > As a result of the decision of United States Court of Appeals in *New York* v. *NRC,* 681 F.3d 471 (DC Cir. 2012), the NRC cannot rely upon its Waste Confidence Decision and Rule until it has taken those actions that will address the deficiencies identified by the D.C. Circuit. Although the Waste Confidence Decision and Rule did not assess the impacts associated with disposal of spent nuclear fuel and high-level waste in a repository, it did reflect the Commission's confidence, at the time, in the technical feasibility of a repository and when that repository could have been expected to become available. Without the analysis in the Waste Confidence Decision and Rule regarding the technical feasibility and

> availability of a repository, the NRC cannot assess how long the spent fuel will need to be stored onsite.

78 Fed. Reg. at 37,323. Clearly, despite denying the existence of a relationship between waste confidence findings and spent fuel disposal impacts in the DGEIS, the NRC considered the relationship significant enough to hold off finalizing environmental findings regarding spent fuel disposal impacts in the license renewal rule.

- There is no environmental impact statement where the NRC discusses the significant costs of a repository and spent fuel storage in a cost-benefit analysis for licensing of nuclear reactors. The only environmental document where costs related to spent fuel disposal are considered is Table S-3, but Table S-3 reports only that if there are no radiation releases from a repository there will be no costs. Table S-3 says nothing about the costs of a repository. And the DGEIS says nothing about the costs of spent fuel storage. As discussed in the Declaration of Mark Cooper, costs of spent fuel storage and disposal could be high enough to tip the cost-benefit analysis in a reactor licensing or re-licensing decision away from a recommendation to license a reactor. But NRC provides no mechanism for integrating the high costs of spent fuel storage and disposal into the cost-benefit analysis and comparison of energy alternatives for reactor licensing cases.

- In license renewal cases, the NRC refuses to consider the no-action alternative, which includes energy conservation. 61 Fed. Reg. 28,467, 28,471-73 (June 5, 1996). Yet, as described in the Cooper Declaration, energy conservation may be more cost-effective than paying for spent fuel storage and disposal. But the NRC's regulatory system provides no method for evaluating the effects of spent fuel storage and disposal costs on the choice of the no-action alternative.

- The NRC evaluates the environmental impacts of pool storage of spent fuel in two different contexts: during reactor operation (in the license renewal rule) and afterwards. The NRC makes no attempt to integrate these analyses or assess the cumulative impacts of storing massive amounts of spent fuel in high-density storage pools at every reactor site around the country. This division of environmental analysis makes no sense from a technical basis, and results in an understatement of environmental impacts. See e.g., Thompson Declaration, pars. X-60–X-61.

The NRC's piecemeal and disjointed approach to the consideration of spent fuel storage and disposal impacts violates the NEPA principle that an agency may not segment its analysis in a manner that conceals the environmental significance of its action. *Taxpayers Watchdog, Inc. v. Stanley*, 819 F.2d 294, 298 (D.C. Cir. 1987) ("'Piecemealing' or 'Segmentation' allows an agency to avoid the NEPA requirement that an EIS be prepared for all major federal actions with significant impacts by dividing an overall plan into component parts, each involving action with less significant environmental effects."). *See also Coalition on Sensible Transportation v. Dole*, 826 F.2d 60, 68 (D.C. Cir. 1987). *See also National Wildlife Federation v. Appalachian Regional Commission*, 677 F.2d 883, 890 (D.C. Cir. 1981) ("The existence of a comprehensive program with cumulative environmental effects cannot be escaped by disingenuously describing it as only an amalgamation of unrelated smaller projects."); *Natural Resources Defense Council* *v. Hodel*, 865 F.2d 288, 297-98 (1988). In order to provide a true picture of the environmental impacts of pool storage of spent fuel, for example, the NRC may not divide it into smaller segments based on arbitrary time periods. And it is "simply illogical" to view the admittedly interrelated waste confidence proposed rule and DGEIS separately from NRC's environmental impact analyses for spent fuel disposal. *See One Thousand Friends of Iowa v. Mineta*, 364 F.3d 890, 894 (8th Cir. 2004) ("A segmentation is improper when the segmented project . . . is simply illogical when viewed in isolation.").

The NRC claims that its piecemeal approach constitutes permissible "tiering." DGEIS at 1-17–1-22.[32] But tiering is only permissible when the cross-referenced environmental analyses are valid. Here, the NRC relies to a significant extent on Table S-3, whose basis the NRC itself has repudiated. An agency "errs when it relies on old data without showing that the data remains accurate." *Western Watersheds Project v. Abbey* , 719 F.3d 1035, 1052 (9th Cir. 2013) (citing *N. Plains Res. Council, Inc. v. Surface Transp. Bd.*, 668 F.3d 1067, 1086–87 (9th Cir.2011) (concluding that the Surface Transportation Board did not take a "hard look" at environmental impacts when it relied on ten-year-old aerial surveys)). *See also* 10 C.F.R. § 51.92 (requiring NRC to prepare supplemental EISs if, "[t]here are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts"); *City of Olmsted Falls, OH v. FAA*, 292 F.3d 261 (D.C. Cir 2002) (quoting *Wisconsin v. Weinberger*, 745 F.2d 412 (7th Cir. 1984)) (agency must consider new information that "provides a seriously different picture of the environmental landscape.")

Here, the disjointed nature of NRC's program for evaluation of environmental impacts related to spent fuel storage and disposal is not only piecemeal but internally inconsistent, full of gaps, and riddled with outdated information. As a result, the NRC utterly fails to support its safety

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[32] The CEQ regulations explain tiering as follows:

> A. Tiering refers to the coverage of general matters in broader environmental impact statements . . . with subsequent narrower statements or environmental analyses . . . incorporating by reference the general discussions and concentrating solely on the issues specific to the statement subsequently prepared. Tiering is appropriate when the sequence of statements or analyses is:
>
> (a) From a program, plan, or policy environmental impact statement to a program, plan, or policy statement or analysis of lesser scope or to a site specific statement or analysis.
>
> (b) From an environmental impact statement on a specific action at an early stage (such as need and site selection) to a supplement (which is preferred) or a subsequent statement or analysis at a later stage (such as environmental mitigation). Tiering in such cases is appropriate when it helps the lead agency to focus on the issues which are ripe for decision and exclude from consideration issues already decided or not yet ripe.

10 C.F.R. § 1508.28; see also 10 C.F.R. Part 51, App'x A(1)(b).

findings with an adequate environmental analysis, thus violating both the Atomic Energy Act and NEPA. In addition, the NRC fails to provide decisionmakers and the public with a reasonably comprehensive analysis of environmental impacts and how they could be avoided or mitigated through the avoidance of licensing or the imposition of reasonable alternatives. *Baltimore Gas & Elec. Co. v. NRDC*, 462 U.S. 87, 96 (1983) ("The key requirement of NEPA . . . is that the agency consider and disclose the actual environmental effects in a manner that will ensure that the overall process . . . brings those effects to bear on decisions to take particular actions that significantly affect the environment.").

IX. PETITION FOR RULEMAKING

In order to bring the NRC's disjointed regulatory program for safety and environmental analysis of spent fuel management and disposal risks into compliance with NEPA, the Organizations respectfully request the NRC to revise and integrate its disparate and inconsistent regulations regarding spent fuel storage and disposal in a cohesive and consistent whole. The NRC should prepare a programmatic EIS to ensure that the cumulative nature of the impacts covered by these balkanized regulations are considered.

The regulations that must be revised and integrated are:

Table S-3. As discussed above and in the Makhijani Declaration, the basis for Table S-3 has been repudiated. It is also inconsistent with Table B-1.

Table B-1. Table B-1 is inconsistent with Table S-3. For one thing, Table B-1 does not include a finding as to whether the impacts of spent fuel disposal are significant or not. Instead, it states that the impacts are not large enough to change a license renewal decision. This suggests that the impacts *would* be large enough to change an initial licensing decision (which is covered by Table S-3). The inconsistencies and questions raised by comparing Table S-3 and Table B-1 are unacceptable under NEPA's standard for clarity and rigor of scientific analysis.

10 C.F.R. §§ 51.53(c) and 51.71(d). These regulations excuse license renewal applicants and the NRC from addressing spent fuel storage impacts in license renewal cases. They also excuse any discussion of need for power. As demonstrated above, it is essential to incorporate the economic costs of spent fuel storage and disposal in reactor cost-benefit analyses. In addition, as Dr. Thompson points out, by excluding need for power from consideration in re-licensing decisions, the draft GEIS cripples its ability to assess the environmental impacts of storing spent fuel. Thompson Declaration, par. IX-2. This results in an "unbounded" analysis of radiological risk from spent fuel fires. Thompson Declaration, par. IX-3.

10 C.F.R. §51.23 (the proposed rule). This proposed rule appears in Part 51 of NRC regulations, indicating that it is an environmental regulation. Yet, it has safety language. To make matters more confusing, the NRC has dropped the "reasonable assurance" findings formerly made in the waste confidence decision. The Atomic Energy Act and NEPA both require the NRC to make findings. Safety findings should be included in Parts 50 and 52 and environmental findings should be included in Part 51. The NRC should also explain that safety findings must be supported by an adequate NEPA analysis.

After three decades of distorted and partial environmental analysis leading to uninformed licensing and re-licensing decisions, it is time now for the NRC to come into compliance with NEPA. The NRC must update its outdated and repudiated assumptions, conduct an environmental study that provides an integrated examination of all environmental impacts and costs related to spent fuel management, and promulgate a new set of regulations that provides for meaningful consideration of these impacts in individual licensing decisions.

X. CONCLUSION

The proposed rule marks a turning point for the NRC. After thirty years of making baselessly optimistic "reasonable assurance" findings about the future availability of a disposal solution for spent reactor fuel, and having allowed many thousands of tons to accumulate at reactor sites around the country based on those findings, the NRC has finally stopped issuing them. Instead of confidently assuring the public that human health and the environment will be protected from highly radioactive spent fuel as long as it remains dangerous, the NRC now claims only to have hope in a theoretical possibility. But hope cannot satisfy the Atomic Energy Act. The NRC has effectively conceded that it lacks a statutory basis for licensing the further generation of spent fuel. It must therefore continue to suspend all reactor licensing unless and until some basis for reasonable assurance findings are restored. The DGEIS cannot cure this fundamental failure to satisfy the Atomic Energy Act. And even if it could, the DGEIS is utterly inadequate to satisfy NEPA.

Respectfully submitted,

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December 20, 2013

December 20, 2013

UNITED STATES OF AMERICA
BEFORE THE NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
	)	
Proposed Rule: Waste Confidence – Continued Storage of Spent Nuclear Fuel 10 C.F.R. Part 51	)	Docket No. 2012-0246
	)	
Draft Waste Confidence Generic Environmental Impact Statement	)	

**DECLARATION OF DR. ARJUN MAKHIJANI
REGARDING THE WASTE CONFIDENCE PROPOSED RULE
AND DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT**

Under penalty of perjury, I, Dr. Arjun Makhijani, declare as follows:

1.0 STATEMENT OF QUALIFICATIONS

1.1. I am President of the Institute for Energy and Environmental Research (IEER), an independent non-profit organization located in Takoma Park, Maryland. Under my direction, IEER produces technical studies on a wide range of energy and environmental issues to provide advocacy groups and policymakers with sound scientific information and analyses as applied to environmental and health protection and for the purpose of promoting the understanding and the democratization of science. IEER has been doing nuclear-related studies for about 26 years.

1.2. As demonstrated in my attached curriculum vitae (CV), and as summarized below, I am qualified by training and extensive professional experience to render my professional opinion regarding technical, economic, and public health issues related to radioactive waste management and disposal.

1.3. I have a Ph.D. (Engineering), granted by the Department of Electrical Engineering and Computer Sciences of the University of California, Berkeley, where I specialized in the application of plasma physics to controlled nuclear fusion. I also have a master's degree in electrical engineering from Washington State University and a bachelor's degree in electrical engineering from the University of Bombay.

1.4. In addition, over a period of more than 25 years, I have developed extensive experience in evaluating nuclear fuel cycle-related issues, including proposed classification and strategies for radioactive waste storage and disposal, accountability with respect to measurement of radioactive effluents from nuclear facilities, health and environmental effects of nuclear testing and nuclear facility operation, strategies for disposition of fissile materials, energy efficiency, and comparative costs of energy sources including nuclear power. I have authored or co-authored many publications on these subjects. I have testified before Congress on several occasions regarding issues related to nuclear waste, reprocessing, environmental releases of radioactivity, and regulation of nuclear weapons plants.

1.5. An extensive part of my work has been to analyze various issues related to radioactive waste management, classification, and disposal. This work includes studies on low-level waste characteristics, high-level waste characteristics, methods of spent fuel disposal, characteristics of geologic repositories, and research related to geologic repositories. I have studied radioactive waste in both the commercial and military sectors. On two occasions, I was the director of teams that analyzed ANDRA's research plans for a geological repository for high level radioactive waste in France on behalf of a French government-sponsored stakeholder committee (2004, 2011). I am the principal author of a book on nuclear waste, *High-Level Dollars Low-Level Sense: A Critique of Present Policy for the Management of Long-Lived Radioactive Waste and Discussion of An Alternative Approach* (Apex Press 1992). This book included an analysis of U.S. waste classification regulations. I am the principal author of an assessment of the costs of managing and disposing of depleted uranium from the National Enrichment Facility (2004 and 2005).

1.6. I also have served on a number of oversight and advisory committees and boards with respect to my areas of expertise. Between 1997 and 2002, I was on the expert team monitoring independent audits of the compliance of Los Alamos National Laboratory with the radiation release portion of the Clean Air Act (40 CFR 61 Subpart H). The monitoring program was conducted under a Consent Decree that resulted from a federal court finding that Los Alamos was out of compliance with Subpart H. In that capacity, I reviewed extensive records, models, facilities, procedures, measurements, and other aspects of the Los Alamos National Laboratory air emissions control and measurement program in order to determine whether the audits were being properly conducted and whether they were thoroughly done. I also served as a member of the Radiation Advisory Committee of the U.S. Environmental Protection Agency's (EPA's) Science Advisory Board from 1992 to 1994 and the EPA's Advisory Subcommittee on cleanup standards of the National Advisory Committee on Environmental Policy and Technology during part of the 1990s. In addition, I have served as an expert consultant to numerous organizations regarding technical, economic, and public health issues related to radioactive waste management. I have also been a consultant on energy issues to several U.N. agencies, the Tennessee Valley Authority, the Lower Colorado River Authority, the Lawrence Berkeley Laboratory, Edison Electric Institute, and the Congressional Office of Technology Assessment. I was elected a Fellow of the American Physical Society in 2007, an honor granted to at most one-half of one percent of APS members.

1.7. I have written or co-authored a number of books and other publications analyzing the safety, economics, and efficiency of various energy sources, including nuclear power and sustainable energy sources such as wind and solar energy. I was the principal author of the first evaluation of energy end-uses and energy efficiency potential in the U.S. economy (published by the Electronics Research Laboratory, University of California at Berkeley in 1971). I was also the principal author of the first overview study of the relationship between energy and agriculture, *Energy and Agriculture in the Third World* (Ballinger 1975). This study included consideration of both traditional and modern energy sources. I was one of the principal technical staff persons of the Ford Foundation Energy Policy Project, and a co-author of its final report, *A Time to Choose*, which helped shape U.S. energy policy during the mid-to-late 1970s. I am a co-author of *Investment Planning in the Energy Sector*, which is an economic model published by the Lawrence Berkeley Laboratory in 1976. I am also the principal author of *Nuclear Power Deception* (Apex Books 1999), an analysis of nuclear power policy, safety, and the promises of energy "too cheap to meter" in the United States. On behalf of the SEED Coalition, I assessed the capital costs of proposed nuclear power reactors in South Texas (2008). In addition, I am the author of *Carbon-Free and Nuclear-Free* (RDR Books and IEER Press 2007, reprinted in 2008 and 2010). To the best of my knowledge, *Carbon-Free and Nuclear-Free* is the first detailed analysis of a transition to a U.S. economy based completely on renewable energy, without any use of fossil fuels or nuclear power.

1.8. I have also done extensive work with respect to the health and environmental effects of nuclear weapons production. I am the principal author of the first independent assessment of radioactivity emissions from a nuclear weapons plant (1989) and co-author of the first audit of the cost of the U.S. nuclear weapons program (*Atomic Audit* 1998). I am also the principal editor and a co-author of the first global assessment of the health and environmental effects of nuclear weapons production (*Nuclear Wastelands* 1995 and 2000), which was nominated for a Pulitzer Prize by MIT Press.

1.8. I am co-author (with Yves Marignac) of an analysis of the post-Fukushima complementary safety assessments (including waste management and storage) prepared by the French nuclear power plant and reprocessing plant operators. The report in French is entitled *Sûreté nucléaire en France post-Fukushima : Analyse critique des Évaluations complémentaires de sûreté (ECS) menées sur les installations nucléaires françaises après Fukushima* (Post-Fukushima Nuclear Safety in France: Analysis of the Complementary Safety Assessments (CSAs)). A summary is available in English.

2.0 PURPOSE OF DECLARATION AND SUMMARY OF EXPERT OPINION

2.1. The purpose of this declaration is to provide the Nuclear Regulatory Commission (NRC) with my expert opinion regarding the environmental analysis supporting the NRC's proposed Waste Confidence rule as well as the proposed rule itself.[1] This environmental analysis is presented in the NRC's draft Waste Confidence Generic Environmental Impact Statement[2] (Draft GEIS). In conducting my review of these documents, I focused on the NRC's discussion of environmental impacts of long-term spent fuel storage and spent fuel disposal.

2.2. In addition to reviewing the proposed rule and the Draft GEIS, I have also reviewed a number of other relevant documents. These documents include the relevant reference documents

[1] 78 Fed. Reg., pp. 56621-56622 (Sept. 13, 2013), NRC 2013a, NRC 2013b
[2] NRC 2013a

cited in the Draft GEIS and the NRC's final license renewal rule.[3] I have also reviewed the proposed and final versions of the 2010 Waste Confidence Decision Update,[4] and prepared comments on the earlier proposed version.[5] In addition, I am familiar with the proposed and final versions of the 2010 Temporary Storage Rule,[6] and I reviewed and commented on the NRC's 2013 scoping proposal for the draft GEIS.[7] Further, I am familiar with the NRC's uranium fuel cycle rule and relevant associated reference documents. And I am familiar with the NRC's now-suspended Long-Term Waste Confidence Project and related documents.[8] Finally, I am familiar with relevant aspects of governing law and guidance, including the National Environmental Policy Act (NEPA) and relevant NRC implementing regulations. My comments on the scope of the Draft GEIS are incorporated here by reference.[9]

2.3. In the Draft GEIS, NRC seeks to support three findings that are presented in proposed 10 CFR 51.23(a)(2) and Table B-1: (a) that it is feasible to store spent fuel safely and without significant adverse environmental impacts for an indefinite period, (b) that it is feasible to have a mined geologic repository within 60 years following the life of a licensed reactor, and (c) that spent fuel disposal will not have impacts on the environment that are significant enough to foreclose extended operation for any nuclear power plant.[10] In my professional opinion, the Draft GEIS is extremely inadequate to support these proposed findings. Significant evidence exists to show that the environmental impacts of long-term or indefinite storage of spent fuel will likely be significant and could cause significant risks to human health. In the case of indefinite storage, they are likely to be catastrophic; among other things it is likely that institutional control will be lost. For purposes of this declaration, I use the same definitions of "long-term" and "indefinite" as those used in the Draft GEIS.[11]

2.4. The NRC's first proposed findings are that spent fuel can be safely stored for an indefinite time period (10 CFR 51.23(a)(2)) and that it can be stored indefinitely without significant adverse environmental impacts (Table B-1).[12] These findings have scant technical support; the available analysis generally points in the opposite direction. The Draft GEIS fails to provide a detailed quantitative analysis of the impacts to public health and the environment that would occur in the event of an accidental release of radiation during spent fuel storage or transfer. Given the high level of radioactivity in spent fuel, the high burnup of much of the spent fuel, and the very long half-lives of certain radioactive materials (including plutonium-239 and long-lived fission products with half-lives that range from 30 years to millions of years), these impacts could be substantial.

[3] 78 Fed. Reg., p. 37282 (June 20, 2013)
[4] NRC 2008a and NRC 2010a
[5] Makhijani 2009
[6] NRC 2008b and NRC 2010b
[7] NRC 2012c and Makhijani 2013
[8] *See, e.g.,* NRC 2010a, p. 81040 and Borchardt 2012
[9] Makhijani 2013
[10] NRC 2013b, p. 56804-56805
[11] NRC 2013a, p. 1-12
[12] NRC 2013b, p. 56804-56805

2.5. In addition, the Draft GEIS contains almost no information about spent fuel characteristics that could cause adverse safety risks and environmental impacts during long-term or indefinite storage. That is perhaps due to the fact that, in other contexts, the NRC itself has acknowledged that it currently lacks sufficient information to reach informed conclusions about the behavior of spent fuel in storage over the long term. Little-understood factors affecting the safety of spent fuel storage include the degree to which spent fuel and its host containers corrode and degrade over a prolonged period of time, the phenomenon of "failed fuel," and the effect of high burnup fuel on the integrity of cladding and storage containers. For instance, although high burnup fuel now makes up a significant portion of spent fuel inventories, there is no explicit consideration of long-term dry storage and disposal of failed high-burnup fuel. The cladding of such fuel degrades much more during reactor operation than low burnup fuel; continued degradation appears likely during prolonged storage. The NRC currently has little or no empirical data regarding its behavior under extended dry storage conditions. The NRC itself identified the data gaps in a Draft Study of Technical Needs in 2012[13] but failed to note these gaps in the Draft GEIS. The NRC's amnesia regarding its own study undermines the credibility and integrity of the Draft GEIS. The Draft GEIS contains no analysis of how high burnup spent fuel characteristics may contribute to the risk of an accidental release of radioactivity from spent fuel that has been stored for a long period in dry casks, preceded by prolonged (60 to 120 years) of storage in spent fuel pools; or how degradation may contribute to accidental releases and radiation exposure risks during the many transfers that would take place in case of long-term or indefinite storage. The NRC should factor in its own prior acknowledgement of the potential for degradation of high burnup spent fuel and the low state of knowledge of a number of critical factors prior to declaring its confidence in the safety of long term or indefinite spent fuel storage.[14]

2.6. My second major criticism of these first findings is that they depend on the unsupported assumption that institutional controls will remain effective indefinitely. Instead of addressing the risk of accidental radioactivity releases posed by the poorly understood behavior of spent fuel in long-term storage, the NRC simply assumes that current regulations and institutional measures for managing spent fuel will remain in place indefinitely, and that any new problems that arise will be resolved, such that spent fuel storage will never pose a significant health or environmental problem. In my opinion, this assumption of active institutional control for an indefinite period of time lacks any factual, historical, or financial foundation and even common sense when it extends to very long time periods. First, it is fundamentally inconsistent with federal law and policy (including NRC's own regulations) that institutional controls should only be relied on for a period of decades, not hundreds of years. Second, it is contradicted by the experience of history that governments tend to fail or change substantially over time. To assume

[13] NRC 2012a

[14] The Draft GEIS makes just one explicit substantive statement about degradation of high burnup fuel and that related to the "short-term" time frame: "This [reduced ductility] phenomenon could influence the approach used for repackaging spent fuel but the NRC is not aware of information that would require it to conclude that high-burnup fuel would need to be repackaged during the short-term timeframe defined in the draft GEIS. Should spent fuel cladding be more brittle, greater care could be required during handling operations, regardless of when repackaging would occur, to limit the potential for damage to spent fuel assemblies that could affect easy retrievability of the spent fuel and complicate repackaging operations." (NRC 2013a, p. B-13)

that the federal government will exist for tens of millennia and each year appropriate significant sums of money to manage spent fuel at sites that produce no revenue flies in the face of current facts and U.S. history, including a dozen federal government shut downs since 1980, not to speak of the Civil War, when the United States did not have a single government, budget, or currency. In this century, the White House had received a number of petitions, some with thousands of signatures, for secession from the United States as of November 12, 2012.[15]

2.7. Finally, even under the assumption of institutional controls for an indefinite period, the Draft GEIS fails to address the expense of those measures, the risk that they may fail, and how such costs and risks may impact reactor licensing and license extension decisions.

2.8. The question of feasibility of spent fuel disposal cannot be evaluated without considering the probability that a repository will safely contain radioactivity for the hundreds of thousands of years required. And, in order to evaluate that probability, it is necessary to evaluate the environmental impacts of disposing of spent fuel in a range of geologic media. NRC cannot simply presume that a repository is feasible. Disposal impacts are relevant because they are part of the waste confidence finding that a mined geologic repository is feasible. By definition of such feasibility, such a repository must meet reasonable health and safety standards. Moreover, we note that Table S-3 at 10 CFR 51.51 is invalid for estimating high-level waste disposal impacts. Among other things, its underlying assumption of disposal in a bedded salt repository for spent fuel disposal was repudiated by the NRC itself in 2008.[16] Therefore, the NRC must prepare a new disposal impact analysis in the context of its waste confidence decision. Further, *sufficient capacity* at one or more such sites meeting safety criteria must be available to accommodate spent fuel from any and all commercial light water reactors that may be built. The Draft GEIS sets no upper limit on the amount of spent fuel to be disposed of. By failing to evaluate spent fuel disposal impacts, the NRC has excluded a major part of the picture regarding the feasibility of spent fuel disposal. The concept of feasibility also includes cost. What will it cost to isolate spent fuel for many thousands of years? Is the cost affordable when compared with the profit that a nuclear reactor will yield? These questions must be evaluated in order to assess the feasibility of spent fuel disposal. As part of this analysis, the NRC should also evaluate the probability that sufficient repository capacity will be available in a timely manner so as to avoid excessive storage risks and costs. Of course, by doing so it would also be calculating the probability that sufficient repository capacity will *not* be available. In the proposed rule, the NRC fails to even address the question of repository capacity. And it only refers to "a" mined geologic repository, as if one were enough. This is a significant deficiency. As we will show, persuasive arguments can be made that two repositories may be needed if there is a resurgence of nuclear power. Appeals to repository programs in Sweden and Finland do not resolve this issue – their nuclear power programs are very small compared to the United States and therefore involve a small amount of spent fuel.

2.9. Further, the NRC has no valid environmental analysis on which it can rely for an evaluation of spent fuel disposal impacts. Table B-1 depends on the EPA standard for Yucca Mountain.[17] The proposed rule simply asserts that because the Yucca Mountain rule limits radiation doses in

[15] Weiner 2012
[16] NRC 2008a, p. 59555
[17] The Yucca Mountain standard at 40 CFR 197.

principle, "that the impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR part 54 should be eliminated."[18] This is like saying that the existence of a law against drunken driving allows society to conclude that the impacts of drunken driving would in fact not be large enough to worry about. In addition, the licensing proceeding for Yucca Mountain is far from complete (if it is ever completed); so it is not clear that Yucca Mountain would meet the required performance specified in 40 CFR 197.

2.10. In view of the above, it is my conclusion that the NRC lacks a factual and scientific basis for a finding of confidence that spent fuel can be safely stored for the long-term, much less indefinitely. The NRC also lacks a factual and scientific basis for a finding of confidence that spent fuel can be disposed of safely within acceptable, legally binding health and safety standards. In fact, the available evidence suggests that both long-term storage and disposal of spent fuel could pose significant safety and environmental risks. Further, the costs of long-term storage and disposal could run into hundreds of billions of dollars. The NRC should prepare a new Draft GEIS that meaningfully examines these risks.

2.11. My declaration is organized as follows:

- In Section 3, I will provide background information regarding past environmental studies and regulations and the Draft GEIS.
- In Section 4, I will discuss the basis for my expert opinion that the NRC's proposed finding that spent fuel can be stored for a long-term or indefinite period safely and without significant environmental impacts is not supported by adequate data or analysis.
- In Section 5, I will address criticality risks and high burnup fuel.
- In Section 6, I will address the unreasonableness of the NRC's critical assumption of perpetual institutional control and continued funding of spent fuel storage and management for millennia, tens of millennia, or longer.
- In Section 7, I will address the potential consequences of indefinite storage that have been ignored or treated very inadequately in the Draft GEIS, notably in case of a loss of institutional control.
- In Section 8, I will discuss the basis for my expert opinion that the NRC's proposed findings regarding the feasibility and safety of spent fuel disposal are unsupported.
- In Section 9, I will discuss site-specific issues that are not amenable to resolution in a generic manner.
- Section 10 contains a summary of the main points of my declaration.
- Section 11 provides a list of references. Electronic copies of these documents are also being provided.

[18] NRC 2013b

3.0 PROPOSED RULE AND ASSOCIATED DRAFT GEIS

A. Proposed Rule

3.1. Proposed Section 51.23(a)(2) makes the following predictions:

> i. It is "feasible to safely store spent nuclear fuel following the licensed life for operation of a reactor" and
> ii. It is "feasible to have a mined geologic repository within 60 years following the licensed life for operation of a reactor."[19]

And it states that these conclusions are consequent upon preparation of the Draft GEIS.[20] No time limit is placed on the feasibility of storage safety in paragraph i above.

3.2. The proposed finding regarding the feasibility of having a mined repository in 60 years does not include a finding that the capacity of the repository will be sufficient. This is a change from the 2010 Waste Confidence Decision, which included a finding that "sufficient mined geologic repository capacity will be available . . . when necessary."[21] It appears the NRC thinks the sufficiency of repository capacity is no longer an issue, because spent fuel can be stored safely for an indefinite period:

> Based on the preceding discussion, the NRC believes that for the storage timeframes considered in the draft GEIS, regulatory oversight will continue in a manner consistent with NRC's regulatory actions and oversight in place today to provide for continued storage of spent fuel in a safe manner until sufficient repository capacity is available for the safe disposal of all spent fuel.[22]

3.3. Proposed Table B-1 categorizes spent fuel storage impacts as "SMALL."[23] It also makes the following finding regarding the safety and environmental impacts of spent fuel storage:

> The expected increase in the volume of spent fuel from an additional 20 years of operation can be safely accommodated onsite with small environmental effects through dry or pool storage at all plants, if a permanent repository or monitored retrievable storage is not available.[24]

3.4. With respect to impacts of disposing of spent reactor fuel, proposed Table B-1 states:

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[19] NRC 2013b, p. 56804
[20] NRC 2013b, p. 56804
[21] NRC 2010a, p. 81067
[22] NRC 2013a, p. B-20
[23] NRC 2013b, p. 56805
[24] NRC 2013b, p. 56805

> For the high-level waste and spent-fuel disposal component of the fuel cycle, the EPA established a dose limit of 15 millirem (0.15 mSv) per year for the first 10,000 years and 100 millirem (1.0 mSv) per year between 10,000 years and 1 million years for offsite releases of radionuclides at the proposed repository at Yucca Mountain, Nevada.
>
> The Commission concludes that the impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR Part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the impacts of spent fuel and high level waste disposal, this issue is considered Category 1.[25]

3.5. Proposed Table B-1 is inconsistent with another regulation that also makes a finding on the same subject: Table S-3 in 10 CFR 51.51.[26] Table S-3 summarizes the NRC's conclusion that the impacts of spent fuel disposal will be zero, based on the assumption that spent fuel will be disposed of in a bedded salt repository. Proposed Table B-1 contradicts Table S-3 by concluding that long-term doses could be as high as 100 millirem per year. But the NRC does not attempt to reconcile proposed Table B-1 and Table S-3; nor does it address the fact that in the 2008 Draft Waste Confidence Update, it repudiated bedded salt as a geologic medium for a repository.[27] Nothing in the NRC's response to public comments on this point negated this repudiation of the unsuitability of bedded salt for spent fuel disposal.[28]

B. Waste Confidence Draft GEIS

3.6. The Draft GEIS considers three different time periods for spent fuel storage: short-term (60 years), long-term (160 years), and indefinite storage. As described in the Draft GEIS:

> The first, most likely, timeframe is the short-term timeframe, which analyzes 60 years of continued storage after the end of a reactor's licensed life for operation. The NRC acknowledges, however, that the short-term timeframe, although the most likely, is not certain. Accordingly, the draft GEIS also analyzed two additional timeframes. The long-term timeframe considers the environmental impacts of continued storage for a total of 160 years after the end of a reactor's licensed life for operation. Finally, although the NRC considers it highly unlikely, the draft GEIS includes an analysis of an indefinite timeframe, which assumes that a repository does not become available.[29]

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[25] NRC 2013b, p. 56805

[26] The Draft GEIS acknowledges that "[t]he environmental impacts of portions of the uranium fuel cycle that occur before new fuel is delivered to the plant and after spent fuel is sent to a disposal site have been evaluated and are codified" in 10 CFR 51.51 and Table S-3. (NRC 2013a, p. 1-22)

[27] NRC 2008a, p. 59555

[28] NRC 2010a, pp. 81043 and 81044

[29] NRC 2013a, p. xxvii

3.7. The Draft GEIS addresses spent fuel storage impacts in Appendix B. Issues regarding spent fuel storage integrity are divided into pool storage (Section B.3.1.1) and dry storage (Section B.3.2.1). With respect to the integrity of spent fuel stored in pools, the NRC cites several studies done between 1977 and 2006 for the conclusion that "[d]egradation of the spent fuel [stored in pools] should be minimal over the short-term storage timeframe."[30] The Draft GEIS also states that: "the NRC is not aware of any information that would call into question the technical feasibility of continued safe storage of spent fuel in spent fuel pools beyond the short-term storage timeframe."[31]

3.8. With respect to the integrity of fuel in dry storage, the Draft GEIS asserts that "spent fuel has been safely stored in dry casks for more than 25 years." [32] The Draft GEIS cites four "[r]ecent studies" that "have confirmed dry cask storage reliability:" Bare et al. 2001, Einziger et al. 2003, IAEA 2006, and EPRI 1998."[33] The Draft GEIS also states:

> Although the current record for dry cask storage supports the technical feasibility of continued safe storage, the NRC constantly works to investigate and monitor the behavior of spent fuel storage systems to identify any unexpected and deleterious safety conditions before there are adverse impacts.[34]

The 2013 NRC guidance on the state of knowledge of high burnup fuel (HBF) states the following:

> The experimental confirmatory basis that low burnup fuel (≤45 GWd/MTU) will maintain its integrity in dry cask storage over extended time periods was provided in NUREG/CR-6745 (Ref. 1), "Dry Cask Storage Characterization Project—Phase 1; CASTOR V/21 Cask Opening and Examination" and NUREG/CR-6831 (Ref. 2), "Examination of Spent PWR Fuel Rods after Years in Dry Storage."
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> A confirmatory basis, which includes information over a similar length of the time available for low burnup fuel, does not exists for HBF (>45 GWd/MTU). Certification and licensing HBF for storage was permitted for an initial 20-year-term using the guidance contained in ISG-11, Rev. 3, (Ref. 3) which was based on short term laboratory tests and analysis that may not be applicable to the storage of HBF beyond 20 years, particularly with the current state of knowledge regarding HBF cladding properties. (Ref. 4)[35]

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[30] NRC 2013a, p. B-9
[31] NRC 2013a, p. B-9
[32] NRC 2013a, p. B-12
[33] NRC 2013a, p. B-12
[34] NRC 2013a, pp. B-12 – B-13 (citing Interim Staff Guidance-24, *Use of a Demonstration Program as Confirmation of Integrity for Continued Storage of High Burnup Fuel Beyond 20 Years*, Accession No. ML13056A516)
[35] NRC Interim Staff Guidance 24 (2013), p. 1

3.9. But, the NRC acknowledges in the Draft GEIS that it is "aware of concerns regarding potential detrimental effects of hydride reorientation on cladding behavior (e.g., reduced ductility)."[36] As described in the Draft GEIS:

> Reduced ductility, which makes the cladding more brittle, increases the difficulty of keeping spent fuel assemblies intact during handling and transportation. Research performed in Japan and the United States (Billone et al. 2013) indicated that: (1) hydrides could reorient at a significantly lower stress than previously believed and (2) high-burnup fuel could exhibit a higher ductile-to-brittle transition temperature due to the presence of radial hydrides. This phenomenon could influence the approach used for repackaging spent fuel but the NRC is not aware of information that would require it to conclude that high-burnup fuel would need to be repackaged during the short-term timeframe defined in the draft GEIS. Should spent fuel cladding be more brittle, greater care could be required during handling operations, regardless of when repackaging would occur, to limit the potential for damage to spent fuel assemblies that could affect easy retrievability of the spent fuel and complicate repackaging operations.[37]

3.10. With respect to dry storage of spent fuel during the "short term," *i.e.*, 60 years, the Draft GEIS concludes that:

> Based on available information and operational experience, degradation of the spent fuel should be minimal over the short-term storage timeframe if conditions inside the canister are appropriately maintained (e.g., consistent with the technical specifications for storage). Thus, it is expected that only routine maintenance will be needed over the short-term storage timeframe.[38]

3.11. With respect to long-term (160 years) and indefinite dry storage of spent fuel, the Draft GEIS concludes:

> Repackaging of spent fuel may be needed if storage continues beyond the short-term storage timeframe. In the draft GEIS, the NRC conservatively assumes that the dry casks would need to be replaced if storage continues beyond the short-term storage timeframe. The NRC assumes replacement of dry casks after 100 years of service life, even though studies and experience to date do not preclude a longer service life. [39]

In addition, the NRC asserts that it "continues to evaluate aging management programs and to monitor dry cask storage so that it can update its service life assumptions as necessary and consider any circumstances that might require repackaging spent fuel earlier than anticipated."[40]

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[36] NRC 2013a, p. B-13
[37] NRC 2013a, p. B-13
[38] NRC 2013a, p. B-13
[39] NRC 2013a, p. B-13
[40] NRC 2013a, p. B-13

3.12. The Draft GEIS asserts that "[a]ccidents associated with repackaging spent fuel are evaluated in Section 4.18 and the environmental impacts are SMALL because the accident consequences would not exceed the NRC accident dose standard contained in 10 CFR 72.106."[41] However, the discussions of accidents in Section 4.18.1.2 (regarding design-basis dry storage accidents) and Section 4.18.2.2 (regarding severe dry storage accidents) do not indicate whether NRC considered the contribution to accident risk by spent fuel deterioration during long-term and indefinite storage. Further, the purpose of the study cited was "solely" to show the method of the calculation as it should be applied to specific situations. "Thus, no inferences or conclusions should be drawn with regard to the study's regulatory implications."[42] Yet the Draft GEIS has applied its results to a generic regulatory situation.

3.13. The Draft GEIS does not address the environmental impacts of spent fuel disposal. Instead, it states that: "The environmental impacts addressed in this draft GEIS are limited to the environmental impacts of continued storage."[43] As clarified in the Scoping Process Summary Report:

> Spent nuclear fuel disposal is outside the scope of the Waste Confidence analysis, which will consider the environmental impacts of continued storage prior to ultimate disposal. The development of a national repository, the licensing of Yucca Mountain or another repository site, environmental impacts associated with disposal in a repository, funding issues, recycling, and other waste disposal strategies are outside the scope of this GEIS.[44]

4.0 THE NRC'S PROPOSED FINDING THAT SPENT FUEL CAN BE STORED FOR A LONG-TERM OR INDEFINITE PERIOD SAFELY AND WITHOUT SIGNIFICANT ENVIRONMENTAL IMPACTS IS NOT SUPPORTED BY ADEQUATE DATA OR ANALYSIS.

4.1. The NRC's first proposed findings are that spent fuel can be safely stored for an indefinite time period (10 CFR 51.23(a)(2)(i)) without significant adverse environmental impacts (Table B-1). These findings are almost devoid of valid technical support so far as long-term and indefinite storage is concerned.

A. Environmental Impacts of Storage

4.2. The Draft GEIS should comprehensively analyze all aspects of accidents involving dry cask storage and inter-cask fuel transfers based on sound scientific information. When the information is incomplete or has significant uncertainties, these should be stated. If there are methodological studies that provide a guide to how calculations should be done, the guidance should be used to

[41] NRC 2013a, p. B-13
[42] NRC Pilot 2007, p. v
[43] NRC 2013a, p. 1-4
[44] NRC Scoping 2013, p. 42

develop estimates. In some cases, the data gaps are so large, that a realistic calculation of uncertainties can be operationally meaningless in the sense of its usefulness for choosing among alternative courses of action. The Draft GEIS should have assessed data gaps in this manner. Instead of such a procedure, the Draft GEIS has improperly used a pilot study (hereafter Pilot Study) intended to demonstrate a method to declare that public health impacts due to an accident during spent fuel storage transfer would be SMALL[45] for the purpose of the waste confidence regulation, when the study explicitly states that it should not be used for regulatory purposes:

> The methodology developed in this study can be used as a guide for performing other similar PRAs [probabilistic risk assessments]. Moreover, the results of this study can be used in conjunction with the methodology selected to determine the need for other PRAs, improvements in data gathering and analysis, and additional engineering design analysis. It should be noted that the focus of this pilot study *was solely on the methodology* and its limited (i.e., case-specific) application. Thus, *no inferences or conclusions should be drawn with regard to the study's regulatory implications*.[46]

4.3. There are a number of reasons that the study should not be used in a generic, regulatory context, especially in a situation where the impacts of indefinitely long periods of storage and repeated transfers are being assessed, as is the case in the Draft GEIS. First, it was a pilot study done to develop methodology; it was not designed for general use. For instance, the study considered high burnup Boiling Water Reactor (BWR) spent fuel.[47] Most U.S. reactors are pressurized water reactors. The space between the fuel pellet and the fuel rod decreases with burnup. However, the gap between the fuel pellet and the fuel rod is reduced much more in a PWR than a BWR.[48] As the NWTRB has pointed out "[h]igh-burnup fuels tend to swell and close the pellet-cladding gap, which increases the cladding stresses and can lead to creep and stress corrosion cracking of cladding in extended storage."[49] This shows that the difference in the fuel pellet cladding gap between PWRs and BWRs is of material importance for high burnup fuel; it needs to be taken into account in the analysis of impacts of spent fuel storage and transport.

4.4. The Pilot Study listed a number of uncertainties but did not consider them in its quantitative analysis:

> The changes that occur in the properties of the fuel and the cladding while in-reactor may introduce *large errors* into the determination of the release factors, because of the uncertainty of the database....*No attempt has been made to quantify the degree of the uncertainties* or to determine if they are significant to the risk.[50]

[45] NRC 2013a, pp. 4-82 and 4-83
[46] NRC Pilot 2007, p. v, italics added
[47] NRC Pilot 2007, p. 1-2
[48] NRC Pilot 2007, Table D-2, p. D-8
[49] NWTRB 2010, p. 11
[50] NRC Pilot 2007, p. D-19, italics added

By implication, the estimate of health impact cited in the Draft GEIS has not considered a substantial number of uncertainties. We will discuss areas where data are lacking or poor in paragraphs 4.9 to 4.11.

4.5. The study cited by the NRC for public health impact only considered spent fuel stored in a pool for 10 years followed by dry storage for 20 years.[51] The experiments of Billone et al. on high burnup fuel – the only study cited in the Draft GEIS regarding damage to spent fuel as a result of high burnup – showed significant damage to high burnup fuel upon drying:

> Pre-storage drying-transfer operations and early stage storage subject cladding to higher temperatures and much higher pressure-induced tensile hoop stresses relative to in-reactor operation and pool storage. Under these conditions, radial hydrides may precipitate during slow cooling and provide an additional embrittlement mechanism as the cladding temperature decreases below the ductile-to-brittle transition temperature (DBTT).[52]

Photographs in Billone et al. show clear damage, including significant cracks in the cladding. The Draft GEIS statement that this "could influence the approach used for repackaging spent fuel" is so limited in scope as to provide almost no insight into the environmental impacts during accidents, further degradation during prolonged storage, and during handling and transfer operations. Repackaging is far from the only or even the most important issue from the environmental point of view. We note that the NRC has yet to demonstrate how it will transfer damaged spent fuel from one cask to another (see paragraph 4.27 below).

Figure 1 shows the trends in burnup for PWRs and BWRs. It shows that high burnup fuel (more than 45 GWd per metric ton) started being discharged from reactors only around the turn of the century. Most of this is still in spent fuel pools. Examination of high burnup spent fuel after dry storage of 15 years, as was done for low burnup Surry fuel,[53] is not yet possible, though some experimental work with high burnup fuel cladding has been done.[54]

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[52] Billone et al. 2013, p. 431

[52] Billone et al. 2013, p. 431

[53] Einziger et al. 2003

[54] Billone et al. 2013

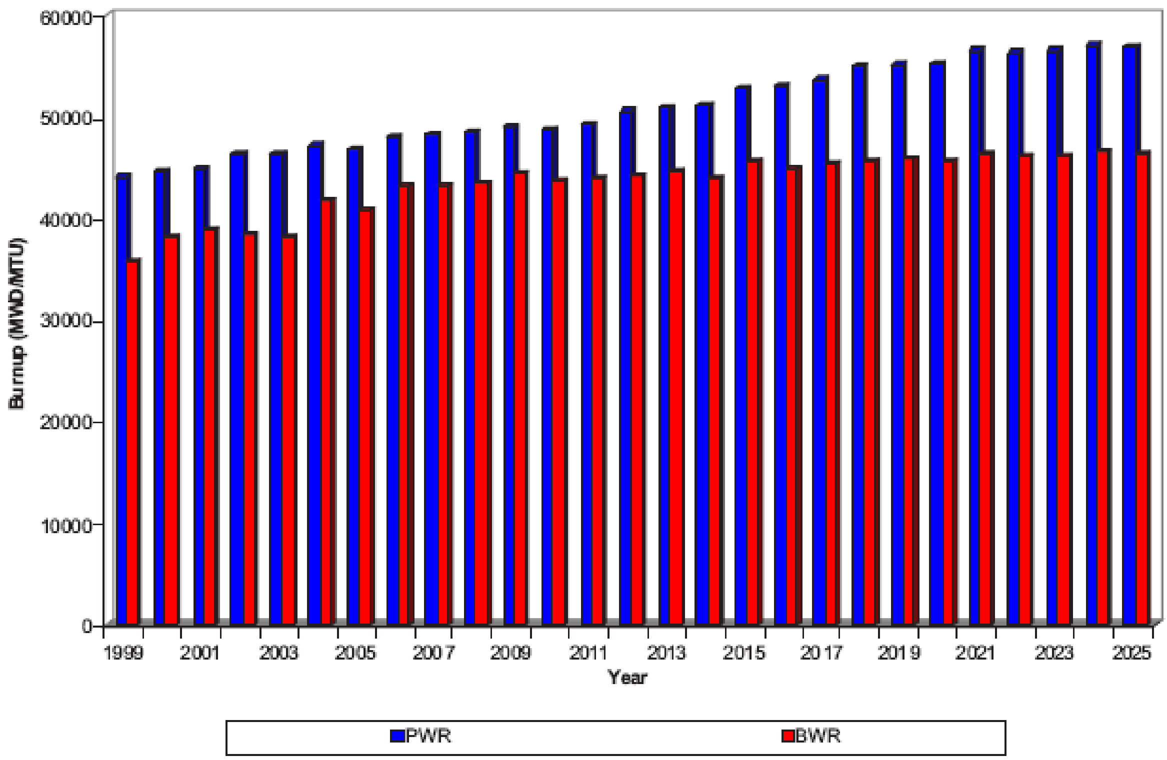

Figure 1. Burnup trends for PWR and BWR reactors in the United States (Reproduced from IAEA 2011, Fig. 6 (p. 9), with note: Courtesy of Energy Resources International)

B. NRC's Previously Raised Concerns about Spent Fuel Characteristics

4.6. The Draft GEIS assumes that spent fuel bundles can be stored for millennia and repeatedly transferred hundreds of times from one cask to another without large releases of radioactivity. But the Draft GEIS contains almost no information about spent fuel characteristics that could cause adverse safety risks and environmental impacts in case of long-term or indefinite storage, both during storage and during the many transfers that must take place. As noted in paragraph 4.5 above, even drying upon removal from the spent fuel pool and early dry cask storage drying induce significant embrittlement in high burnup spent fuel. Further, Billone et al. also found that the degradation is dependent upon the specific zirconium alloy used in the cladding material. Specifically, there was a significant difference in radial hydriding and the ductile-to-brittle transition temperature between ZIRLO and zircaloy-4 cladding subjected to high burnup.[55] The Draft GEIS says nothing about the significance of these findings for accident impacts, inter-cask transfer operations, or transportation risks. Further, little-understood factors affecting the safety of spent fuel storage include the degree to which spent fuel and its host containers corrode and degrade over a prolonged period of time, the phenomenon of "failed fuel," and the effect of high

[55] Billone et al. 2013, p. 446

burnup fuel on the integrity of cladding and storage containers. The Draft GEIS contains no analysis of how spent fuel characteristics may contribute to the risk of an accidental release of radioactivity during extended storage of dry casks; or how these factors may contribute to accident risks during the many transfers that would take place over an extended period of time, *i.e.*, transfers between pools and casks, transfers between storage casks, transfers between storage and transportation casks, and transfers between transportation casks and casks used for ultimate disposal of spent fuel.

4.7. **The** NRC has cited just one study (Billone et al. 2013) that has evidence about the deterioration of high burnup spent fuel during drying and subsequent storage.[56] Even so, the lessons contained in this study, such as the implications of degradation for accident consequences or the differences between risks of various zirconium alloys used as cladding material are not discussed in the Draft GEIS. However, the NRC has acknowledged elsewhere that it has a serious lack of information about the behavior of spent fuel stored for long periods. In May 2012, the NRC published a *Draft Report for Comment: Identification and Prioritization of the Technical Information Needs Affecting Potential Regulation of Extended Storage and Transportation of Spent Nuclear Fuel* (Draft Report on Technical Information Needs).[57] This report catalogs what is known, as well as the gaps in knowledge, of spent fuel degradation mechanisms. Some of the gaps will require extensive new data and a considerable amount of time to fill.

4.8. The Draft Report on Technical Information Needs was based on a number of prior reports, data from physical examination of some "lower burnup" spent fuel, and extrapolation from this data to 80 years. Based on this data, the Draft Report concluded as follows:

> ….The current regulatory framework supports at least the first 80 years of dry cask storage (i.e., a 40-year initial licensing term, followed by a license renewal for a term of up to 40 years, although many of the existing facilities were licensed for an initial term of 20 years under the regulations in place at the time).
>
> The technical basis for the initial licensing and renewal period is supported by the results of a cask demonstration project *that examined a cask loaded with lower burnup fuel* (approximately 30 GWd/MTU [gigawatt-days per metric ton

[56] NRC 2013a, p. B-13. Two of the four other studies cited, Bare et al. 2001 and Einziger et al. 2003, deal with low burnup fuel that has been stored – in fact, they relate to an examination of the same low burnup fuel from the Surry plant in Virginia. The third, IAEA 2006, makes a general assertion that international experience indicates that dry storage is satisfactory and only "a few" rod failure have been detected by sampling of cover gases. The study also refers to the same Surry cask examination as the other two as evidence of storage (IAEA 2006, p. 21). It does not deal explicitly with safety issues that might arise with high burnup fuel, though it notes that there is "a strong interest in extending the technical basis to license storage of power reactor fuel assemblies with burnups above 45 000 MW·d/MTU." (IAEA 2006, p. 21). The fourth, EPRI 1998, was prepared early in the high burnup era. Even so it flagged concerns about high burnup spent fuel at several points, including at the very start: "As the utilities push to higher and higher burnups, eventually the behavior of the fuel in storage of any duration will need to be considered." The document goes on to identify a number of concerns (EPRI 1998, p. iv). The EPRI study notes that high burnup spent fuel had not been studied "to date." (EPRI 1998, p. 6-7).
[57] NRC 2012a

> uranium] average; all fuel burnup in this paper is given as peak rod average value). Following 15 years of storage, the cask internals and fuel did not show any significant degradation (Einziger et al., 2003). The data from this study can be extrapolated to maintain a licensing safety finding that *low burnup SNF* can be safely stored in a dry storage mode for at least 80 years with an appropriate aging management program that considers the effects of aging on systems, structures, and components (SSCs).[58]

Note that the existing licensing and license extension procedures are based on examination of a single cask of relatively low burnup uranium dioxide spent fuel that had been in dry storage for only 15 years. The paper lists data requirements for extending this analysis to:

- high burnup spent fuel that would be stored from 120 years to 300 years[59] – that is from about six times to about 16 times longer than the total 19-year storage time (15 years of dry storage plus four years of wet storage) of the spent fuel that was examined in Einziger et al. 2003;[60]
- spent fuel burnups up to about 62.5 GWd/MTU,[61] about double the irradiation of the spent fuel that was examined;
- mixed oxide (MOX) spent fuel (which has plutonium-239 instead of uranium-235 as the fissile material that sustains the chain reaction), even though there are hardly any data on MOX fuel degradation after dry storage; MOX fuel may be "more susceptible" to some forms of degradation, according to the Nuclear Waste Technical Review Board;[62]
- "new cladding, fuel compositions, and assembly designs that have been and will continue to be put into use."[63]

4.9. The data requirements are extensive even by the NRC staff's own accounting. According to Table 6-1 in the Draft Report on Technical Information Needs, there are 23 different degradation phenomena that have a ranking of "high" in terms of "the need for further research"[64] in addition to the data available from the lower burnup/short storage time evaluations. Table 6-1 below shows the list of those items; it is reproduced from NRC 2012a (Table 6-1 (pp. 6-2 to 6-4)). Of these 23 degradation phenomena (grouped into 19 regulatory categories), 10 had the highest (#1) priority and the rest had the second highest priority.

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[58] NRC 2012a, p. 1-1, italics added
[59] NRC 2012a, p. 1-2
[60] The wet storage time was about 3.7 years (Einziger et al. 2003, p. 6); it has been rounded to four years for this calculation.
[61] NRC 2012a, p. 3-1
[62] NRC 2012a, p. A2-2, A2-4, and A4-3, for instance
[63] NRC 2012a, p. 3-1
[64] NRC 2012a, p. 6-1 and Table 6-1

Table 6-1. Summary of Regulatory Research Areas						
Component	**Degradation Phenomena**	**Regulatory Significance**	**Level of Knowledge**	**Overall Ranking**	**Reason for Ranking High**	**Research Priority**
Cladding	Galvanic corrosion	CO, RE, SR	L	H*†	This is only high if the drying task indicates that sufficient water remains in the canister. This may revert to low if sufficient water is not present. The level of knowledge is low.	2
	Stress corrosion cracking (SCC)		L	H§‡	All three mechanisms depend on a source of stress that would come from pellet swelling. If the stress is not present, the mechanisms become benign. If operative, these mechanisms could increase the source term and increase cladding stress. The latter could affect containment, especially if other degradation processes have compromised the canister.	2
	Delayed hydride cracking	CO, RE, SR	M	H§‡		2
	Low temperature creep	CO, CR, RE, SR	L	H‡		2
	Propagation of existing flaws	CO, RE, SR	L	H	There is little current knowledge of the initial flaw size distribution in high burnup cladding, and as a result, it currently cannot be determined whether the cladding will fail in the long term. Breached cladding affects the containment source term.	2
Fuel-cladding interactions	Fission gas release during accident	CO	L	H	Both of these mechanisms will result in an increased pressure in the canister and potential containment issues. The level of knowledge is low.	1
	Helium release					
	Pellet swelling	CO	L	H§	The level of knowledge is low, and swelling of the pellets would be the only source of stress for long duration cladding failure.	1
	Additional fuel fragmentation	CO	L	H	Additional fuel fragmentation will release fission gas to pressurize the rod and result in an increased source term for containment.	1
Fuel assembly hardware and damaged-fuel cans	Metal fatigue caused by temperature fluctuations	CR, RE, SR	M	H¦	Loss of assembly hardware would put the fuel in an unanalyzed state for criticality. The extent of the fatigue will depend on the size of the temperature fluctuations determined from the thermal crosscutting task.	2
	Wet corrosion and SCC	CR, RE, SR	M	H*†	This is only high if the drying task indicates that sufficient water remains in the canister. This may revert to low if sufficient water is not present	2

Table 6-1. Summary of Regulatory Research Areas (continued)						
Component	**Degradation Phenomena**	**Regulatory Significance**	**Level of Knowledge**	**Overall Ranking**	**Reason for Ranking High**	**Research Priority**
Fuel baskets	Weld embrittlement	CR, SH	L	H	The knowledge of this mechanism is low and failure of the basket will leave the fuel in an unanalyzed condition for criticality.	2
	Metal fatigue due to temperature fluctuations	CR, SH	M	H	The knowledge of this failure mechanism is medium, and failure will place the fuel in an unanalyzed condition.	2
Stainless steel (SS) canister body and weld	Atmospheric SCC Pitting and crevice corrosion	CO, CR, RE, SH, TH	L	H	The canister is the primary containment vessel in storage and may be needed for moderator exclusion of high burnup fuel in transportation. It may also be the primary means of retrieval. It is currently not known whether conditions are applicable for the mechanism to be active or in what timeframe it will occur.	1
SS, steel, and cast iron body, welds lids and seals	Microbiologically influenced corrosion	CO, CR, RE, SH, TH	L	H	Under the correct conditions, this mechanism could corrode seals and/or the cask body that affect containment. Little is known about whether the conditions are ripe for this mechanism to be operative.	2
Cask bolts	Corrosion, SCC, and embrittlement Thermal-mechanical degradation	CO, CR, SH, SR	L	H	While the level of knowledge is medium, failing or loosening bolts can, in the long term, compromise containment and the inert atmosphere in the canister These cladding degradation mechanisms are inoperative only if the inert atmosphere is maintained.	1
Neutron absorber	Thermal aging effects	CR	L	H#	Displacement of absorbers from their original positions can impact criticality safety in the event of canister breach and water ingress. Absorbers in welded canisters cannot currently be monitored or replaced.	2

Table 6-1. Summary of Regulatory Research Areas (continued)						
Component	**Degradation Phenomena**	**Regulatory Significance**	**Level of Knowledge**	**Overall Ranking**	**Reason for Ranking High**	**Research Priority**
Concrete Overpack	Multiple mechanisms	SH, SR	H	H	Concrete is the primary shielding for storage and transportation in most systems. Knowledge of the various degradation mechanisms is variable, but overall has been rated high assuming that monitoring can identify early signs of degradation. If analysis of monitoring methods shows that early degradation cannot be reliably detected, then evaluation of individual degradation mechanisms will have higher priority.	2
Crosscutting for multiple components	Drying	CO, CR, RE, SR	L	H	These crosscutting issues affect many components and mechanisms. Many of the other degradation mechanisms, listed previously, can be eliminated if the canister is dry, there is a good knowledge of the temperatures, and adequate monitoring is conducted. The monitoring task is to gain knowledge of the necessary monitoring intervals and adequacy of monitoring.	1
	Thermal calculations	CO, CR, RE, SR, TH	L	H		1
	Monitoring	CO, CR, RE, SR, TH	L	H		2

H=High
M=Medium
L=Low
CO=Confinement
CR=Criticality
RE=Retrievability
SH=Shielding
SR=Structural
[TH=Thermal]
*Rated high because it can indirectly affect criticality.
†High only if there is residual moisture after drying, otherwise low. Drying is being evaluated in a separate task.
‡Will only be high if stress generated from helium swelling of the fuel is shown to be operative.
§These rankings may change based on the results of work on pellet swelling.
¦While the level of knowledge is now medium, this is assigned high priority because it may impact criticality safety.
#Structural absorbers only

Source: NRC 2012a, Table 6-1 (pp. 6-2 to 6-4)

4.10. In Table 6-1, above, the level of knowledge of 23 degradation phenomena in the top two priorities was deemed by the NRC staff to be "low" in 18 cases, "medium" in four cases, and "high" in only one case.

4.11. The NRC Staff proposed to undertake a seven-year study of the phenomena identified in the *Draft Report on Technical Information Needs* (NRC 2012a). But funding previously designated for this research was redirected to preparation of this Draft GEIS.[65]

4.12. The NRC's failure to mention in the Draft GEIS the agency's own previously expressed concerns about the data gaps essential to understanding high burnup and MOX spent fuel and spent fuel with new cladding materials is an egregious technical omission. The missing data are critical to assessing the health and environmental impacts of spent fuel; gathering the data will need extensive additional research, which appears essential for a credible impact analysis including placing operationally meaningful uncertainty bounds on impacts. Without this basic information, the NRC has an inadequate foundation for scientifically sound predictive safety findings regarding the behavior of high burnup spent fuel in long-term storage conditions. The Draft GEIS made no attempt to place uncertainty bounds on impacts. On the contrary, as noted in paragraph 4.4 above, the one study that the NRC cited to justify its conclusion that impact accident consequences would be low explicitly did *not* consider uncertainties. The explicit reason cited in that study for not estimating uncertainties was that "the uncertainty of the database" was such that it "may introduce large errors…" in the analysis.[66] The data gaps relevant to long-term storage of high burnup fuel are much greater than those considered in the Pilot Study. The problem of putting bounds on the impacts is therefore much more serious, in light of the issues listed in Table 6-1 above. The NRC's failure to mention its own documented concerns about spent fuel characteristics seriously compromises the scientific integrity of the Draft GEIS.

C. NWTRB on High Burnup Spent Fuel

4.13. The NRC's failure to acknowledge the amount of information that is lacking regarding spent fuel behavior over the long-term is all the more disturbing in light of the fact that the Nuclear Waste Technical Review Board (NWTRB) has expressly acknowledged the dearth of information. In 2010, NWTRB reported with respect to spent fuel integrity and degradation:

> Only limited references were found on the inspection and characterization of fuel in dry storage, and they all were performed on low-burnup fuel after only 15 years or less of dry storage. *Insufficient information is available on high-burnup fuels to allow reliable predictions of degradation processes during extended dry storage, and no information was found on inspections conducted on high-burnup fuels to confirm the predictions that have been made.*[67]

[65] Vietti-Cook 2012
[66] NRC Pilot 2007, p. D-19, italics added
[67] NWTRB 2010, p. 11, italics added

Thus, NWTRB confirms that at present no U.S. data are available for high burnups (up to 62.5 GWd/MTU) for any of the NRC's storage scenarios, or for periods of storage anywhere comparable to the long time frame of hundreds of years that the NRC will have to consider in its EIS in one or more scenarios. Predictions, estimates or projections that the NRC may make of the effects of high burnup spent fuel storage, particularly over long-term periods, in its GEIS cannot be validated with scientific data or observations with presently available information. Such validation is essential for reliable and scientifically acceptable estimates of environmental and health impact of long-term storage and transportation.

4.14. The NWTRB also commented on the lack of information about interactions between different degradation mechanisms as well as the possible effect of high burnup on those interactions:

> These [degradation] mechanisms and their interactions are not well understood. New research suggests that the effects of hydrogen absorption and migration, hydride precipitation and reorientation, and delayed hydride cracking may degrade the fuel cladding over long periods at low temperatures, affecting its ductility, strength, and fracture toughness. *High-burnup fuels tend to swell and close the pellet-cladding gap, which increases the cladding stresses and can lead to creep and stress corrosion cracking of cladding in extended storage.* Fuel temperatures will decrease in extended storage, and cladding can become brittle at low temperatures.[68]

Hence, high burnup could possibly combine with other factors to create conditions that would result in severe, if not catastrophic, releases of radioactivity. This possibility must be studied.

4.15. Besides the NRC staff's 2012 proposal, the NWRTB has also proposed an extended research program to address the problem of the lack of data. The NWTRB research and development recommendations include:[69]

- Understanding the ultimate mechanical cladding behavior and fuel-cladding degradation mechanisms potentially active during extended dry storage, including those that will act on the materials introduced in the last few years for fabrication of high-burnup fuels
- Understanding and modeling the time-dependent conditions that affect aging and degradation processes, such as temperature profiles, in situ material stresses, quantity of residual water, and quantity of helium gas
- Modeling of age-related degradation of metal canisters, casks, and internal components during extended dry storage

[68] NWTRB 2010, p. 11, italics added
[69] The bullet points are quoted from NWTRB 2010, p. 14

- Inspection and monitoring of fuel and dry-storage systems to verify the actual conditions and degradation behavior over time, including techniques for ensuring the presence of helium cover gas
- Verification of the predicted mechanical performance of fuel after extended dry storage during cask and container handling, normal transportation operations, fuel removal from casks and containers, off-normal occurrences, and accident events
- Design and demonstration of dry-transfer fuel systems for removing fuel from casks and canisters following extended dry storage

As discussed above, a valid impact analysis requires collection of this information at least to a sufficient extent to make a central estimate of impacts and to put meaningful uncertainty bounds on those impacts.

D. View of other institutions on high burnup spent fuel

4.16. Other institutions have also analyzed the critical data gaps regarding high burnup degradation and its implications for storage, transport and disposal. For instance, a 2012 paper published by the National Academy of Engineering noted the following:

> Based on its assessment, the study board concluded that the technical basis for the spent fuel currently being discharged (high utilization, burnup fuels) is not well established and that the possibility of degradation mechanisms, such as hydriding, will require more study. The NWTRB recommended periodic examinations of representative amounts of spent fuel to ensure that degradation mechanisms are not in evidence.[70]

As concerning as the serious data gaps is the fact that as recently as 2012 neither the NRC nor the nuclear power industry had implemented the periodic examinations of spent fuel recommended by the NWTRB in 2010.

4.17. We are aware that an agency preparing an EIS can proceed even when important information is missing. But it is obliged to at least specify the important information and data gaps in any EIS and provide a discussion of the available evidence of the importance of the missing data. This is not only legally required under 40 CFR 1502.22, it is a basic element of scientific integrity and a part of the meaningful assessment of uncertainties. In case the data gaps are in critical areas and are so large that meaningful uncertainty bounds cannot be put on the impacts, the NRC should make that finding in its assessment of the problem. In this case, the NRC and other agencies know the data gaps well. Moreover, the NRC itself was on a path to remedy them at least to some extent over the coming years. But the Draft GEIS fails to discuss the consequences of a failure to include that information in its environmental impact analysis and on its conclusions.

[70] Kadak 2012, p. 30

E. Effect of Degradation of Storage Impacts

4.18. In Table 6-1 above (reproduced in paragraph 4.9 from the NRC Draft Report on Technical Information Needs (NRC 2012a)), all of the categories of "regulatory significance" of the 23 degradation phenomena – confinement, criticality, retrievability, shielding, structural, and thermal – are relevant to estimating environmental impacts, some of which could be serious. Such impacts could arise because some of the spent fuel could be degraded badly enough to result in (i) environmental releases during spent fuel inter-cask transfer and (ii) more severe impacts in cases of accidents.

4.19. For instance, in the case of microbiologically induced corrosion, Table 6-1 states that "little is known" about the conditions under which it "could corrode seals and/or the cask body that affect containment." Laboratory work and examination of spent fuel of different levels of burnup stored for long periods in spent fuel pools followed by long-term storage in dry casks is needed. It is only on this basis that models to extrapolate the environmental impacts of storage, followed by transportation (and in all but one scenario) disposal can be evaluated and extrapolated in a manner that can be scientifically validated.

4.20. As another example, consider phenomena listed near the top of Table 6-1: stress corrosion cracking, delayed hydride cracking, and low temperature creep. The NRC Draft Report on Technical Information Needs notes that "[a]ll three mechanisms depend on a source of stress that would come from pellet swelling. If the stress is not present, the mechanisms become benign. If operative, these mechanisms could increase the source term and increase cladding stress. The latter could affect containment, especially if other degradation processes have compromised the canister."[71] In other words, the NRC does not know at present whether corrosion of seals or the canister body may occur to an extent that compromises containment. Damage to canisters could set the stage for severe releases either during inter-cask transfer or because the canister itself degrades. This is an example of a case where the present state of knowledge is so low that the uncertainties appear to be so large as to be operationally meaningless.

4.21. High burnup fuels also tend to build up much thicker levels of oxide during the in-reactor period as well as much higher levels of hydrogen in the cladding. Figure 2 below shows that the typical increase in outer oxide layer thickness increases from about 20 microns at 30 GWd/MTU to about 100 microns at about 62 or 63 GWd/MTU at discharge from the reactor.[72] Moreover, the spread in the oxide layer thickness increases with burnup, indicating that some fraction of fuel rods may be at a much greater risk of failure.

4.22. Figure 3 shows that the maximum wall thickness hydrogen content increases from 200 ppm to 800 ppm at discharge over approximately the same burnup range as in Figure 2. In both cases the variability is also much greater at the higher burnup. For instance, Figure 3 shows oxide layer thicknesses for a burnup of 30 GWd/metric ton ranging from roughly 12 microns to (at most) 35 microns – a spread of 23 microns. At 63 GWd per metric ton the thickness range from

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[71] NRC 2012a, p. 6-2

[72] The range of blue data points at about 63 GWd/MTU is from about 70 microns to about 130 microns. (NWTRB 2010, Figure 20 (p.56))

about 70 microns to 130 microns, a spread of 60 microns. In fact these data show that the *variability* in oxide layer thickness at 63 GWd/MT burnup is almost *twice as large as the maximum* thickness at 30 GWd/MT. The oxidation and hydriding in-reactor data point to (i) a higher probability of failure and (ii) more severe failures in some fraction of the rods in cases when failures occur upon prolonged spent fuel pool and dry storage for high burnup spent fuel. High oxide and hydrogen levels in cladding create a host of vulnerabilities in spent fuel, including increased brittleness upon drying, high hoop stresses, and other phenomena that could cause fuel to fail – that is, to develop cracks and fissures that are significant enough to cause release of fission products. Reasonable confidence in the integrity of spent fuel after long periods of storage would not only require examination of typical high burnup fuel rods but also the ones at the higher levels of initial degradation that are clearly indicated by currently available information of in-reactor performance.

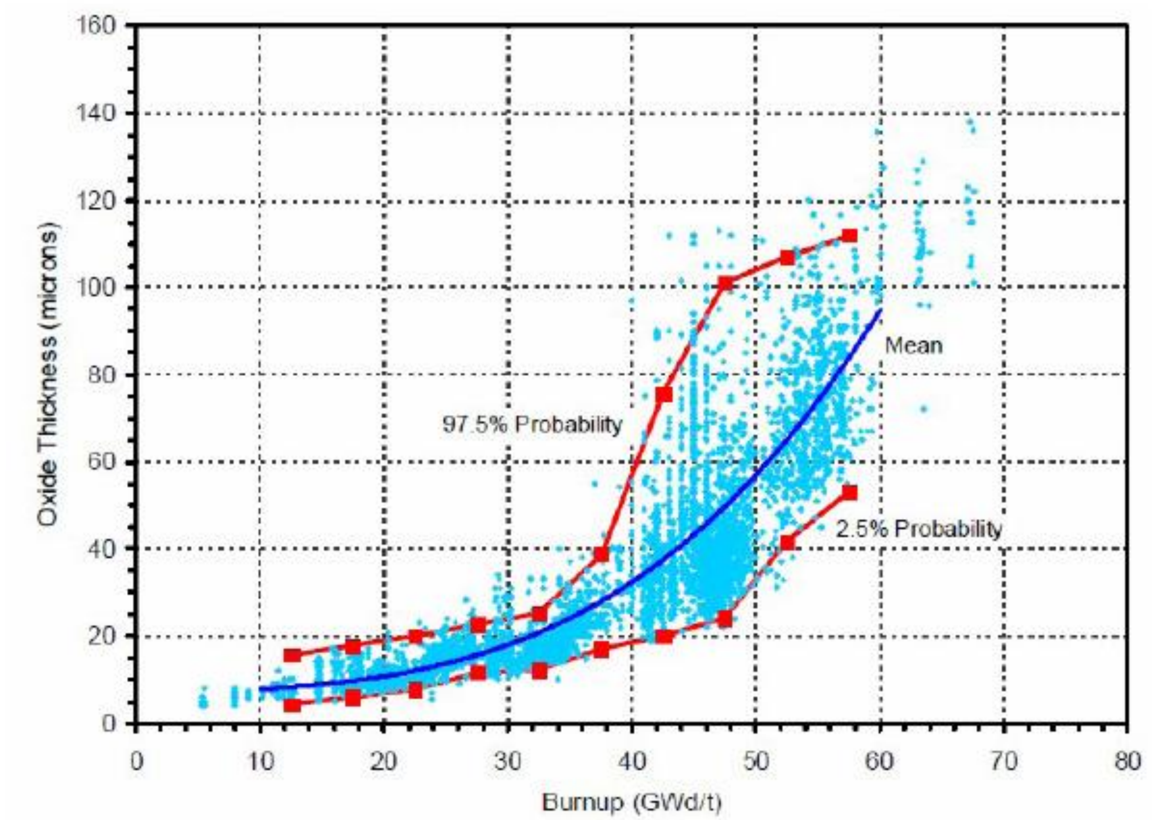

Figure 2. Cladding outer surface oxide thickness layer versus rod average burnup (Reproduced from NWTRB 2010, Figure 20 (p.56))

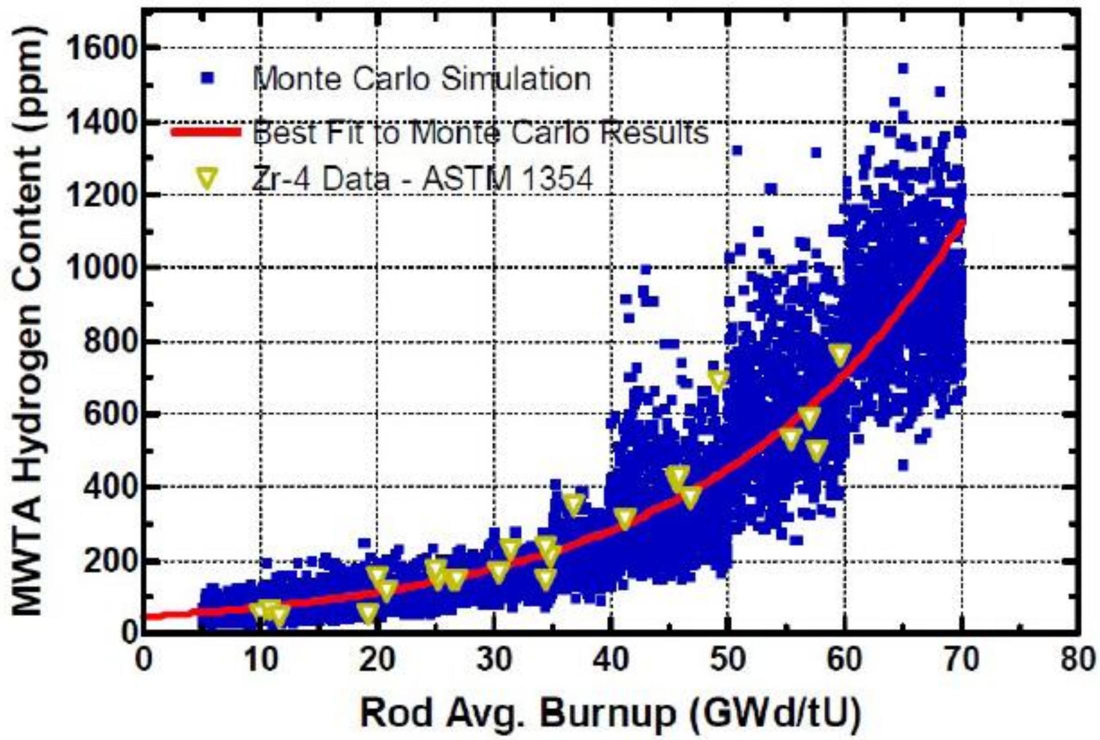

Figure 3. Maximum Wall Thickness Average Hydrogen Content in Low-Tin Zircaloy-4 Cladding (Reproduced from NWTRB 2010, Figure 21 p.56))

4.23. The Draft GEIS cites an at-reactor dry storage facility at Surry as a successful example of dry storage.[73] The spent fuel from Surry that was examined after about 15 years of dry storage was found upon inspection to be functionally undamaged.[74] Hence one can safely assume that the spent fuel was also functionally undamaged at the time of transfer from wet to dry storage. The results of the Surry study are unlikely to be applicable to fuel that has developed some damage during irradiation, for instance, due to higher burnup, or during spent fuel pool storage. Lack of damage during much more prolonged dry storage of high burnup fuel also cannot be assumed based on the Surry study. The NWTRB has issued the following caution about prolonged spent fuel pool storage:

> Cladding may already have some small defects like tiny holes or hairline cracks, internal and external corrosion that has decreased the original metal wall-thickness, absorbed hydrogen, and hydride precipitation; however, it is very rare that new defects are detected while in the pool. Significant cladding defects can be detected during wet storage by monitoring stack off-gas for fission product gas leaks; if leaks are found, then assemblies are further inspected and breached fuel-rods are canned if necessary. Generally, a visual inspection is made of assemblies to identify fuel assemblies that may need to be classified as damaged and require

[73] NRC 2013a, p. B-12
[74] Einziger et al. 2003, p. ix

> special handling. If the cladding is functionally undamaged, there is an insignificant risk of expected fuel oxidation [at the time of transfer to dry storage]. Given undamaged cladding and the visible transfer of assemblies into and out of wet storage, the fuel-assembly containment criterion is deemed satisfied. Thus, during wet pool storage, used fuel is not expected to experience significant deterioration before dry storage. *If pool storage of fuel is continued for an extended period, it will be necessary to assess and evaluate the effects on intact or damaged fuel*.[75]

Though Draft GEIS assumes that pool storage could continue for periods approaching 140 years (the first spent fuel discharged during 80 years of total licensed operation, plus 60 years of post-operating license storage), it has not included any uncertainty analysis relating to impacts of damage that may occur in some fraction of the spent fuel during such prolonged storage.

F. Failed Fuel

4.24. Fuel failure occurs when there is a rupture in the fuel cladding, allowing fuel pellets direct contact with the environment around the fuel, the reactor coolant, spent fuel pool water, the canister environment, or the general environment during inter-cask transfer of failed fuel. If detected during cask loading, failed fuel is normally put in a "can," which is a special sleeve, prior to loading into the cask. But if failure occurs after dry storage commences, some fuel pellets could be exposed to the environment during transfer. The NRC has refused to state how it would transfer failed spent fuel. It plans to figure it out then, as noted in paragraph 4.27 below.

4.25. In the NWTRB study described above, NWTRB identified hydriding, creep, and stress corrosion cracking to be "[t]he most significant potential degradation mechanisms affecting the fuel cladding during extended storage."[76] These phenomena can lead to "failed fuel" under certain conditions.[77] The Draft GEIS concludes that these phenomena are unlikely to cause significant problems in the "short-term."[78] With respect to long-term storage, the NRC claims to be ignorant of any studies "that would cause it to question the technical feasibility of continued safe storage of spent fuel in dry casks."[79] But Table 6-1 of the Draft Study of Technical Needs admits that the level of knowledge regarding galvanic corrosion, stress corrosion cracking, low-temperature creep, and propagation of existing flaws is "low"; and that knowledge of delayed hydride cracking is only "medium." The NRC's amnesia regarding its own study undermines the credibility and integrity of the Draft GEIS.

4.26. The only explicit mention of failed fuel in the Draft GEIS is in the context of spent fuel pool leaks:

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[75] NWTRB 2010, p. 60, italics in the original
[76] NWTRB 2010, p. 10
[77] NRC 2012a, pp. A1-6 and A1-7
[78] NRC 2013a, p. B-13
[79] NRC 2013a, p. B-13

> Impacts from spent fuel pool leakage occur from radionuclide contaminants present in spent fuel pool water. The sources of radionuclide contaminants in spent fuel pool water are activation products and fission products. Activation products are elements formed from the neutron bombardment of a stable element and fission products are elements formed as a byproduct of a nuclear reaction and radioactive decay of other fission products. *The sources of activation products are corrosion and wear deposits (including corrosion films on the fuel bundle surfaces)*. Fission products come from bundles with rods that failed in-reactor or from intact bundles that adsorbed circulating fission products.[80]

This is grossly insufficient, since the principal long-term risks are likely to arise after prolonged storage has resulted in serious fuel degradation of some fraction of the fuel rods, notably in the case of high burnup spent fuel.

4.27. The NRC's failure to address the effects of failed fuel on safety and environmental risk is all the more remarkable in the context of the NRC's own admission that it does not yet know how it will transfer such failed spent fuel. The NRC has no experience in transferring failed fuel from one cask to another. By NRC's own admission, it has not even developed the procedures to do so, as illustrated by the following 2001 decision by the NRC's technical staff:

> *The NRC staff believes that the petitioner has identified a valid concern regarding the potential recovery of fuel assemblies that unexpectedly degrade during storage***.** However, in this unlikely event, the NRC staff has concluded that there is reasonable assurance that a licensee can safely unload degraded fuel or address other problems. This conclusion is based on the NRC's defense-in-depth approach to safety that includes requirements to design and operate spent fuel storage systems that minimize the possibility of degradation; requirements to establish competent organizations staffed with experienced, trained, and qualified personnel; and NRC inspections to confirm safety and compliance with requirements. The NRC staff finds acceptable these procedures for detecting degraded fuel through sampling and, on the basis of the sample results, the implementation of appropriate recovery provisions that reflect the ALARA (as low as is reasonably achievable) requirements. The NRC staff's acceptance of this approach is based on the fact that the spent fuel storage cask can be maintained in a safe condition *during the time needed to develop the necessary procedures and to assemble the appropriate equipment before proceeding with cask unloading.* The NRC staff also relies on the considerable radiological safety experience available in the nuclear industry in its assessment that appropriately detailed procedures can be prepared for the specific circumstances in a timely manner.[81]

While this "kicking the can down the road" may have been a legally valid response to the petition, it can no longer be sustained in the context of the waste confidence GEIS. The issue is material to environmental impacts, which the NRC is obliged to estimate.

[80] NRC 2013a, p. E-10, italics added

[81] NRC 2001, p. 9058, italics added

4.28. The NRC also has no basis in data or experience in estimating how much additional damage could be done to failed fuel by transferring it between casks. This would apply even to damaged medium burnup fuel stored for short or moderate periods of time (up to two or three decades) in dry casks. It is *a fortiori* true of high burnup spent fuel that has been stored for many decades or even a few hundred years, given the considerations about such spent fuel discussed in the rest of this section.

4.29. Indeed, it should be noted in this context, that no spent fuel bundle, damaged or not, has ever been transferred from one dry cask to another. Further, while the Draft GEIS postulates a Dry Transfer System for fuel inspection, repackaging and transfer, such a facility has never been built in the United States. And as discussed in paragraph 4.27, the NRC even refuses to say how it would handle and repackage failed fuel. This makes the lack of discussion of the impacts of the transfer of failed spent fuel bundles even more problematic since the NRC lacks sufficient empirical basis for estimating the probabilities and consequences of the spread of radioactivity during transfers in the normal case.

4.30. In failing to address the issue of failed spent fuel inter-cask transfers, the NRC has ignored the fact that failed spent fuel bundles are already stored in dry casks, but have never had to undergo inter-cask transfers. For instance, there are 95 failed spent fuel bundles stored in 15 dry casks at San Onofre Nuclear Generating Station alone.[82]

4.31. As discussed above, NWTRB has proposed an extended research program to address the lack of data regarding spent fuel characteristics. It is also important to have dry storage performance data on the newer cladding materials that have been developed to enable high fuel burnup, which is a relatively recent practice (since about the turn of the century[83]). There are practically no such data. Indeed, even the research has been focused mainly on in-reactor behavior of high burnup fuels rather than on degradation during prolonged storage:

> Because of the more severe conditions created by burning fuel to higher levels, new cladding materials have been developed for in-reactor service and employed by vendors such as Areva's M5 alloy, Westinghouse's optimized ZIRLO, Siemen's Duplex, and Mitsubishi's M-MDA material. Currently there is much more behavioral data available on Zircaloy-2 and -4 cladding, but work is ongoing to study the new cladding materials (mostly proprietary). From the limited information reviewed it appears new cladding research is focused primarily on in-reactor behavior and not behavior during extended storage.[84]

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[82] NRC 2011b, p. 11
[83] NWTRB 2010, p. 72
[84] NWRTB 2010, p. 52

G. Other Forms of Spent Fuel – MOX Spent Fuel and Stainless Steel Spent Fuel

4.32. The United States is building a MOX plant to convert weapons-grade plutonium into commercial reactor fuel. There is no significant experience with irradiation of such MOX fuel in a commercial reactor in the United States. Only lead test assemblies have been irradiated. There is essentially no experience with storage of commercial MOX spent fuel in the United States in wet or dry storage for any length of time. France, which has the most experience with MOX spent fuel, stores it in pools and has no dry storage. The draft GEIS simply assumes away the problem of MOX spent fuel with the following statement:

> Because the MOX fuel that would be generated at the Mixed Oxide Fuel Fabrication Facility is substantially similar to existing light water reactor fuel and is, in fact, intended for use in existing light water reactors in the United States, MOX fuel from this project is within the scope of this draft GEIS.[85]

Contrary to the claim in the Draft GEIS, MOX fuel is decidedly *not* "substantially similar to existing light water reactor fuel." In the former the fissile material is plutonium, which has different nuclear characteristics (a smaller delayed neutron fraction, for instance) than current low-enriched uranium reactor fuel. Even more importantly for the present purposes, the characteristics of the spent fuel will be different. For instance, uranium spent fuel from a PWR with initial 4.25 percent enrichment and burnup of 50 GWd per metric ton would have about 1 percent plutonium isotopes in it at discharge, including about half-a-percent plutonium-239. For the same burnup MOX fuel would typically have 8.46 percent total plutonium to start with. The spent fuel from a PWR would have about five times as much total plutonium and about three-and-half-times as much plutonium-239.[86]

4.33. In the example provided (50 GWd per metric ton burnup in a PWR), the MOX spent fuel would have about six-and-half-times the amount of plutonium-241 as the uranium spent fuel. Plutonium-241 decays into americium-241 relatively rapidly with a half-life of just 14.4 years. Amercium-241 has a half-life of 432 years.[87] Unlike plutonium-239 and plutonium-241, americium-241 is a powerful gamma radiation emitter; it would pose special problems during spent fuel transfer, long after the main gamma-emitting fission product, cesium-137 (half-life about 30 years), would have decayed away. These problems associated with americium-241 gamma radiation dose would extend to post-accident recovery in case of release of radionuclides from the spent fuel.

4.34. It stretches credulity that the NRC staff is not aware of these critical differences that would make a significant difference between impacts of MOX spent fuel and uranium spent fuel. In

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[85] NRC 2013a, p. 2-8

[86] IAEA 2007, Tables 18 and 25, pp. 65 and 70 respectively. The MOX fuel in this case started with reactor-grade plutonium. MOX fuel made with weapon-grade plutonium would have a somewhat different mixture of plutonium isotopes in the spent fuel, but it would, in any case, be much higher than the total plutonium in uranium dioxide spent fuel.

[87] Properties of radionuclides, including half-lives and dose conversion factors can be found in FGR 13 CD 2002.

any case, the Draft GEIS assertion that the two are substantially similar is wrong. A specific impact analysis is needed for MOX spent fuel.

4.35. Stainless steel fuel cladding was used as fuel cladding early in the history[88] of U.S. commercial reactors. By 1994, only one reactor had any stainless steel clad fuel in its core.[89] By 1992, a total of 679 metric tons spent fuel (uranium heavy metal content) had been generated from the stainless steel clad fuel.[90] Further, the use of stainless steel cladding was discontinued partly because in-reactor degradation of stainless steel cladding. For instance, the stainless steel cladding in the Connecticut Yankee reactor "experienced a number of fuel element failures" between 1977 and 1980, even though it had performed well in this regard prior to that time.[91] The degradation characteristics of stainless steel fuel are different than zircaloy fuel and needed to be explicitly considered in the Draft GEIS. The Draft GEIS catalogs the amount of stainless steel spent fuel but does not discuss the failed fuel or its transfer from one dry cask to another. It does not discuss whether accidents involving such failed fuel would have more or less severe consequences than failed zircaloy-clad fuel.

5.0 CRITICALITY RISKS AND HIGH BURNUP SPENT FUEL

5.1. The Draft EIS has considered only criticality accidents in spent fuel pools.[92] However criticality is an issue for dry cask storage and transport, notably for high burnup fuel as noted in NUREG/CR-6835.

> Irradiation of nuclear fuel to high-burnup values increases the potential for fuel failure during normal and accident conditions involving transport and storage. The objective of this work is to investigate the consequences of potential fuel failure on criticality safety and external dose rates for spent nuclear fuel (SNF) storage and transport casks, with emphasis on high-burnup SNF. Analyses were performed to assess the impact of several damaged/failed fuel scenarios on the effective neutron multiplication factor *(k_{eff})* and external dose rates. The damage or failure was assumed to occur during use in storage or transport, particularly in an accident. Although several of the scenarios go beyond credible conditions, they represent a theoretical limit on the effects of severe accident conditions. Further, the results provide a basis for decision making with regard to failure potential and a foundation to direct future investigations in this area.[93]

5.2. As the abstract quoted above in paragraph 5.1 notes, the study explored the theoretical limit of criticality risks for high burnup fuel. The fuel was assumed to have been in storage for 20 years. The Draft GEIS could have used these calculations to provide bounding calculations on

[88] EIA 1994, p. 23
[89] EIA 1994, p. 23
[90] EIA 1994, Table 9 (p. 27) and Table 10 (p. 28)
[91] Rivera and Meyer 1980, p. 1
[92] NRC 2013a, pp. 4-69 - 4-70
[93] NUREG/CR-6835 (2003), p. iii

doses to the public and to workers in the event of an accident approaching the limits described. But it did not consider criticality risks associated with dry storage at all.

5.3. NUREG/CR-6835 considered risks only from uranium spent fuel with various enrichment levels up to 5 percent.[94] It did not consider MOX spent fuel. As noted in paragraph 4.32 and 4.33, MOX spent fuel contains several times more plutonium-239 than uranium spent fuel with the same burnup. Since the Draft GEIS includes MOX spent fuel in its scope, it should address criticality risks of such spent fuel in dry storage and during transportation as well.

6.0 THE DRAFT GEIS FLIES IN THE FACE OF FACTS, HISTORY, AND COMMON SENSE BECAUSE IT ASSUMES INDEFINITE RELIABILITY OF INSTITUTIONAL CONTROLS

6.1. One of the Draft GEIS's greatest defects is its assumption that institutional controls of the most active sort will persist essentially forever, which in the context of spent fuel is tens or hundreds of thousands of years:

> Institutional controls, i.e., the continued regulation of spent nuclear fuel, will continue. This assumption avoids *unreasonable speculation regarding what might happen in the future regarding Federal actions* to provide for the safe storage of spent fuel. Although government agencies and regulatory safety approaches can be expected to change over long periods of time into the future, the history of radiation protection has generally been towards ensuring increased safety as knowledge of radiation and effectiveness of safety measures has improved. For the purpose of the analyses in this draft GEIS, the NRC assumes that regulatory control of radiation safety will remain at the same level of regulatory control as currently exists today.[95]

6.2**.** The Draft GEIS goes so far as to say that it is "remote and speculative" to assume that the U.S. government and its agencies will not maintain control indefinitely. This is because "a dry storage facility is typically a visible surface structure requiring active maintenance and security, making loss of institutional control so unlikely that it is a remote and speculative occurrence."[96]

6.3. Specifically the following are implicit or explicit in the NRC's assumption of institutional control for the indefinite future:

- The NRC will continue to regulate its licensees for tens of thousands of years.
- Corporations holding reactor licenses today and post-closure nuclear material possession licenses after the expiry of reactor operation licenses would continue to exist for tens of thousands of years.

[94] NUREG/CR-6835 (2003), p. 3
[95] NRC 2013a, pp. 1-14 - 1-15, italics added
[96] NRC 2013a, footnote 2, p. 1-15

- Congress will appropriate funds each year for site security and every hundred years for new casks and cask transfer facilities essentially forever.
- Congress will increase appropriations for site security after a couple of hundred years when the radiation barrier is mostly decayed away and spent fuel is more vulnerable to theft.
- Congress will appropriate funds even though there may be no more revenues flowing from reactor operation.
- State emergency planning structures will remain in place.
- Major upheavals will not disrupt society so as to make appropriations impossible even if the U.S. Government continues to exist.

6.3. The NRC may intend to use the phrase "remote and speculative" to avoid its legal obligation to analyze the impacts of the loss of institutional control. But the Draft GEIS has failed to recognize that simply throwing the phrase at the problem does not make loss of institutional control "remote and speculative" in legal or physical reality. On the contrary, it is the Draft GEIS's contention that institutional control will be maintained essentially forever to the required degree that is remote and speculative.

6.4. Given U.S. and world history, it is not unreasonable to assume that the endurance of institutions to the degree required in paragraph 6.3 will persist for a 100 years. This is a common assumption about institutional control that is factually defensible, though even that is not without caveats (see paragraph 6.6 below).

6.5. For example, empires usually fade in a few centuries. During such periods governments and societies often suffer tremendous upheavals and internal institutional changes. The NRC's assumption of institutional control is so sweeping that it not only requires the U.S. government to endure for tens of thousands of years but that its functions and institutions remain operative and vigilant.

6.6. Consider some elementary facts close to home. The half-life of plutonium-239 is more than 24,000 years. The U.S. government has existed for less than one percent of that time. In that period of time, the United States has suffered a Civil War during which it did not have a unified government. Indeed, it had two governments, with two budgets, two armies, two navies, and two currencies. The United States has also been in two world wars in less than 100 years. It has suffered a devastating terrorist attack just over a decade ago on September 11, 2001, that could have targeted a nuclear power plant. Even closer in time was the federal government shutdown in the first half of October 2013; there was a near-default on the U.S. sovereign debt in the same month. There have been a dozen federal government shutdowns since about 1981.[97] During the October 2013 federal government shutdown, most of the NRC was shut down. Some waste management functions, even for "visible" facilities almost came to a halt. For instance, the Fernald Preserve, which includes a large visible mound of radioactive waste from the Fernald uranium plant that was part of the nuclear weapons complex was closed. Had the government shutdown lasted much longer, the pump and treat operations that are a mandated part of water

[97] As cataloged in Wikipedia at http://en.wikipedia.org/wiki/Government_shutdown_in_the_United_States.

quality objectives, would have come to a halt.[98] The NRC, without any analysis of these facts, has ruled it remote and speculative that the necessary degree of institutional controls will exist for many half-lives of plutonium-239. In fact, the Draft GEIS puts no upper bound on the time for which such controls will exist.

6.7. It is to be noted that there were no federal government shutdowns before 1981. There have been a dozen since then.[99] This points to the need for a serious analysis of the reliability of federal government funding even over much shorter periods than the funding for millennia assumed in the Draft GEIS. Specifically, the short-term time frame of 60 years beyond the operating license life of "a" reactor needs to be considered, especially as it could be any reactor past, present, or future. It is also important to consider the "long-term" timeframe of 100 years beyond the "short-term." The federal government will have to continue to appropriate funds each year to compensate for its failure to fulfill its contracts with nuclear utilities to begin taking spent fuel from them starting on January 31, 1998. The discontinuities in the federal government's functioning and the uncertainties surrounding budgetary processes require specific analysis in the Draft GEIS in the context of its assumptions about institutional longevity.

6.8. In view of the above-mentioned historical facts and current events, the attempt of the Draft GEIS to use the legalism of the phrase "remote and speculative" to avoid considering the consequences of the loss of institutional control is ridiculous, bizarre, and even surreal. Given the fact, an assumption of institutional control extending to millennia with the stringent set of controls required for spent fuel management, such as those listed in paragraph 6.3 above, is entirely remote, unreasonable, and speculative.

6.9. Many existing authorities, including the National Research Council, have concluded that long-term waste and remediation policy should be based on the assumption that institutional controls will eventually fail. In reviewing Department of Energy cleanup plans the National Research Council stated the following:

> The Committee on Remediation of Buried and Tank Wastes finds that much regarding DOE's intended reliance on long-term stewardship is at this point problematic….
> […]
> Other things being equal, **contaminant reduction is preferred to contaminant isolation and imposition of stewardship measures whose risk of failure is high.**
> […]

[98] Crawford 2013. Personal email communication from Lisa Crawford, Fernald Residents for Environmental Safety and Health, October 7, 2013. "Folks, the Fernald Preserve is CLOSED due to the Gov. Shut Down -- no big deal really except -- if this goes on much longer it will then begin to affect the pump and treat of the aquifer which is mandated by the OEPA & USEPA and DOE. The site is telling me that it can go about a month and then it's down to little or nothing or shut off. That could be a disaster. Since most of the site is contracted out to Stoller Co. -- those folks are still on the job, but the site is closed. Crazy if you ask me. Lc"

[99] Wikipedia: http://en.wikipedia.org/wiki/Government_shutdown_in_the_United_States. Accessed on November 8, 2013.

> *The committee believes that the working assumption of DOE planners must be that many contamination isolation barriers and stewardship measures at sites where wastes are left in place will eventually fail, and that much of our current knowledge of the long-term behavior of wastes in environmental media may eventually be proven wrong. Planning and implementation at these sites must proceed in ways that are cognizant of this potential fallibility and uncertainty.*[100]

6.10. Indeed, even the NRC itself put a time limit on institutional controls in its low-level waste disposal regulations at 10 CFR 61.7(b)(4) and (b)(5). These regulations effectively assume that active controls (as defined in 10 CFR 61.2) will fail after 100 years. Intruder barriers, which are passive controls, are assumed in the rule to last at most 500 years. NRC's low-level waste regulations are consistent with EPA regulations for managing and disposing of high-level waste and transuranic waste. [101] The Draft GEIS has not taken account of the technical basis for these regulations.

6.11. It is to be noted that Department of Energy's (DOE) Yucca Mountain Final EIS "No-Action Scenario 1" examined the case of continued institutional control assumed for 10,000 years as well as an alternative "Scenario 2" in which that control was lost after 100 years.[102] Similarly, regulations of the EPA for "Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" at 40 CFR 191.14 mandate that "active institutional controls" be limited to 100 years after disposal. Since dry storage can be licensed after reactor closure, the 100 years may start after expiry of the dry storage license. EPA's regulation relating to uranium mill tailings, 40 CFR 192.02, requires active management measures for 200 years and, if feasible, up to 1,000 years. But, unlike the Draft GEIS, active measures are not assumed to be feasible beyond 1,000 years.

6.12. The Draft GEIS notes that the EPA allows for "permanent" institutional control under some Superfund scenarios and that DOE has also assumed perpetual control of portions of the Savannah River Site.[103] However, just because these agencies assume perpetual control does not relieve the NRC from its obligation under NEPA to examine the environmental impacts of an eventuality that is reasonably foreseeable in case a repository is not developed. For instance, the DOE has assumed perpetual control under a variety of circumstances. However, the DOE also did consider loss of institutional control in its Yucca Mountain EIS, as noted below in paragraph 6.13. Similarly, the DOE considered and evaluated the loss of institutional controls in its EIS relating to the Waste Isolation Pilot Plant (WIPP),[104] which is cited in the Draft GEIS.[105]

6.13. The Yucca Mountain EIS recognized that "[h]istory is marked by periods of great social upheaval and anarchy followed by periods of relative stability and peace.

[100] NAS-NRC 2000, pp. 3 and 5, original italics; bold added.
[101] 40 CFR 191.14(a), 2011
[102] DOE 2002, Vol. I, pp. 2-70 – 2-72
[103] NRC 2013a, footnote 2, pp. 1-14 and 1-15
[104] DOE 1997, p. 4-33
[105] NRC 2013a, footnote 2, pp. 1-14 and 1-15

Throughout history, governments have ended abruptly, resulting in social instability, including some level of lawlessness and anarchy."[106]

6.14. The main barrier preventing theft of spent fuel in case of a loss of institutional control is external radiation from cesium-137. This radiation barrier decays with a half-life of about 30 years and is therefore less and less effective after one to two centuries. After time of that order of magnitude, the obstacles to theft of spent fuel bundles extracted from the casks would be far lower – low enough to present a real proliferation problem. Every metric ton of spent fuel (heavy metal content) contains more than enough plutonium to make a nuclear weapon. Extracting the plutonium from the spent fuel would also be greatly simplified due the loss of almost all of the radiation barrier. It is therefore essential for the GEIS to evaluate the potential for theft of spent fuel in case of a loss of institutional control and the potential impacts of the possible resultant proliferation.

6.15. I am not arguing here that the NRC should not evaluate a case where institutional control would be maintained for a prolonged period. If the NRC wants to examine a remote and speculative case, it is free to do so. But that cannot be the basis for scientifically valid conclusions about environmental impacts. The NRC is obligated under NEPA to consider the environmental impacts in case of a loss of institutional control because, contrary to the assertion in the Draft GEIS, such an eventuality is not "remote and speculative" for the extremely long periods in question. Rather, it is reasonably foreseeable, given the facts of history, though the exact process is not and though one might wish otherwise.

7.0. ESTIMATION OF IMPACTS OF INDEFINITE STORAGE IN THE ABSENCE OF INSTITUTIONAL CONTROLS.

7.1. As discussed in Section 6 above, it is essential for the NRC to evaluate the environmental impacts of indefinite storage in case of a loss of institutional control. These impacts are likely to be catastrophic under a variety of circumstances.

7.2. The NRC has cited the catastrophic impacts in case of loss of institutional control that were found in the Yucca Mountain EIS:

> DOE's approach to the loss of institutional controls at a dry cask storage facility was provided in its Yucca Mountain EIS (DOE 2008). In its analysis, DOE found that the loss of institutional controls resulted in catastrophic impacts for several resource areas.[107]

[106] DOE 2002, Vol. II, Appendix K, p. K-35
[107] NRC 2013a, footnote 2, pp. 1-14 and 1-15

7.3. The 2008 Yucca Mountain EIS, which is a supplement to the DOE's 2002 Yucca Mountain EIS (DOE 2002), estimates that in case of loss of institutional control there would be 1,000 "latent" cancer fatalities in the first 10,000 years and a hundred times more in the period up to a million years after that – though it considers the latter figure to be very uncertain. The impact in the longer time frame is estimated to be the result of "the unchecked deterioration and dissolution of the materials." The document describes these impacts as "catastrophic."[108]

7.4. While I agree with DOE 2008 that the impacts of the loss of institutional control in case of indefinite onsite storage would be catastrophic, I also note that the DOE *deliberately underestimated the impacts in this scenario*. It did so because it did not want to overstate the relative environmental benefits of deep geologic disposal at Yucca Mountain, its preferred alternative, compared to the no-action alternative. Without any implications as to the overall merits of the Yucca Mountain EIS or the DOE's license application, DOE's approach to the loss of institutional control was reasonable. If the underestimated impacts of the no action alternative are much greater than those of the preferred action, it allows a technical case to be made for the preferred action, which was, after all, the goal of that EIS. However, for the waste confidence GEIS, such an underestimation is not permissible, since the court has explicitly asked it to estimate the impacts in case a repository never becomes available. This requires as full and complete estimation of impacts as reasonably as possible.

7.5. I provide some examples of impacts that were ignored in the Yucca Mountain EIS loss of institutional control scenario that must be included in the waste confidence GEIS.

7.6. The DOE "did not attempt to quantify adverse health impacts from chemical toxicity of the waste forms (principally uranium dioxide and *borosilicate glass*) that could occur within the exposed population."[109]

7.7. The DOE did not quantify some of the most critical ecosystem and economic impacts of the deterioration of containers in storage after institutional control is lost, but noted the following:

> Under Scenario 2 [no institutional control after 100 years], more than 20 major waterways of the United States (for example, the Great Lakes, the Mississippi, Ohio, and Columbia rivers, and many smaller rivers along the Eastern Seaboard) that currently supply domestic water to 30.5 million people would be contaminated with radioactive material. The shorelines of these waterways would be contaminated with long-lived radioactive materials (plutonium, uranium, americium, etc.) that would result in exposures to individuals who came into contact with the sediments, potentially increasing the number of latent cancer fatalities.[110]

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[108] DOE 2008, p. S-51. We note here that in the 2002 EIS to which DOE 2008 is a supplement, the DOE estimated latent cancer fatalities in the first 10,000 years as 3,300. (DOE 2002, Vol. II, Appendix K, p. K-28)

[109] DOE 2002, Vol. I, p. 7-35, emphasis in original

[110] DOE 2002, Vol. II, Appendix K, p. K-29

7.8. When food pathways other than drinking water are considered, the DOE estimated that the radiation doses and, hence, fatalities would triple.[111] The impact of dispersed waste on vast aquifers, areas of land, and the country's most important rivers that could not be used again because of contamination was not explored in detail. The Fukushima accident that began on March 11, 2011 has shown that the economic, social, and ecological impacts of the spread of radiation contamination are far larger than indicated by a narrow view of latent cancer fatalities alone.

7.9. The Yucca Mountain EIS was completed before any physical evaluation of high burnup fuel that had been in dry storage for any length of time. This aspect needs to be included in the waste confidence GEIS.

7.10. Climate change uncertainties were not evaluated in the Yucca Mountain EIS No-Action Alternative.

7.11. In conclusion, the impacts from a failure of institutional controls are likely to be catastrophic – much more so than estimated in the Yucca Mountain EIS. Since a failure of institutional controls over millennia is reasonably foreseeable, given the facts of world and U.S. history, the NRC must realistically analyze those impacts.

8.0 THE DRAFT EIS DOES NOT SUPPORT THE NRC'S PROPOSED FINDINGS REGARDING THE FEASIBILITY AND SAFETY OF DEEP GEOLOGIC DISPOSAL OF SPENT FUEL.

8.1. In proposed 10 CFR 51.32(a)(2)(ii), the NRC proposes to make the following finding:

> (2) The analysis in NUREG-2157 supports the Commission's determinations that it is feasible to:
> …
> (ii) have *a* mined geologic repository within 60 years following the licensed life for operation of *a* reactor.[112]

8.2. The NRC's proposed finding that it is feasible to "have *a* mined geologic repository within 60 years following the licensed life for operation of *a* reactor"[113] is so vague and incomplete that it is essentially meaningless. It is also unsupported in a number of respects. Specifically, the proposed finding is about "a mined repository" – the indefinite article is used. Will it have enough capacity to accommodate all spent fuel from all reactors? Could it safely accommodate all types of spent fuel, including failed high burnup spent fuel? The proposed rule does not say.

[111] DOE 2002, Vol. II, Appendix K, p. K-29 and K-32
[112] NRC 2013b, p. 56804; italics to the indefinite article "a" added in two places
[113] NRC 2013b, p. 56776, italics added to both indefinite articles

8.3. The failure of the proposed rule to assure that sufficient repository capacity will be available is contrary to the prior waste confidence assertion in the 2008 version of 10 CFR 51.23, which stated:

> Further, the Commission believes there is *reasonable assurance* that *at least one* mined geologic repository will be available within the first quarter of the twenty-first century, and *sufficient repository capacity* will be available within 30 years beyond the licensed life for operation of any reactor to dispose of the commercial high level waste and spent fuel originating in such reactor and generated up to that time.[114]

8.4. The proposed rule's assertion of the feasibility of a repository does not guarantee that there will be a repository with sufficient capacity to accommodate all the spent fuel envisioned. Moreover, the Draft GEIS proposes no upper limit to spent fuel. On the contrary, it includes reactors beyond the existing ones, including new reactor designs such as small modular reactors. The NRC's conclusion that "a" repository is feasible does not provide any assurance that spent fuel from all reactors covered by the Draft GEIS will find space in it.

8.5. Every geologic location would have some limit to the amount of spent fuel it can hold due to considerations such as the faults running through the site, natural resources availability, etc. Yucca Mountain, for instance, had a legal limit of 70,000 metric tons (equivalent) of commercial and military waste. Proponents of disposal there argued that the technical limits could be much greater. But no one, so far as I am aware, has asserted that there was no technical limit. Such a limit was considered, for instance, in a paper by Professor Per Peterson of the University of California at Berkeley in the context of a prospective increase in nuclear reactor orders in 2003. He argued that the technical capacity of Yucca Mountain could be increased.

> This [analysis] suggests a minimum "technical" site capacity of approximately 75 x 2,000 = 150,000 MT of spent fuel, with a maximum site capacity greater by perhaps a factor of two or three. *Thus any substantial construction of new U.S. nuclear power infrastructure in the coming decades will almost certainly create a technical requirement (perhaps as soon as 2030 to 2050) either for additional repositories or for the construction of infrastructure for recycling spent fuel*.[115]

Thus, one of the most prominent authorities on nuclear power and nuclear waste in the United States,[116] has opined that, in the absence of reprocessing, a second repository may be needed in the United States – and would "almost certainly" be needed in the event of a nuclear power resurgence. In this context, it is important to note that this entire exercise is part of the process of licensing new reactors or extending the licenses of existing reactors. Cost is therefore a very material consideration. Long-term storage (or longer) followed by disposal in one repository could add up to between $214 billion and $351 billion. A second repository could add $34

[114] 10 CFR 51 2008, at 51.23(a); italics added

[115] Peterson 2003, italics added

[116] Professor Peterson was a member of the Blue Ribbon Commission on America's Nuclear Future which delved into the problem of spent fuel at the behest of then Energy Secretary Steven Chu.

billion to $171 billion.[117] These are huge sums of money. The NRC must take these into account when assessing the reasonableness of its assumptions regarding long-term storage followed by disposal – or indefinite storage, which would be even more expensive.

8.6. The proposed rule neither puts limits on spent fuel nor assures that there will sufficient room to dispose of all spent fuel that may arise, including as a result of the government's own actions to promote nuclear energy. Unless there is a specific and reasonable assurance in this regard based on technical and social reality, then spent fuel may well be stranded at reactor sites essentially forever. It is also possible to envisage a case where there is one repository that is insufficient. In that case, there would be impacts both from disposal as well as impacts from indefinite storage at reactors of a part of the spent fuel inventory.

8.7. The Draft GEIS has a section on the issue of repository technical feasibility (Section B.2.1) and one entitled "Availability of Repository Capacity" (Section B.2.2)[118] These sections appeal to the international consensus that repositories are feasible, to the Waste Isolation Pilot Plant in New Mexico, where transuranic wastes generated by the nuclear weapons program of the Department of Energy are being disposed of, and to the Swedish and Finnish Programs. We consider each of these in turn to show that they are, singly or together, insufficient to establish feasibility in the sense that there will be a repository that will meet specified safety standards and that it will have sufficient capacity.

8.8. We note first of all that Yucca Mountain has not been licensed. The State of Nevada raised a host of technical issues[119] before the DOE informed the NRC that it was withdrawing its application. Yucca Mountain therefore cannot be used to assert repository feasibility, in the sense of meeting the standard that the EPA set forth in 40 CFR 197.

8.9. The proposed changes to 10 CFR 51, Table B-1, make reference to the Yucca Mountain standards as follows:

> For the high-level waste and spent-fuel disposal component of the fuel cycle, the EPA established a dose limit of 15 millirem (0.15 mSv) per year for the first 10,000 years and 100 millirem (1.0 mSv) per year between 10,000 years and 1 million years for offsite releases of radionuclides at the proposed repository at Yucca Mountain, Nevada.
>
> The Commission concludes that the impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the impacts of spent fuel and high level waste disposal, this issue is considered Category 1.

[117] Cooper 2013. Exhibit MNC-4, p. 25
[118] NRC 2013a, p. B-2 and p. B-4
[119] See *U.S. Department of Energy (High-Level Waste Repository)*, LBP-09-06, 69 NRC 367, aff'd in part and rev'd in part, CLI-09-14, 69 NRC 580 (NRC 2009).

8.10. The second paragraph in the quote from Table B-1 above does not follow the first. The existence of a standard does not provide any assurance or even any indication of the actual performance of the site. Indeed, it is a *non sequitur*.

8.11. The appeal to WIPP does not provide much assurance. As noted, in paragraph 3.5, the NRC itself has repudiated a salt repository for spent fuel.

8.12. The Finnish and Swedish repository programs are more advanced than those in other countries. However, it should be noted that both these counties have very small amounts of spent fuel compared to the United States. Sweden has just ten reactors, with nuclear energy production at about eight percent of the United States. Finland has just four with production, about three percent of the United States.[120] As noted in paragraph 8.5 above, even one very large repository, accommodating hundreds of thousands of tons of spent fuel may not be sufficient under a nuclear power resurgence scenario. Moreover, size matters, because the larger the repository that is needed, the more constrained the choices for locating it are likely to be. A smaller capacity at a particular site could well mean two repositories.

8.13. Showing feasibility in the context of the U.S. power program that may expand considerably beyond the present level means showing that sufficient capacity will exist for all reactors that may be built. It is not enough to say that there will be “a” repository 60 years after the license expiry of “a” reactor. The NRC must specify the amount of spent fuel to be disposed of and show that there will be sufficient capacity to dispose of all of the spent fuel in a manner that would comply with reasonable safety standards. The Draft GEIS has not done that.

8.14. The Draft GEIS has considered questions of technical feasibility without actually examining the impact of spent fuel disposal in a repository. This is essential for a waste confidence finding. For instance, the original waste confidence finding in 1978 was connected to Table S-3 in 10 CFR51.51. The latter assumed zero impact after repository closure because the former assumed disposal in bedded salt.[121] We show below, in paragraph 8.22 that the NRC itself now acknowledges that radiation doses would, or at least could, be well above zero and even above the Yucca Mountain EPA standard of 100 millirem per year in 40 CFR 197. It is essential that a new waste confidence finding in regard to the feasibility of a repository be based on a contemporary understanding and actual scientifically valid estimates of radiation doses that might be expected at different sites in the United States.

8.15. The NRC was explicit about the exclusion of repository impacts in its response to public comments on the scope of the GEIS:

> The NRC received comments related to spent nuclear fuel disposal. Spent nuclear fuel disposal is outside the scope of the Waste Confidence analysis, which will consider the environmental impacts of continued storage prior to ultimate disposal. The development of a national repository, the licensing of Yucca

[120] NRC Information Digest 2013, Appendix T

[121] We note below in paragraph 8.21 that this was shown to be incorrect five years later in 1983, but it was the NRC’s understanding in 1978 when the waste confidence rule was issued. The NRC’s understanding today is that radiation doses to the public could be well above the zero exposure assumed in Table S-3.

> Mountain or another repository site, *environmental impacts associated with disposal in a repository*, funding issues, recycling, and other waste disposal strategies *are outside the scope of this GEIS*.[122]

8.16. Two of the three scenarios in the Draft GEIS involve repository disposal. It is essential at least for the NRC to demonstrate in the GEIS that one or more sites with sufficient capacity exist in the United States that would likely meet reasonable health and safety rules.

8.17. The NRC itself has recognized the interrelated nature of spent fuel storage and disposal impacts in the recent License Renewal Rule.[123] In Table B-1, the NRC declared that the impacts of spent fuel disposal are "uncertain" and that "[t]he generic conclusion of offsite radiological impacts of spent nuclear fuel and high-level waste is not being finalized pending the completion of a generic environmental impact statement on waste confidence."[124] In a footnote, the NRC explained:

> As a result of the decision of United States Court of Appeals in *New York* v. *NRC,* 681 F.3d 471 (DC Cir. 2012), the NRC cannot rely upon its Waste Confidence Decision and Rule until it has taken those actions that will address the deficiencies identified by the D.C. Circuit. *Although the Waste Confidence Decision and Rule did not assess the impacts associated with disposal of spent nuclear fuel and high-level waste in a repository, it did reflect the Commission's confidence, at the time, in the technical feasibility of a repository and when that repository could have been expected to become available.* Without the analysis in the Waste Confidence Decision and Rule regarding the technical feasibility and availability of a repository, the NRC cannot assess how long the spent fuel will need to be stored onsite.[125]

As the Commission acknowledges, the question of feasibility of spent fuel disposal is integrally related with the question of what are the environmental impacts of spent fuel storage for an indeterminate period of time. By evaluating only spent fuel storage impacts, the NRC excludes a major part of the picture regarding the environmental impacts of the back end of the nuclear fuel cycle. Specifically, if a repository becomes available, some spent fuel storage impacts will be avoided, and there will be some repository impacts. Similarly, if there is no repository, the spent fuel storage impacts will increase considerably, for a variety of reasons, including the potential loss of institutional control.

8.18. Before discussing the inadequacy of Table S-3 to support an environmental analysis of spent fuel disposal impacts, I will provide some background information. Table S-3 is based on WASH-1248, Environmental Survey of the Uranium Fuel Cycle (1974).[126] The NRC also published a narrative explanation of the table in 1981. Table S-3 contains no numerical entry for an estimate of radiation releases from a geologic repository. Instead, the table makes two key assumptions: (i) that disposal of high-level waste resulting from reprocessing and/or of spent fuel

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[122] NRC Scoping 2013, p. 42; italics added
[123] 78 Fed. Reg., p. 37282 (June 20, 2013)
[124] 78 Fed. Reg., p. 37322 (June 20, 2013)
[125] 78 Fed. Reg., p. 37323 (June 20, 2013); italics added
[126] WASH-1248

will be in a bedded salt repository[127] and (ii) that post-closure releases from such a repository will be essentially zero. Footnote 1 in Table S-3 explains that "where no entry appears . . . the Table should be as if a specific zero entry had been made." Footnote 2 also refers to WASH-1248, which contains a more detailed version of Table S-3 stating that 0.005 curies per year of releases from the repository have been included in total for transuranic and fission product gaseous releases. WASH-1248 also contains further narrative explanation of the assumptions in Table S-3. According to WASH-1248:

> The most significant solid radiological waste consists of the fission products separated from the spent fuel of an annual fuel requirement in the reprocessing operation. These high level wastes will be stored onsite for a maximum of 10 yrs., and will ultimately be shipped, probably by rail, to a Retrievable Surface Storage Facility (RSSF). The RSSF will be established to store and manage high level solid wastes under constant surveillance for up to 100 years, or until such time as a more permanent Federal repository can be established. The facility will be designed to prevent the release of significant amounts of radioactive material to the environment under all credible environmental conditions and human actions. *Therefore, such waste will not be released as effluents to the environment*.[128]

8.19. The same assumption of essentially zero release and zero impact has evidently been applied to spent fuel as well. The NRC's 1981 background information on Table S-3 affirms this:

> It has been assumed that spent fuel or high-level wastes will be disposed of in a geologic, bedded salt repository. Operation of repository facilities is similar for both spent fuel and high level waste, and *it has been assumed that a repository in bedded salt will be designed and operated so as to retain the solid radioactive waste indefinitely*. However, the radiological impacts related to the geologic disposal of spent fuel are based on the assumption that all gaseous and volatile and [sic] radionuclides in spent fuel are released before the geologic repository is sealed. Since the gaseous and volatile radionuclides are the principal contributors to environmental dose commitments, this assumption umbrellas the upper bounds of the dose commitments that may be associated with the disposal of spent fuel.[129]

8.20. Table S-3 is inadequate, incorrect, or obsolete in a number of respects. First, it assumes disposal in bedded salt; this assumption is obsolete. The NRC itself has ruled out disposal of spent fuel in salt formations on grounds of possible instability during repository operation:

> Although there are relative strengths to the capabilities of each of these potential host media [i.e., crystalline rock, clay, and salt], no geologic media previously identified as a candidate host, **with the exception of salt formations for SNF, has been ruled out based on technical or scientific information**. Salt formations are being considered as hosts only for reprocessed nuclear materials

[127] Table S-3 does not explicitly mention salt; that is in the background information, as noted in paragraph 8.19.
[128] WASH-1248, p. S-23, italics added
[129] 46 Fed. Reg., p. 15154 (March 4, 1981) Section II.1, italics added

> because heat generating waste, like SNF, exacerbates a process by which salt can rapidly deform. This process could cause problems with keeping drifts stable and open during the operating period of a repository.[130]

8.21. Second, Table S-3's assumption that disposal of spent fuel or high-level waste in bedded salt will result in zero releases (and hence zero radiation doses to the public after repository closure) has been shown to be incorrect as a generic conclusion. The most comprehensive review of radiation releases and radiation doses to the public from deep geologic disposal in a variety of geologic settings was done following the passage of the NWPA in a 1983 study by the National Research Council of the National Academies.[131] This study was commissioned by the Department of Energy. It shows that there is a risk of significant radiation doses[132] in all geologic media that were quantitatively examined, *including bedded salt*.[133] More recent assessments have confirmed that there is a risk of significant radiation releases and doses from a variety of geologic media. The NRC's assumption of zero releases and radiation doses from deep geologic disposal is therefore incorrect for both high-level waste and spent fuel even for bedded salt repositories.

8.22. The NRC itself has conceded for well over a decade that the assumption of zero releases and zero doses for geologic disposal in Table S-3 is incorrect. It has not done so in so many words, but it has admitted in other regulatory contexts that radiation doses to the public would not be zero. In 1996, in the first license renewal GEIS (NUREG-1437), the NRC abandoned the zero-release, zero-dose assumption of Table S-3:

> For the high-level-waste and spent-fuel disposal component of the fuel cycle, there are no current regulatory limits for off-site releases of radionuclides for the candidate repository site at Yucca Mountain. If we assume that limits are developed along the lines of the 1995 National Academy of Sciences (NAS) report, *Technical Bases for Yucca Mountain Standards*, and that, in accordance with the Commission's Waste Confidence Decision, 10 CFR 51.23, a repository can and likely will be developed at some site that will comply with such limits, peak doses to virtually all individuals will be 100 mrem/year or less. While the Commission has reasonable confidence that these assumptions will prove correct, there is considerable uncertainty because the limits are yet to be developed, no repository application has been completed or reviewed, and uncertainty is inherent in the models used to evaluate possible pathways to the human environment. The National Academy report indicates that 100 mrem/year should be considered as a starting point for limits for individual doses, but notes that some measure of consensus exists among national and international bodies that the limits should be a fraction of the 100 mrem/year. The lifetime individual risk from 100-mrem/year dose limit is about $3x10^{-3}$.

[130] NRC 2010a, p. 81059, emphasis added

[131] NAS-NRC 1983, Chapter 9. Bedded salt radiation dose estimates are shown in Figure 9-5 (p. 262).

[132] I define "significant" doses in this context as being comparable to or greater than those defined in 40 CFR 190.10(a), which limits doses to the public from uranium nuclear fuel cycle operations.

[133] See Chapter 9 of NAS-NRC 1983. Bedded salt radiation dose estimates are shown in Figure 9-5 (p. 262).

> Estimating cumulative doses to populations over thousands of years is more problematic.[134]

8.23. As the above quote in paragraph 8.22 shows, the NRC cannot even assure that doses will remain limited to 100 millirem per year, the current annual limit in 10 CFR 20, much less any more stringent limit that is recommended by “national and international bodies.”

8.24. In addition, Table S-3 does not cover MOX fuel use, though the waste confidence rule purports to cover it.[135] It is clear that Table S-3 does not give the NRC the basis for a waste confidence statement that includes MOX spent fuel.

9.0 THE EIS SHOULD ACKNOWLEDGE THAT CERTAIN IMPACTS CANNOT BE ANALYZED IN A GENERIC MANNER.

9.1. The Draft GEIS claims to have considered site specific issues sufficiently to draw generally applicable conclusions regarding waste confidence so that such issues could not be brought up during reactor or specific storage facility licensing cases.[136]

9.2. I would agree that some impacts are generic and can, given adequate data, be bounded on that basis. This is the case, for instance, with the on-site impacts of transferring spent fuel from one cask to another. But other issues cannot be analyzed in a generic manner. This is because different kinds of impacts are incommensurate with each other. Therefore, it is necessary to have a bounding analysis for each major type of impact. I provide several examples in the following paragraphs.

9.3. Consider, for instance the Draft GEIS claim that a generic analysis would suffice for environmental justice issues:

> In the present case, however, the NRC has determined that it can provide an assessment of the environmental justice impacts during continued storage compared to environmental justice impacts of storage during reactor operations. …[T]his draft GEIS and the Waste Confidence rule are not licensing actions and do not authorize the continued storage of spent fuel. The environmental analysis in this draft GEIS fulfills a small part of the NRC’s NEPA obligation with respect to the licensing or relicensing of a nuclear reactor or spent fuel storage facility. Further, the site-specific NEPA analysis that is required prior to an NRC licensing action will include a discussion of the impacts on minority and low income populations, and will appropriately focus on the NRC decision directly related to specific licensing actions. As with all other resource areas, this site-specific analysis will allow the NRC to make an impact determination with respect to

[134] NUREG-1437 (1996), p.6-19
[135] NRC 2013a, p. xxix
[136] NRC 2013a, p. xxiv

> environmental justice for each NRC licensing action. *A generic determination of the human health and environmental effects impacts during continued storage is possible because the NRC understands* how the environmental impacts change when a nuclear power plant site transitions from reactor operations to continued storage. Based on this knowledge, the NRC can provide an assessment of the potential human health and environmental effects during continued storage. As discussed in the following sections, the NRC has determined that the human health and environmental effects from continued storage would be small compared to the impacts that are normally experienced during reactor operations.[137]

But once a determination is made that spent fuel storage impacts are small even for indefinite storage, they cannot be raised in a site-specific licensing process even if they were not considered in the waste confidence GEIS.

9.4. Take the example of the storage of spent fuel at the Columbia Generating Station in Washington State. A realistic analysis, including loss of institutional control, indicates that there would likely be catastrophic impacts that would contaminate Columbia River and its fish, including salmon. Indefinite storage would have devastating cultural and environmental justice impacts that could no longer be brought up for that site once a generic determination is made regarding the safety of indefinite storage. The tribes who have Columbia River-related rights would be precluded from bringing up the issue for any future new reactor or storage licenses or license extensions. The Draft GEIS does mention plants of special significance in the vicinity of the Prairie Island reactors, but provides no specific impact analysis in case of indefinite storage and dispersal of radioactivity or in case of severe accidents with high burnup failed spent fuel bundles.

9.5. The NRC's statement quoted above is an attempt to foreclose any consideration of radiation-related environmental justice site-specific issues, especially those associated with long-term or indefinite storage of spent fuel, notably in case of a failure to site a repository and indefinite on-site storage.

9.6. Health and property damage impacts provide another example. The Draft GEIS acknowledges that population densities are highly variable and that the environs of the Indian Point nuclear plant has the highest density of all. Yet, the consequences of a spent fuel pool fire are considered for the Surry plant, where the density is much lower. Moreover, the analyses cited are all more than a decade old and cannot therefore reflect the impact of growing amount of high burnup fuel in spent fuel pools.[138] It is possible to bound impacts of such accidents by focusing on high density population sites with high property value concentrations. But the Draft GEIS has not done this.

9.7. Impacts on river systems may be bounded by sites that are quite different in character. For instance, large scale dispersal of radioactivity from spent fuel storage at Prairie Island could

[137] NRC 2013a, p. 4-11, italics added

[138] NRC 2013a, Appendix F, Table F-2 (p. F-8). The most recent document cited in the notes to this table dates from 2002.

create long-term damage to the entire Mississippi River system, including agricultural lands around it, cities that are vulnerable to flooding on its shores, barge traffic that is a major artery of commerce, and so on. Agricultural impacts alone may be bounded by sites like Fort Calhoun in Nebraska or Duane Arnold in Iowa. Such impacts would be especially important to evaluate in the case of long-term storage and indefinite storage accompanied by loss of institutional control.

9.8. It is impossible to bound critical ecological impacts in a generic manner. They will require site specific discussion. For instance, the Calvert Cliffs reactors in Maryland are situated in one of the most sensitive and unique ecosystems of the United States – the Chesapeake Bay. The impacts of a major radioactivity release into the Chesapeake Bay ecosystem are likely to be quite different than those of a similar release at Turkey Point in Florida, which has barrier islands and Biscayne National Park a few miles away or Diablo Canyon, in California, where a major release could severely impact oceanic ecosystems. It is important to remember in this context that the inventory of long-lived radioactivity in spent fuel pools in the United States is generally far larger than that in Chernobyl Unit 4, which had a severe accident and radioactivity releases in 1986. It is essential for the waste confidence GEIS to analyze critical ecosystem impacts on a site specific basis unless it can classify sites based on types of ecosystems and address bounding impacts for similar sites.

9.9. From the above examples, it is clear that the NRC should create a list of site-specific issues that are excluded from the purview of the GEIS and therefore could be brought up in individual licensing cases. In the alternative, it must show that it has bounded the impacts in a generic manner for each type of impact. This is especially important for long-term storage and indefinite storage with loss of institutional control. A GEIS must include bounding estimates for (i) the number of cancers attributable in case of a worst case release of radionuclides; (ii) the worst case damage to riverine ecosystems, such as the Mississippi River or the Columbia River; (iii) the worst case loss of agricultural land and production; (iv) the ecosystem damage to each unique ecosystem, including the Chesapeake Bay, the Mississippi River Delta, the Columbia River, and oceanic ecosystems, and (v) the worst case property damage. These evaluations should include not just today's source terms but the projected source terms based on the dates of the expiry of the licenses and the total accumulated spent fuel at that time.

10.0 SUMMARY AND CONCLUSIONS

10.1. The Draft GEIS fails to provide a detailed quantitative analysis of the impacts to public health and the environment that would occur in the event of an accidental release of radiation during spent fuel storage or transfer. Given the high level of radioactivity in spent fuel, the very long half-lives of certain radioactive materials (including plutonium-239 and long-lived fission products with half-lives that range from 30 years to millions of years), and the high burnup of much of the spent fuel, these impacts could be substantial.

10.2. The Draft GEIS contains almost no information about spent fuel characteristics that could cause adverse safety risks and environmental impacts during long-term or indefinite storage. In other contexts, the NRC itself has acknowledged that it currently lacks sufficient information to reach informed conclusions about the behavior of spent fuel in storage over the long term. Yet, it failed to note the data gaps identified as recently as 2012 in its Draft GEIS. The NRC's amnesia regarding its own study undermines the credibility and integrity of the Draft GEIS. Little-understood factors affecting the safety of spent fuel storage include the degree to which spent fuel and its host canisters corrode and degrade over a prolonged period of time, and the effect of high burnup fuel on the integrity of cladding and storage canisters. For instance, although high burnup fuel now makes up a significant portion of spent fuel inventories, there is no explicit consideration of long-term dry storage and disposal of failed high-burnup fuel. The NRC currently has little or no empirical data regarding its behavior under extended dry storage conditions. The Draft GEIS contains no analysis of how high burnup spent fuel characteristics may contribute to the risk of an accidental release of radioactivity during extended storage in pools, followed by long-term storage in dry casks. The one study of high burnup spent fuel degradation that the Draft GEIS cites (Billone et al. 2013) found that different high burnup fuel cladding material degrade at markedly different rates. The Draft GEIS took no account of this finding, which indicates that a generic analysis may not be sufficient to estimate impacts unless it is designed to be bounding, having taken such differences explicitly into account.

10.3. The Draft GEIS has made an unsupported assumption that institutional controls will remain effective indefinitely on the ground/An assumption that the federal government will be there to protect health and safety even thousands of years from the present is remote and speculative. On the contrary, global and U.S. history shows that it is highly remote and speculative to assume institutional control for an indefinite period. It is also fundamentally inconsistent with federal law and policy (including NRC's own regulations) to assume that institutional controls will last forever. For instance, the NRC's low-level waste regulations assume that institutional controls will last no more than 100 years and that physical barriers to intruders will last no more than 500 years. To assume that the federal government will exist for tens of millennia and each year appropriate significant sums of money to manage spent fuel at sites that produce no revenue flies in the face of current facts and U.S. history, including a dozen federal government shut downs since 1980, not to speak of the Civil War, when the United States did not have a single government, budget, or currency.

10.4. Even under the assumption of institutional controls for an indefinite period, the Draft GEIS fails to address the expense of those measures, the risk that they may fail, and how such costs and risks may impact reactor licensing and license extension decisions.

10.5. The question of feasibility of spent fuel disposal is integrally related with the questions of the health and safety standards for disposal and whether any specific repository can comply with them. The Draft GEIS did not evaluate disposal impacts. By excluding them from its scope, the NRC has excluded a major part of the picture regarding the environmental impacts of the back end of the nuclear fuel cycle.

10.6. The Draft GEIS has failed to demonstrate the feasibility of a repository in the sense of showing that there is a site in the United States that will meet safety standards with reasonable assurance. Nor has it demonstrated that there will be sufficient repository capacity, especially given that the Draft GEIS puts no quantitative limits on how much spent fuel can be produced under the proposed waste confidence rule. Persuasive arguments can be made that two repositories may be needed if there is a resurgence of nuclear power. Appeals to repository programs in Sweden and Finland do not resolve this issue – their nuclear power programs are very small compared to the United States and therefore involve a small amount of spent fuel. Costs of long-term storage and disposal could run into hundreds of billions of dollars.

10.7. The NRC has no valid environmental analysis on which it can rely for an evaluation of spent fuel disposal impacts. Table B-1 cites the EPA Yucca Mountain standard, which does not apply to any other repository. Moreover, since the licensing proceeding for Yucca Mountain is far from complete (if it is ever completed); so it is not clear that Yucca Mountain would meet the required performance specified in 40 CFR 197. The proposed rule simply refers to the rule and asserts "that the impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR part 54 should be eliminated."[139] This is a non sequitur. It is much like saying that the existence of a law against drunken driving allows one to conclude that the impacts of drunken driving would in fact not be large enough to worry about.

10.8. The other regulation that covers high-level waste disposal impacts of Table S-3 at 10 CFR 51.51. But this table is invalid for estimating high-level waste disposal impacts. Among other things, its underlying assumption of disposal in a bedded salt repository was repudiated by the NRC itself. Therefore, the NRC must prepare a new analysis in the context of its waste confidence decision.

10.9. While some storage impacts can reasonably be addressed on a generic basis, there are many that cannot. At the very least, it is essential for the NRC to group incommensurate site-specific impacts by category, such as high population density areas, reactors on rivers that could affect large populations living along those rivers, and so on.

10.10. In view of the above, it is my conclusion that the NRC lacks a factual and scientific basis for a finding of confidence that spent fuel can be safely stored for the long-term, much less indefinitely. The NRC also lacks a factual and scientific basis for a finding of confidence that spent fuel can be disposed of safely within acceptable, legally binding health and safety standards. In fact, the available evidence suggests that both long-term storage and disposal of spent fuel could pose significant safety and environmental risks. The NRC should prepare a new Draft GEIS that meaningfully examines these risks.

10.11. The GEIS should have a no-action alternative of not issuing any further licenses or license extensions for reactors or for spent fuel storage at least until the basis to do a scientifically valid GEIS exists in the area of high burnup fuel. At present the NRC lacks the factual and analytical basis to do so in a number of areas. This should be the preferred alternative.

10.12. The Draft GEIS should be redone to remedy a number of fundamental defects. Among other things, it is necessary to include a scenario that posits indefinite storage and loss of institutional control 100 years after the end of reactor operating licenses.

[139] NRC 2013b, p. 56805

10.13. The GEIS must evaluate the increasing likelihood of theft after loss of institutional control and a decay of the cesium-137 radiation barrier after 200 to 300 years. It must also evaluate the environmental and proliferation consequences of such theft.

10.14. In view of the lack of factual and analytical basis for assessing the impacts of long-term or indefinite storage of high burnup spent fuel, the NRC should not permit the further production of high burnup spent fuel until such a time that it is able to evaluate the long term spent fuel management issues related to that fuel.

10.15. I have also concluded that it will be necessary to carve out a number of issues for site specific consideration unless the NRC considers groups of sites and specific types of impacts in this GEIS. No single generic analysis can cover the issues presented by indefinite storage onsite.

The facts presented above are true to the best of my knowledge and the opinions contained herein represent my best professional judgment.

Dr. Arjun Makhijani
December 20, 2013

11.0 REFERENCES`

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A recognized authority on energy issues, Dr. Makhijani is the author and co-author of numerous reports and books on energy and environment related issues, including two published by MIT Press. He was the principal author of the first study of the energy efficiency potential of the US economy published in 1971. He is the author of *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy* (2007).

In 2007, he was elected Fellow of the American Physical Society. He was named a Ploughshares Hero, by the Ploughshares Fund (2006); was awarded the Jane Bagley Lehman Award of the Tides Foundation in 2008 and the Josephine Butler Nuclear Free Future Award in 2001; and in 1989 he received The John Bartlow Martin Award for Public Interest Magazine Journalism of the Medill School of Journalism, Northwestern University, with Robert Alvarez. He has many published articles in journals and magazines as varied as *The Bulletin of the Atomic Scientists, Environment, The Physics of Fluids, The Journal of the American Medical Association,* and *The Progressive*, as well as in newspapers, including the *Washington Post*.

Dr. Makhijani has testified before Congress, and has appeared on ABC World News Tonight, the CBS Evening News, CBS 60 Minutes, NPR, CNN, and BBC, among others. He has served as a consultant on energy issues to utilities, including the Tennessee Valley Authority, the Edison Electric Institute, the Lawrence Berkeley Laboratory, and several agencies of the United Nations.

Education:

- Ph.D. University of California, Berkeley, 1972, from the Department of Electrical Engineering. Area of specialization: plasma physics as applied to controlled nuclear fusion. Dissertation topic: multiple mirror confinement of plasmas. Minor fields of doctoral study: statistics and physics.
- M.S. (Electrical Engineering) Washington State University, Pullman, Washington, 1967. Thesis topic: electromagnetic wave propagation in the ionosphere.

- Bachelor of Engineering (Electrical), University of Bombay, Bombay, India, 1965.

Current Employment:

- 1987-present: President and Senior Engineer, Institute for Energy and Environmental Research, Takoma Park, Maryland. (part-time in 1987).
- February 3, 2004-present, Associate, SC&A, Inc., one of the principal investigators in the audit of the reconstruction of worker radiation doses under the Energy Employees Occupational Illness Compensation Program Act under contract to the Centers for Disease Control and Prevention, U.S. Department of Health and Human Services.

Other Long-term Employment

- 1984-88: Associate Professor, Capitol College, Laurel, Maryland (part-time in 1988).
- 1983-84: Assistant Professor, Capitol College, Laurel, Maryland.
- 1977-79: Visiting Professor, National Institute of Bank Management, Bombay, India. Principal responsibility: evaluation of the Institute's extensive pilot rural development program.
- 1975-87: Independent consultant (see page 3 for details)
- 1972-74: Project Specialist, Ford Foundation Energy Policy Project. Responsibilities included research and writing on the technical and economic aspects of energy conservation and supply in the U.S.; analysis of Third World rural energy problems; preparation of requests for proposals; evaluation of proposals; and the management of grants made by the Project to other institutions.
- 1969-70: Assistant Electrical Engineer, Kaiser Engineers, Oakland California. Responsibilities included the design and checking of the electrical aspects of mineral industries such as cement plants, and plants for processing mineral ores such as lead and uranium ores. Pioneered the use of the desk-top computer at Kaiser Engineers for performing electrical design calculations.

Professional Societies:

- Institute of Electrical and Electronics Engineers and its Power Engineering Society
- American Physical Society (Fellow)
- Health Physics Society
- American Association for the Advancement of Science

Awards and Honors:

- The John Bartlow Martin Award for Public Interest Magazine Journalism of the Medill School of Journalism, Northwestern University, 1989, with Robert Alvarez
- The Josephine Butler Nuclear Free Future Award, 2001
- Ploughshares Hero, Ploughshares Fund, 2006
- Elected a Fellow of the American Physical Society, 2007, "*For his tireless efforts to provide the public with accurate and understandable information on energy and environmental issues*"
- Jane Bagley Lehman Award of the Tides Foundation, 2007/2008

Advisory Council, Maryland Clean Energy Center, 2013

***Committee Member, Radiation Advisory Committee, Science Advisory Board, U.S. Environmental Protection Agency,* 1992-1994**

Invited Faculty Member, Center for Health and the Global Environment, Harvard Medical School: Annual Congressional Course, *Environmental Change: The Science and Human Health Impacts*, April 18-19, 2006, Lecture Topic: An Update on Nuclear Power - Is it Safe?

Consulting Experience, 1975-1987
Consultant on a wide variety of issues relating to technical and economic analyses of alternative energy sources; electric utility rates and investment planning; energy conservation; analysis of energy use in agriculture; US energy policy; energy policy for the Third World; evaluations of portions of the nuclear fuel cycle.

Partial list of institutions to which I was a consultant in the 1975-87 period:

- Tennessee Valley Authority
- Lower Colorado River Authority
- Federation of Rocky Mountain States
- Environmental Policy Institute
- Lawrence Berkeley Laboratory
- Food and Agriculture Organization of the United Nations
- International Labour Office of the United Nations
- United Nations Environment Programme
- United Nations Center on Transnational Corporations
- The Ford Foundation
- Economic and Social Commission for Asia and the Pacific
- United Nations Development Programme

Languages: English, French, Hindi, Sindhi, and Marathi.

Reports, Books, and Articles (Partial list)

(Newsletter, newspaper articles, excerpts from publications reprinted in books and magazines or adapted therein, and other similar publications are not listed below)

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CV updated September 4, 2013

Critique of the Analysis of Safety and Environmental Risks Posed by Spent Fuel Pool Leaks in the NRC's Draft Waste Confidence Generic Environmental Impact Statement

Declaration of David Lochbaum

Under penalty of perjury, I, David Lochbaum, declare as follows:

I. INTRODUCTION

1.1 I am the director of the nuclear safety project for the Union of Concerned Scientists (UCS). The UCS puts rigorous, independent science to work to solve our planet's most pressing problems. Joining with citizens across the country, we combine technical analysis and effective advocacy to create innovative, practical solutions for a healthy, safe, and sustainable future. The UCS has over 93,000 members.

1.2 I have been retained by a group of environmental organizations to assist in the preparation of comments invited by the U.S. Nuclear Regulatory Commission (NRC), on its Draft Generic Environmental Impact Statement on the Waste Confidence Decision (WC DGEIS).

1.3 The purpose of my declaration is to address the adequacy of the discussion of spent fuel pool leak risks in the WC DGEIS to support the NRC's proposed finding in 10 CFR. § 51.23(a)(2) that it is feasible to safely store spent nuclear fuel in spent fuel pools after nuclear power reactors permanently cease operation.

1.4 My declaration is organized as follows:

- Appendix A summarizes the results from NRC's inspections of voluntary groundwater protection programs implemented at nuclear power plant sites.
- Appendix B lists inspections routinely conducted by the NRC at operating nuclear power plants.
- Appendix C shows results from NRC's inspection efforts at operating nuclear power plants.
- Appendix D provides my curriculum vitae.

1.5 In preparing this declaration, I have reviewed the WC DGEIS, the relevant references listed in the WC DGEIS, and the documents listed in Section X of this declaration.

II. PROFESSIONAL QUALIFICATIONS

2.1 As stated in Section I, I am the director of the nuclear safety project for the UCS. I graduated in June 1979 from The University of Tennessee with a Bachelor of Science degree in nuclear engineering. Appendix D contains my curriculum vitae.

2.2 Except for a one-year gap beginning in March 2009, I have worked for UCS since October 1996. In directing UCS's nuclear safety program, I monitor developments in the nuclear industry, serve as the organization's spokesperson on nuclear safety issues, initiate action to correct safety concerns, author reports and briefs on safety issues, and present findings to the Nuclear Regulatory Commission (NRC), the US Congress, state and local officials, and others. From March 2009 to March 2010, I was a reactor technology instructor for the Nuclear Regulatory Commission where I provided initial qualification and re-qualification training on boiling water reactor technology for NRC employees. My assigned duties included revising chapters of the training manual, conducting classroom and control room simulator training sessions, maintaining the test question database, and administering examinations. From June 1979 through September 1996, I worked in the U.S. commercial nuclear power industry. Most of that period was spent in assignments at nuclear plant sites supporting operating reactors. I began as a junior engineer responsible for the liquid and solid radioactive waste management systems at the Hatch nuclear plant. I subsequently worked as a reactor engineer and Shift Technical Advisor at the Browns Ferry nuclear plant, and as the supervisor of the reactor engineers and Shift Technical Advisors at the Grand Gulf nuclear plant. I had assignments as a consultant in the licensing departments for the Grand Gulf, Brunswick, Salem, Wolf Creek and Connecticut Yankee nuclear plants and the engineering departments at the Perry, FitzPatrick and Susquehanna nuclear plants.

2.3 I am familiar with nuclear plant regulatory requirements, including those applicable to spent fuel pools, and the NRC's inspection regime. For example, I developed a lesson plan on design and licensing bases issues and conducted training on it to managers at the Perry nuclear plant. I developed a topical report on the station blackout licensing bases for the Connecticut Yankee nuclear plant. I participated in a vertical slice assessment of the spent fuel pool cooling system at the Salem Generating Station. I developed the primary containment isolation devices design basis document for the FitzPatrick nuclear plant. I conducted design reviews of balance of plant systems, including the spent fuel pool cooling and cleanup system, to support the power uprate program for the Susquehanna nuclear plant. I co-authored a report submitted to the NRC in November 1992 pursuant to 10 CFR. Part 21 regarding design and licensing bases inadequacies associated with the two spent fuel pools at the Susquehanna nuclear plant. In January 2010, I was certified as a boiling water reactor technology instructor at the NRC's Technical Training Center. In April 1982, I was certified as a Shift Technical Advisor at the Browns Ferry nuclear plant

2.4 I am the author of *Nuclear Waste Disposal Crisis*, a book published in January 1996 by PennWell Books in Tulsa, Oklahoma. Chapter 1 of this book summarized the history of the nuclear power industry in the United States. Chapter 2 described the nuclear fuel cycle. Chapter 3 summarized the different designs used for U.S. nuclear power reactors. Chapter 4 described spent fuel storage at nuclear plants, including spent fuel pools, storage racks, cooling and cleanup systems for the pools, spent fuel pool temperature and water level instrumentation, and fuel handling equipment. Chapter 5 covered the history of reprocessing of spent fuel in the United States. Chapter 6 addressed plans for disposing of spent fuel in geological repositories. Chapter 7 discussed several actual and proposed methods for interim spent fuel storage at nuclear plant sites. Chapter 8 described the risks from onsite spent fuel storage. Chapter 9 covered the concerns Don Prevatte and I raised to the NRC about spent fuel storage at the Susquehanna nuclear plant in Pennsylvania. (Our concerns were both valid and relevant as evidenced by the NRC issuing a warning letter (NRC 1993) to plants owners and technical report (NRC 1997b) on the issues.) Chapter 10 provided recommendations for managing the interim and long-term risks of spent fuel storage and disposal. And Appendix A of the book covered past spent fuel incidents, including ones involving loss of water inventory from spent fuel pools.

III. BACKGROUND ON SPENT FUEL STORAGE AND CONSIDERATION OF SPENT FUEL POOL LEAKS IN THE WC DGEIS

A. History of Onsite Spent Fuel Storage

3.1 The oldest nuclear power reactors currently operating in the United States were licensed by the Atomic Energy Commission (AEC) (NRC's predecessor) in the 1960s (NRC 2013d, Appendix A). At that time, the strategy called for spent fuel to remain onsite for a relatively short time (weeks to months) before being transferred offsite for either reprocessing or disposal. Consequently, the capacity of spent fuel pools was limited to only about one and one-third reactor cores (Kadak 2012, page 25). This design capacity accommodated the fuel from an entire reactor core if it needed to be offloaded to inspect the reactor vessel and/or its internals or other reasons along with one-third of a reactor core discharged during a recent refueling outage but not yet shipped to a repository or reprocessing facility.

3.2 Safety studies performed by applicants for licenses to operate nuclear power plants and reviewed by the NRC (or AEC) before issuing them examined several postulated accidents and transients having the potential to cause damage to the reactor core. For example, the largest diameter pipe connected to the reactor vessel was postulated to rupture and drain cooling water, and the offsite grid supplying electricity to the plant and its equipment was postulated to fail. These studies supported conclusions that plant design features and procedures adequately protected workers and members of the public from these hazards if they were to occur.

3.3 The only scenarios involving spent fuel at the plants involved handling accidents—an irradiated fuel assembly being dropped onto other irradiated fuel assemblies in storage racks within spent fuel pools or an irradiated fuel assembly being damaged by colliding with something during movement. Other scenarios, such as loss of water inventory[1] from spent fuel pools and interruption of cooling of the spent fuel pool water, were not studied. As noted in paragraph 3.2 above, loss of water inventory and interruption of cooling were studied with regard to their potentially damaging irradiated fuel in the reactor cores.

3.4 It is my professional opinion that spent fuel pool scenarios, other than fuel handling events, were not studied primarily due to the original strategy for onsite spent fuel storage described in paragraph 3.1 above. Because spent fuel was presumed to remain onsite for a short time before being shipped offsite, these "temporary" configurations were subjected to less rigorous evaluations.

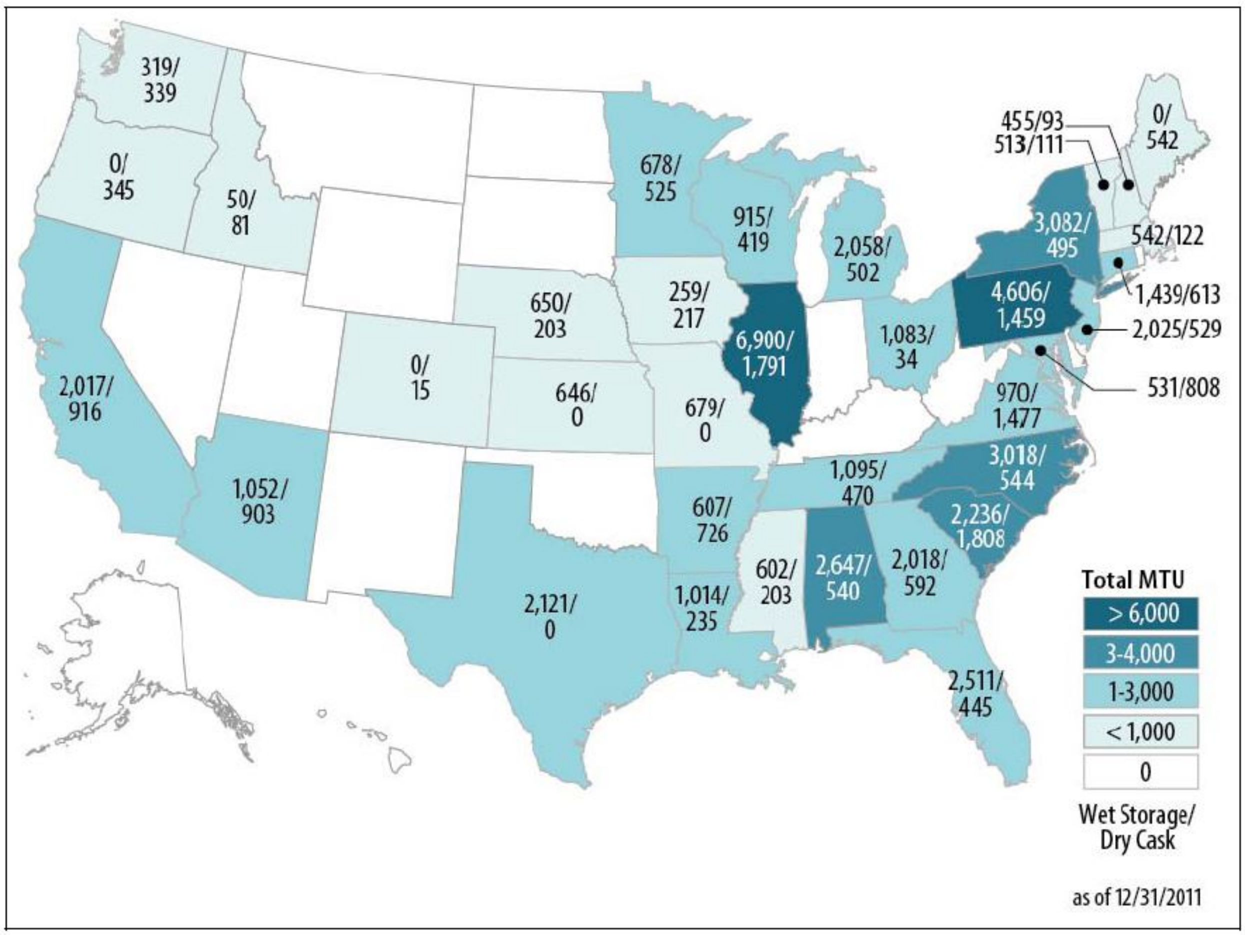
3.5 When the reprocessing option was eliminated in the late 1970s, nuclear plant owners were left with no options other than expanding their onsite spent fuel storage capacities because the repository option was not then—and is still not—available. Low-density storage racks that held

[1] Spent fuel pools were designed and evaluated for protections against loss of water inventory (such as absence of drains and connections below the normal waterline and anti-siphon devices in pipes that enter the pool's volume.) The reactor vessel, and reactor coolant pressure boundary more broadly, are also designed and evaluated for protections against loss of water inventory. But studies are also conducted postulating loss of water inventory anyway to provide assurance that safety system will restore the water level before reactor core damage occurs. Spent fuel pools lack comparable "what if" studies.

irradiated fuel assemblies far apart for protection against inadvertent criticality (i.e., an undesired and uncontrolled nuclear chain reaction) were replaced with high-density storage racks (Lochbaum, 1996). Reracked spent fuel pools can store up to nearly ten reactor cores of spent fuel assemblies.

3.6 As reracked spent fuel pools neared capacity, nuclear plant owners turned to the next method for expanding onsite spent fuel storage capacities—storage in dry casks. Beginning in 1986, owners transferred spent fuel assemblies from their spent fuel pools into dry casks that were stored onsite (NRC 2013d, Appendix P). The transfers to dry cask freed up storage space in the spent fuel pools for discharged from the reactor core during refueling outages.

3.7 As of December 31, 2011, 46,733 metric tons of spent fuel were stored in spent fuel pools across the U.S. and 15,859 metric tons resided in dry casks for a total of 62,592 metric tons. This spent fuel was being stored at 74 individual locations (CRS 2012, Table 1).



(CRS 2012, Figure 5)

These 74 locations were in 35 states. In some states, such as Oregon and Maine, all the spent fuel resided in dry storage. In other states, such as Texas and Missouri, all the spent fuel resided in spent fuel pools. Many other states had spent fuel in both storage methods.

B. NRC's Analysis of Spent Fuel Pool Leaks for its Waste Confidence Draft Generic Environmental Impact Statement

3.8 The NRC developed the WC DGEIS to support a series of proposed findings regarding the safety of spent fuel storage after reactors permanently cease operating. The WC DGEIS also responds to the U.S. Court of Appeals decision that vacated the NRC's Temporary Spent Fuel Storage Rule and Waste Confidence Decision of December 2010 and remanded them back to the agency. According to the NRC, one of the problems found by the Court involved leaks of radioactively contaminated water from spent fuel pools:

> *Related to 60 years of continued storage, the Court concluded that the Commission had not adequately examined the risk of spent fuel leaks in a forward-looking fashion.* (NRC 2013b, page 1-3, lines 19-20)

3.9 In the WC DGEIS, the NRC defined three time periods for continued storage of spent fuel onsite after nuclear power reactors cease operating: short-term (up to 60 years), long-term (up to 160 years including the short-term period), and indefinite. The NRC assumes that spent fuel will be stored in pools only during the short-term period because "decommissioning is normally completed within 60 years after a reactor shuts down" (NRC 2013b, page xxix, lines 28-29). As NRC explains:

> *Spent fuel pools are cooled by continuously circulating water that cools the spent fuel assemblies and provides shielding from radiation. During the short-term storage timeframe, the pools will be used to store fuel until a licensee decides to remove the spent fuel as part of implementing either the SAFSTOR or DECON decommissioning option.* (NRC 2013b, page 2-25, lines 10-13)

3.10 Assuming that spent fuel may be stored in pools for up to 60 years after nuclear power reactors permanently shut down but not for longer periods is supported by existing federal regulation, specifically 10 CFR. §50.82:

> *Decommissioning will be completed within 60 years of permanent cessation of operations. Completion of decommissioning beyond 60 years will be approved by the Commission only when necessary to protect public health and safety.* (NRC 2011a, paragraph (a)(3))

3.11 The assumption of a 60-year storage period in the WC DGEIS is valid because it is backstopped by an existing federal regulation. If an owner wanted to retain spent fuel pool storage for longer than 60 years, 10 CFR. §50.82 would require that owner to obtain the NRC's formal authorization to do so. Because the WC DGEIS only evaluates storage in spent fuel pools for up to 60 years following permanent cessation of reactor operation, no environmental impact study would exist to support spent fuel pool storage beyond 60 years.

3.12 The WC DGEIS concedes a prolonged spent fuel pool leak could cause significant impacts[2] if it was not detected in a timely manner:

> *Public health regulatory limits could be exceeded in the very unlikely event a spent fuel pool leak remained undetected for long periods of time*. (NRC 2013b, page xlii, lines 31-33)
>
> ***
>
> *For impacts to groundwater resources, though highly unlikely, it is possible that a leak of sufficient quantity and duration could occur, resulting in noticeable impacts to groundwater resources.* (NRC 2013b, page lviii, lines 22-24)
>
> ***
>
> *If, in the very unlikely event that a pool leak remained undetected for a long period of time, public health regulatory limits (i.e., EPA drinking water standards) could potentially be exceeded.* (NRC 2013b, page lviii, line 34 to page lix, line 1)
>
> ***
>
> *In the very unlikely event that a leak goes undetected and the resulting groundwater plume reaches the offsite environment, it is possible that the leak could be of a sufficient enough magnitude and duration that contamination of a groundwater source above a regulatory limit (i.e., a Maximum Contaminant Level for one or more radionuclide) could occur.* (NRC 2013b, page E-16, lines 18-22)

3.13 However, the WC DGEIS ultimately concludes that it is very unlikely that a spent fuel pool leak will be large enough or last long enough to cause significant impacts; and that even if a large enough or long enough leak occurred, its impacts will be mitigated by hydrological and monitoring programs:

> *The analysis concludes that (1) there is a low probability of a leak of sufficient quantity and duration to affect offsite locations and (2) site hydrologic characteristics and monitoring programs ensure that impacts from spent fuel pool leaks would be unlikely.* (NRC 2013b, page xxxvii, lines 17-20)
>
> ***
>
> *In the event of uncontrolled and undetected discharges associated with long-term spent fuel pool leaks to nearby surface waters, the annual discharge would be comparable to normal discharges associated with operating reactors, and would likely remain below limits in 10 CFR Part 50, Appendix I.* (NRC 2013b, page lviii, lines 31-34)

[2] "Significant impacts" is used throughout this declaration in referring to the adverse consequences that could occur if a spent fuel pool leak is not readily detected. Section VIII of this declaration addresses several factors that the NRC apparently fails to consider when evaluating potential significant impacts.

3.14 The conclusion in the WC DGEIS that spent fuel pool leak impacts are insignificant is based on three key assumptions. First, the WC DGEIS assumes that any leak rate greater than 100 gallons per day (gpd) will be readily detected. The NRC explains the basis for this assumption in the WC DGEIS as follows:

> *Based on operational experience, the model leak used for analysis here is assumed to correspond to a leak rate of approximately 380 L/day (100 gpd). … In analyzing the impacts of a spent fuel pool leak, the NRC assumed a leak rate similar to the rate of water lost due to evaporation, which would effectively double the makeup rate to the spent fuel pool. A leak of this magnitude would likely be identified in an expeditious manner because of licensee monitoring and surveillance.* (NRC 2013b, page E-10, lines 9-14)

As discussed in Sections IV, V and VI below, this assumption is flawed because past spent fuel pool leaks suggest that leaks of up to and perhaps greater than 100 gallons per day may not be detected within weeks, months, or even years. Licensees are not even legally required to have functioning spent fuel pool water level instrumentation or groundwater monitoring systems during the 60-year short-term storage period, except during very limited and special situations. In addition, this assumption is not supported by any evaluation showing that leaks smaller than 100 gallons per day would be detected before causing significant impacts.

3.15 Second, the WC DGEIS assumes that:

> *A strong regulatory framework that includes both regulatory oversight and licensee compliance is important to the continued safe storage of spent fuel*. (NRC 2013b, page B-15, lines 27-28)

***

> *The analyses in this draft GEIS are based on current technology and regulations.* (NRC 2013b, page 1-17, line 21)

As discussed in Section VII below, this assumption is flawed because it relies on regulatory requirements and measures in place for operating reactors without considering the significant reduction in regulatory requirements and oversight that occurs during storage after reactors cease operating.

3.16 Third and last, the WC DGEIS assumes that potential adverse consequences from spent fuel pool leaks will be minimal. As discussed in Section VIII below, this assumption is not valid because the NRC failed to properly consider consequences like property devaluations and remediation costs that could occur when spent fuel pools leak.

IV. THE WC DGEIS FAILS TO FULLY AND PROPERLY APPLY EXPERIENCE FROM PAST SPENT FUEL POOL LEAKS IN ASSESSING FUTURE SPENT FUEL POOL LEAK RISKS

4.1 In the WC DGEIS, the NRC states:

> *Available data and information indicate that spent fuel pool leakage has occurred at the 13 sites listed in Table E-4*. (NRC 2013b, page E-19, lines 25-27)

Table E-4 in the WC DGEIS, reproduced below, lists sixteen reactors at thirteen U.S. nuclear power plants that experienced spent fuel pool leaks.

Table E-4. Occurrence of Spent Fuel Pool Leakage at U.S. Nuclear Power Plants

Site	Date(s) of Leak Discovery	Radioactive Liquid Released to Environment?	Radionuclides Detected
Hatch	December 1986	Yes	Tritium
Indian Point (Units 1 and 2)	August 2005; Unit 1 leakage predates August 2005	Yes	Tritium, nickel-63, cesium-137, strontium-90, and cobalt-60
Palo Verde (Unit 1)	July 2005	Yes	Tritium, cobalt-60, antimony-125, and cesium-137
Salem (Units 1 and 2)	September 2002 (Unit 1) 2010 (Unit 2)	Yes	Tritium
San Onofre (Unit 1)	1986	Yes[(a)]	Tritium, cesium-137
Seabrook	June 1999	Yes	Tritium
Watts Bar (Unit 1)	August 2002	Yes	Tritium and mixed fission products
Crystal River (Unit 3)	2009	No[(b)]	—
Davis-Besse (Unit 1)	2000	No[(b)]	—
Diablo Canyon (Units 1 and 2)	2010	No[(b)]	—
Duane Arnold	1994	No[(b)]	—
Hope Creek	2009	No[(b)]	—
Kewaunee	2007	No[(c)]	—

Sources: NRC 2006b; NRC 2010c; NRC 2010d; Copinger et al. 2012

(a) Contaminated groundwater was discovered during the decommissioning of San Onofre Unit 1. The source of the contaminated water was not clearly identified, but was suspected to have originated from any of three sources, one of which was leakage from the spent fuel pool that occurred from 19861989 (NRC 2010d). Environmental monitoring performed by the licensee subsequent to the leak did not identify radionuclides in the environment attributable to San Onofre (SCE 1995).

(b) Leaked spent fuel pool water was contained within spent fuel pool leakage-collection system.

(c) White boric acid deposits, possibly boric acid, observed on the wall and ceiling of the waste drumming room adjacent to the spent fuel pool.

Only one (Indian Point Unit 1) of these 16 nuclear power reactors was permanently shut down at the time its leaking spent fuel pool was detected. That reactor had two adjacent nuclear power reactors in operation at the time of the discovery. Thus, no site with only permanently shut down reactors has ever identified a leaking spent fuel pool. It's not conclusive whether this means that no pools have leaked or means that leaking pool(s) have not yet been identified.

4.2 The WC DGEIS fails to include at least two important spent fuel pool leak events: the Yankee Rowe nuclear reactor leak and the Brookhaven National Laboratory leak. By omitting these leaks from the WC DGEIS, NRC has failed to consider all past spent fuel pool leaks and formed an inaccurate picture of the potential for future leaks.

A. Yankee Rowe Leak

4.3 The WC DGEIS fails to consider the spent fuel pool leak at the Yankee Rowe nuclear plant in Massachusetts. The Yankee Rowe leak is important because approximately two million gallons of radioactively contaminated water leaked for perhaps as long as three years before it was detected. Some of this radioactive contamination made its way into nearby springs that flow into the Deerfield River.

4.4 The plant's owner reported this leak to the NRC in July 2006 along with other leaks and spills of radioactively contaminated water at the site. The owner's submittal highlighted the spent fuel pool leak:

> *The most noteworthy release that is believed to be the predominant source of tritium in groundwater, occurred between 1963 and 1965 and involved a leak from the Spent Fuel Pool – Ion Exchange Pit structural interface. This leak is estimated to have resulted in the release of over two million gallons of water to the soil. Tritium concentrations exceeding 1,000,000 pCi/L were measured in Sherman Spring at the time of the leak. The spring discharges on licensed property and flows into the Deerfield River.* (YAEC 2006)[3]

4.5 This Yankee Rowe leak resulting in measured tritium concentrations exceeding one million picocuries per liter[4] with flow into a nearby river should have been evaluated by the NRC in the WC DGEIS. The leak was reported to have occurred between 1963 and 1965—indicating a maximum duration of three years and perhaps lasting less than one year. Two million gallons leaking over a three-year period translates into an average leak rate of 1,826 gallons per day.[5] If the duration was two years, the average leak rate was 2,740 gallons per day. If the duration was only one year, the average leak rate was over 5,479 gallons per day. (For this leak rate to have been "only" 100 gallons per day, the leak would have had to span 54 years, 9 months, and 16 days.) In the WC DGEIS, the NRC assumes that spent fuel pool leakage of 100 gallons per day and greater will be readily detected. The Yankee Rowe leak strongly suggests that leak rates far greater than 100 gallons per day can remain undetected for a long time. The WC DGEIS must explicitly identify the regulatory requirements that remain in place during the 60-year short-term storage period that provide reasonable assurance that future leaks similar to the Yankee Rowe leak—or worse—cannot result in significant impacts.

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[3] The owner's report did not indicate whether the water leak from the spent fuel pool or the ion exchange pit or from both places. Regardless, this event demonstrates that radioactively contaminated water can leak at large rates for a long time without being detected—directly contradicting the assumption in the WC DGEIS being challenged in this declaration.

[4] For context, EPA's regulatory limit for tritium in drinking water is 20,000 picocuries per liter.

[5] Calculated by dividing 2,000,000 gallons by 1,095 days.

4.6 By failing to evaluate this Yankee Rowe leak, the NRC has also failed to establish how this leak was detected. If the leak was detected fortuitously rather than by a formal monitoring process, the WC DGEIS should have considered potential impacts had this leak remained undetected for a longer duration.

B. Brookhaven National Laboratory (BNL) Leak

4.7 NRC has failed to consider the longstanding leakage of radioactively contaminated water from the spent fuel pool at the Brookhaven National Laboratory (BNL) on Long Island, New York.[6] The BNL leak is important because a leak went undiscovered for over a decade, despite extensive, focused monitoring and inspection programs. The NRC did not consider the BNL spent fuel pool leak in the WC DGEIS and therefore failed to demonstrate how the factors that contributed to the BNL leak remaining undetected for such a prolonged period could not also allow a larger and/or longer leak from a spent fuel pool during the 60-year short-term period following permanent reactor shutdown.

4.8 According to a 1997 report by the U.S. General Accounting Office, now called the Government Accountability Office, (GAO) found within the NRC's Agencywide Documents Access and Management System (ADAMS):

> *In January 1997, ground water samples taken by BNL staff revealed concentrations of tritium that were twice the allowable federal drinking water standards–some samples taken later were 32 times the standard. The tritium was found to be leaking from the laboratory's High Flux Beam Reactor's spent fuel pool into the aquifer that provides drinking water for nearby Suffolk County residents*. (GAO 1997, page 1)

4.9 The NRC relies on spent fuel pool water level monitoring and groundwater monitoring in concluding in the WC DGEIS that spent fuel pool leaks could not possibly remain undetected for a long period of time. But both these measures failed to prevent such an outcome at BNL:

> *DOE's and BNL's investigation of this incident concluded that the tritium had been leaking for as long as 12 years without DOE's or BNL's knowledge*. (GAO 1997, page 1)
>
> *Tests conducted after the tritium leak was discovered more accurately accounted for evaporation rates and concluded that the pool was leaking 6 to 9 gallons per day*. (GAO 1997, page 10)

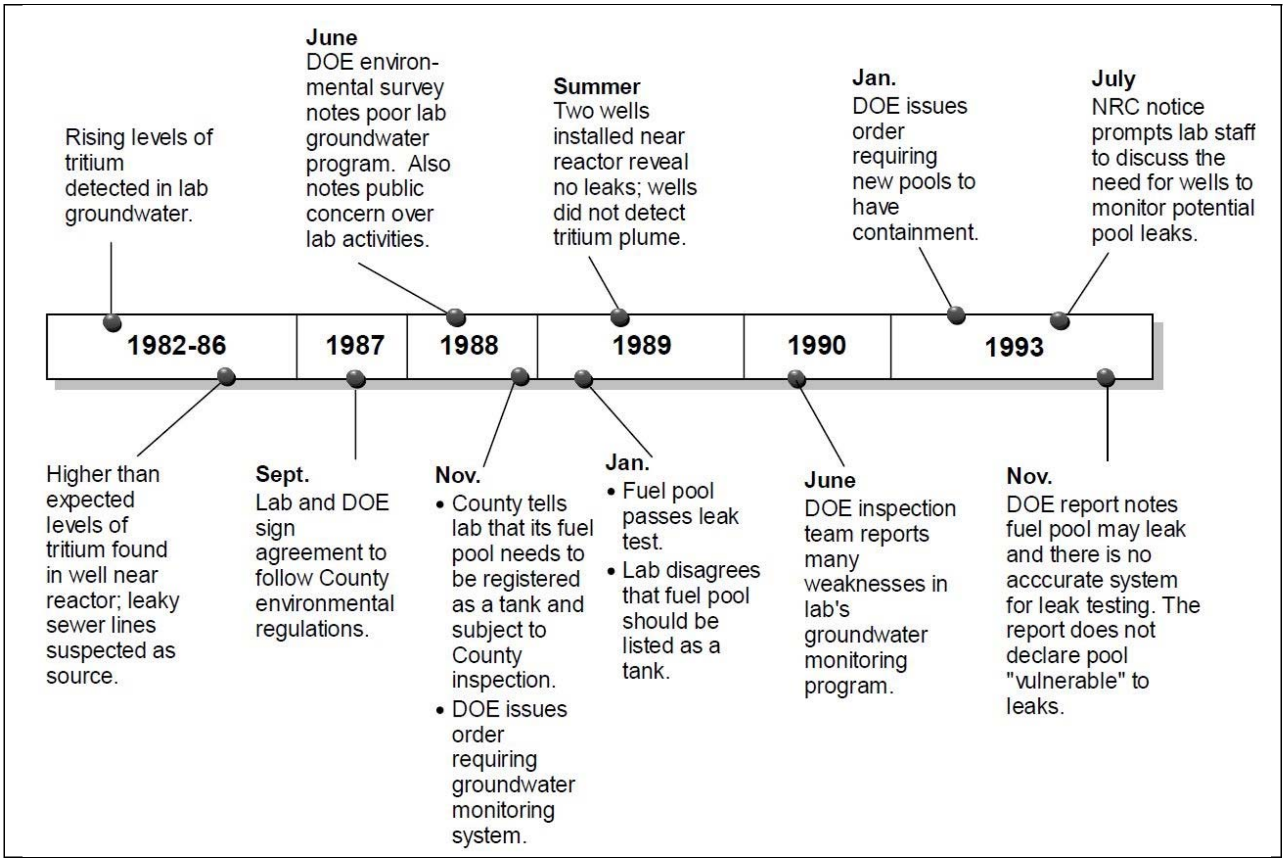
4.10 That the BNL leak remained undiscovered for over a decade clearly illustrates that detection of radioactively contaminated water in monitoring wells or the surrounding soil does not necessarily lead to finding a leaking spent fuel pool. According to the GAO's report:

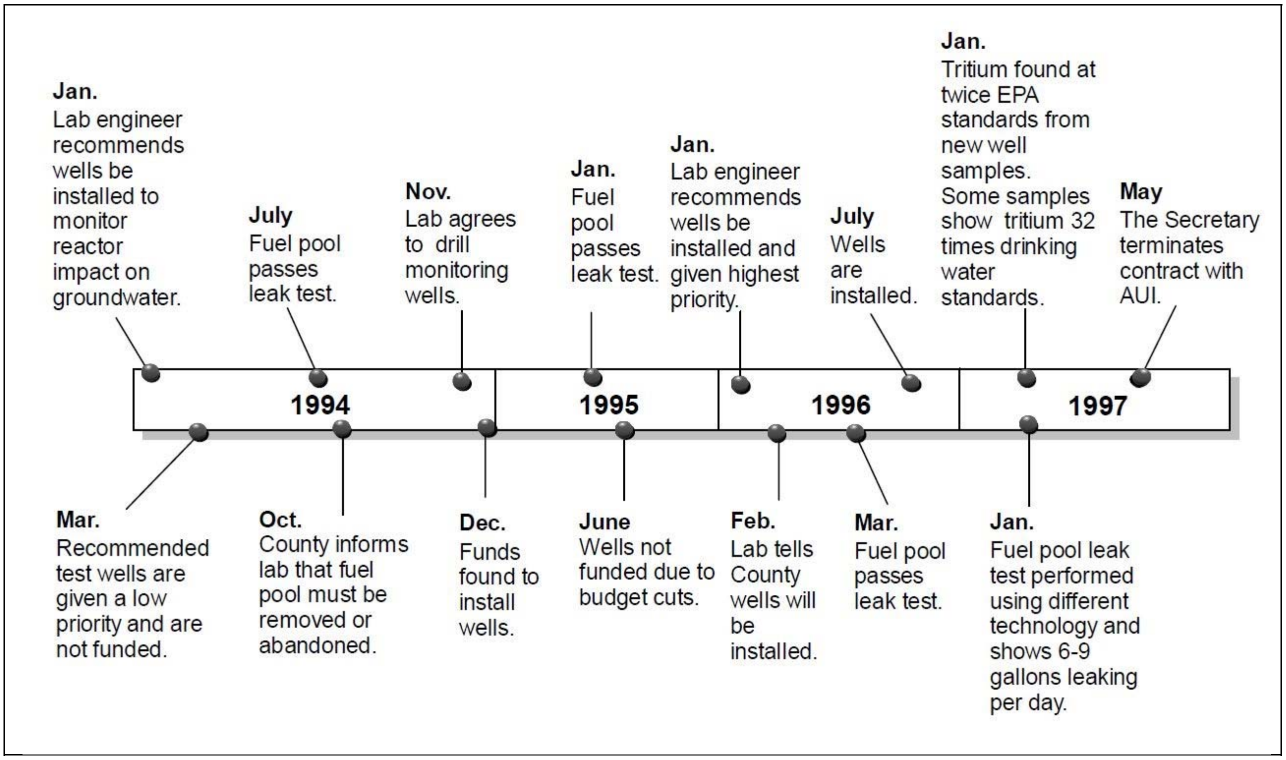
> *In January 1997, ground water samples taken by BNL staff revealed concentrations of tritium that were twice the allowable federal drinking water standards–some samples*

[6] The BNL and its spent fuel pool are not licensed or regulated by the NRC. It is regulated by the U.S. Department of Energy (DOE). But this spent fuel pool leak should be known to the NRC, evidenced by the 1997 GAO report residing within the NRC's electronic library.

> *taken later were 32 times the standard. The tritium was found to be leaking from the laboratory's High Flux Beam Reactor's spent fuel pool into the aquifer that provides drinking water for nearby Suffolk County residents.* (GAO 1997, page 1)

4.11 The following two panels from Figure 1 of the GAO report highlight events occurring between the initial detection of radioactively contaminated water (i.e., tritium) in the soil around BNL and the ultimate discovery of leakage from the spent fuel pool more than a decade later.





4.12 Radioactively contaminated water was detected in monitoring wells during the 1980s, but because the spent fuel pool is not the only potential source of such contamination, it was not considered to be the source:

> *Higher than expected levels of tritium were first discovered in a drinking water well about 500 feet from the reactor in 1986. BNL officials at the time reasoned that the tritium came from local sewer lines and did not suspect the reactor's spent-fuel pool as a source. Sewer lines were a known source of tritium. Tritium originated from condensation that forms inside the reactor building and eventually reached the laboratory's sewer system. No further samples were taken from this well, which was closed because of high levels of other nonradioactive contaminants*. (GAO 1997, pages 7-8)

4.13 Workers tested the spent fuel pool for leaks in January 1989, July 1994, January 1995, and March 1996. Each test concluded was that the spent fuel pool was not leaking. In January 1997, workers conducted a fifth spent fuel pool leak test. This time leakage was detected. These tests were essentially self-fulfilling prophecies, showing no leakage when no leakage was believed to be occurring and finding leakage after monitoring well results suggested leakage was happening.

> *BNL officials acknowledge, in retrospect, that these tests were not carefully conducted because laboratory staff failed to accurately measure the spent-fuel pool's evaporation rate. Tests conducted after the tritium leak was discovered more accurately accounted for evaporation rates and concluded that the pool was leaking 6 to 9 gallons per day*. (GAO 1997, page 10)

> *Using BNL's data as support, a 1993 DOE report noted that the spent-fuel pool was not leaking. The report also noted, however, that there was no reliable means of determining if the spent-fuel pool was leaking*. (GAO 1997, page 8)

4.14 In the summer of 1989, workers installed two additional monitoring wells near the reactor and its spent fuel pool. Samples from these wells did not indicate a leak was in process; not because a leak was not occurring but because they were not in locations to detect an underground plume:

> *BNL officials also relied on well-sampling results to reinforce their position that the spent-fuel pool was not leaking, but these samples did not provide adequate coverage of the area surrounding the reactor where the spent-fuel pool was located*. (GAO 1997, page 10)

4.15 Workers at BNL conducted leak tests of the spent fuel pool and installed monitoring wells to detect radioactively contaminated water leaking into the ground. But rather than causing timely detection of a leaking spent fuel pool, these measures instead gave BNL officials false confidence, and thereby enabled the leakage to continue unabated:

> *Reliance on incomplete tests of water level in the spent-fuel pool and on sample data from monitoring wells scattered around the site led Brookhaven and DOE officials to give low priority to a potential tritium leak.* (GAO 1997, page 2)

***

> *To allay the [Suffolk] country's concerns, BNL said that the pool did not leak because it had successfully passed a leak test in 1989. BNL also said that two monitoring wells that were installed in 1989 near the reactor did not indicate any leaking from the reactor's spent-fuel pool. Although BNL officials later told us that the leak test was not accurate and that the two monitoring wells they installed earlier were in the wrong location to detect the tritium contamination, BNL officials relied on these data as the basis for their confidence that the spent-fuel pool did not leak*. (GAO 1997, page 8)

4.16 It is important to recognize that at BNL, a long-term, low-volume leak from the spent fuel pool occurred due to unreliable water level instrumentation, misplaced monitoring wells, and misdiagnosed monitoring well results. This event and its contributing factors cast extreme doubt on the NRC's spent fuel pool leak evaluation in the WC DGEIS:

> *As a result, this evaluation considers a long-term, low-volume undetected leak from a spent fuel pool as the most probable scenario where spent fuel pool leakage would lead to an offsite environmental impact. To go undetected, a leak would need to be less than the fluctuations in water level of a spent fuel pool due to evaporation. This is so because the spent fuel pool water level is constantly measured by instrumentation and monitored routinely by the reactor operators. Also, licensees must perform routine inspections of leak-detection systems and physically inspect the spent fuel pool area for leakage.* (NRC 2013b, page E-10, lines 1-8)

4.17 If the BNL spent fuel pool leaked at 6 to 9 gallons per day for 12 years, then 26,280 to 39,420 gallons of radioactively contaminated water reached the ground before being detected and terminated. This longstanding leak is an important example that NRC should have considered in the WC DGEIS. The WC DGEIS must explicitly identify the regulatory requirements that remain in place during the 60-year short-term storage period that provide reasonable assurance that future leaks similar to the BNL spent fuel pool leak—or worse—cannot result in significant impacts.

C. Salem Leak

4.18 An event at the Salem nuclear plant in New Jersey is a compelling example that an undetected spent fuel pool leak close to the maximum evaporation rate of about 100 gallons per day (gpd) might not be promptly detected. In other words, this event contradicts the conclusion stated in the WC DGEIS that leaks of this magnitude would be promptly detected.

4.19 Like the majority of U.S. nuclear power reactors, the spent fuel pools for Salem's two reactors have reinforced concrete walls and floors. To prevent outward leakage through the porous concrete, each spent fuel pool is equipped with a stainless steel liner. The small space between the liner and the concrete collects spent fuel pool water leaking through the liner. The tell-tale drain routes this water to collection tanks for treatment and then either re-use or release.[7] The tell-tale drain lines became nearly fully obstructed at Salem. Instead of leaking water flowing through the tell-tale drain lines to the collection tank, spent fuel pool water leaked into the space between the stainless steel liner and the concrete. Some of the spent fuel pool water then leaked outward through the concrete. When blockage of the tell-tale drain lines was finally noticed, workers were sent to clean out the lines. When the tell-tale drain line blockage was removed, the measured and indicated leak rate increased:

> *After the cleaning effort [for the tell-tale drains], the leak rate from the tell-tale drain increased from about 19 liters per day (5 gallons a day) to about 380 liters per day (100 gpd).* (NRC 2004, page 2)

4.20 Some, or all, of this 100 gallon per day flow could have been radioactively contaminated water leaking from the spent fuel pool.[8]

4.21 The leak was finally detected when water leaked through a concrete wall and puddled on the floor of an adjacent room. Thus, the leak of up to 100 gallons per day from the Salem spent fuel pool was *not* detected by the spent fuel pool water level instrumentation or the system installed specifically to detect such leakage. (Salem was an operating reactor at the time with hundreds of workers present to limit the amount of time the puddle remained undetected. Had Salem instead been in the short-term storage period, it is less certain that the much smaller work force making far less frequent trips through the permanently closed plant would have found this leak as quickly. The WC DGEIS must explicitly identify the regulatory requirements that remain

[7] In the WC DGEIS (NRC 2013b, page E-19), this is labeled the leak chase system.

[8] It was not reported how much of this flow was attributed to inward leakage of groundwater through the concrete and how much of it was spent fuel pool water outward through the stainless steel liner.

in place during the 60-year short-term storage period that provide reasonable assurance that future leaks similar to the Salem spent fuel pool leak—or worse—cannot result in significant impacts.)

4.22 Making matters worse, the leak detection system at Salem not only failed to promptly detect leakage from the spent fuel pool, it caused that leakage to reach the environment and contaminate surrounding soil. Had the leak detection system not become blocked, water leaking from the spent fuel pool would have flowed through the tell-tale drain lines to a collection tank. The leakage would have been monitored and stored in a tank specifically designed to hold radioactively contaminated water. Instead, the radioactively contaminated water leaked through concrete walls into the neighboring soil.

4.23 The State of New Jersey compelled Salem's owner to remediate the contaminated soil. On February 16, 2005, workers began pumping water out of extraction wells at the Salem site. The campaign was to process this groundwater to remove radioactivity from it, essentially recovering the radioactivity that had leaked from the spent fuel pool. As of September 2011, over 28 million gallons of groundwater had been recovered and processed (Arcadis, 2012). It represents 28 million reasons *not* to believe that spent fuel pool leaks will be detected before causing significant impact.

D. Indian Point leaks

4.24 Leaks from the spent fuel pools at two of the three reactors at the Indian Point nuclear plant in New York are listed in Table E-4 of the WC DGEIS, but their circumstances are not discussed in much detail. As with the other leaks discussed above, the Indian Point leaks contradict the WC DGEIS in important ways.

4.25 The owner of the Indian Point nuclear plant in New York informed the NRC about leakage from the Unit 2 spent fuel pool (SFP) in the 1990s:

> *It is believed that SFP water leaked out of the construction joint at a rate of about 50 gallons per day for about 2 years, leaking into the underlying ground water.* (Entergy 2008)

4.26 Workers inadvertently punctured the stainless steel liner inside the Indian Point Unit 2 spent fuel pool while modifying the storage racks for spent fuel inside the pool. The hole was repaired, but water collected in the space between the liner and the concrete walls and floor of the pool. The plant's owner estimated that approximately 36,500 gallons of radioactively contaminated water flowed from this location to a construction joint (seam) in the concrete. Water leaked past this joint into the soil and "underlying groundwater" (Entergy 2008, page 2).

4.27 This leak remained undetected until another leak from the same spent fuel pool was discovered in 2005. At that time, workers were excavating the ground outside the Unit 2 fuel handling building and noticed moisture forming on the exposed concrete wall. That discovery prompted an investigation that revealed this ongoing leak through the concrete wall and led to the discovery of the earlier leak through the construction joint (Entergy 2008).

4.28 The leak rate of water from the spent fuel pool through the construction joint was estimated to be 50 gallons per day. That leak remained undetected while it was occurring—the leak was only identified and quantified long after the fact. For the WC DGEIS, the NRC assumed that a leak rate of 100 gallons per day would be readily detected. But the NRC failed to evaluate a longstanding leak of less than 100 gallons per day. In other words, if this undetected leakage of 50 gallons per day had continued leaking throughout the 60-year short-term storage period instead of only two years, it might have resulted in significant impacts.

4.29 In addition, according to a recent evaluation by a consultant retained by Indian Point's owner, leakage from the Unit 2 spent fuel pool may be continuing at a rate of between 10 and 30 gallons per day (GZA 2012, footnote 6). If such leakage persists for 60 years, 219,000 to 657,000 gallons will leak. The inability to determine whether past leakage has been stopped also casts considerable doubt on the ability to definitively conclude whether future leakage has started. After all, contamination measured in a groundwater well can easily be attributed to the old source and not initiate an investigation for a new, and perhaps more significant, source.

4.30 Such masking factored heavily into the reactor vessel head degradation near-miss at the Davis-Besse nuclear plant when workers and the NRC misdiagnosed boric acid accumulation on the outer surface of the reactor vessel head as coming from control rod drive mechanism flange leakage, a recurring problem at this site across several years. When later leakage occurred through the control rod drive mechanism itself—a significantly larger potential hazard—the owner and the NRC missed opportunities to detect and correct it in a timely manner. Boric acid accumulation was falsely blamed on the old, recurring benign source instead of to the new, emerging malignant source (NRC 2002).

4.31 The WC DGEIS fails to conclusively show either that smaller leak rates (e.g., less than 100 gallons per day) can be detected in a timely manner or that smaller leaks cannot possibly result in significant impact. The WC DGEIS must explicitly identify the regulatory requirements that remain in place during the 60-year short-term storage period that provide reasonable assurance that future leaks similar to the Indian Point spent fuel pool leaks—or worse—cannot result in significant impacts.

E. Pattern of Not Discussing Causes of Spent Fuel Pool Leaks in the WC DGEIS

4.32 As discussed above for the Salem and Indian Point spent fuel pool leak events, the NRC does not describe in the WC DGEIS how the leakage was ultimately detected. This is also true for all the other spent fuel pool leak events listed on Table E-4 in the WC DGEIS. Obviously, it is also true for the Yankee Rowe and BNL spent fuel pool leak events since the NRC does not mention them at all in the WC DGEIS.

4.33 By failing to explicitly describe how these past spent fuel pool leaks were detected, the NRC also fails to demonstrate how future spent fuel pool leaks would be discovered. In the WC DGEIS, the NRC must explain how past leaks were detected and identify the regulatory requirements that remain in place during the 60-year short-term storage period that provide reasonable assurance that future leaks will be detected.

V. THE WC DGEIS FAILS TO PROPERLY CONSIDER THE DIFFICULTIES INHERENT IN SPENT FUEL POOL LEAK DETECTION

5.1 The NRC's analysis for the WC DGEIS of spent fuel pool leak detection is flawed because it fails to consider the inherent difficulties associated with leak detection and because its 100 gallon per day threshold for effective leak detection lacks solid foundation. The WC DGEIS simply fails to demonstrate that leaks with greater or less than 100 gallons per day will be detected before causing significant impacts.

5.2 The NRC assumes in the WC DGEIS that spent fuel pool leakage equal to the average evaporation rate of water from spent fuel pools would be promptly detected and therefore could be promptly stopped and remediated. The WC DGEIS explains the basis for this assumption as follows:

> *Based on operational experience, the model leak used for analysis here is assumed to correspond to a leak rate of approximately 380 L/day (100 gpd). … In analyzing the impacts of a spent fuel pool leak, the NRC assumed a leak rate similar to the rate of water lost due to evaporation, which would effectively double the makeup rate to the spent fuel pool. A leak of this magnitude would likely be identified in an expeditious manner because of licensee monitoring and surveillance.* (NRC 2013b, page E-10, lines 9-14)

5.3 This assumption is flawed in the following respect. When a spent fuel pool leaks onto the floor or into a surrounding plant area, the puddle formed helps assure timely detection (see paragraph 4.21 of this declaration for such an example). But when a spent fuel pool leaks into the ground, detection becomes more complicated and timely detection less certain (see paragraphs 4.25 to 4.28 of this declaration for such an example). As the NRC noted in a separate study on leaks of radioactively contaminated water into the groundwater:

> *SFP [spent fuel pool] leak detection may require special techniques since SFPs have an evaporation rate up to several hundred gallons per day. This evaporation rate may mask small leaks in the SFP liner and make small leakage rates difficult to detect by evaluation of make-up rates within a water balance calculation.* (NRC 2006a, page 6)

5.4 In the WC DGEIS, the NRC assumes that the spent fuel pool will leak at a rate equal to an evaporation rate of 100 gallons per day. As discussed in paragraph 4.5 of this declaration, the leak rate at the Yankee Rowe plant significantly exceeded 100 gallons per day and yet remained undetected until two million gallons had been released. But the NRC neither lists this reported leak in Table E-4 of the WC DGEIS nor discusses it anywhere within the report. The Yankee Rowe leak undermines—if not totally refutes—the validity of the NRC's assumption that spent fuel pool leaks of 100 gallon per day or greater would be discovered in a timely manner.

5.5 Likewise, potential leakage of 100 gallons per day from spent fuel pool at Salem might not have been detected in a timely manner (see paragraphs 4.19 to 4.21 of this declaration).

5.6 Thus, the WC DGEIS is flawed because the NRC wrongly assumes that spent fuel pool leaks of 100 gpd and larger would be detected and stopped in a timely manner and that the leaked water would pose no significant impacts.

5.7 The WC DGEIS is also flawed because it fails to show that spent fuel pool leak rates of less than 100 gpd will be detected before causing significant impacts. As previously described in paragraphs 4.7 to 4.17 of this declaration, workers eventually discovered that the spent fuel pool at BNL had been leaking at a rate of 6 to 9 gallons per day for over a decade. Four prior spent fuel pool leak tests at BNL failed to properly account for evaporation rates and missed opportunities to detect a leak. And as discussed in paragraph 4.29 above, the Unit 2 spent fuel pool at the Indian Point nuclear plant may still be leaking at 10 to 30 gallons per day.

5.7 The WC DGEIS cannot summarily dismiss that significant impacts might result from spent fuel pool leaks smaller than 100 gallons per day. Instead, the NRC must either (a) show that smaller leaks cannot result in significant impacts even when undetected throughout the 60-year short-term storage period, or (b) identify the regulatory requirements providing reliable assurance that a smaller leak would be detected before it has significant impact. The WC DGEIS cannot merely wish significant impacts away.

5.8 A showing that smaller leaks for prolonged periods cannot result in significant impacts could be made by evaluating potential consequences from the most vulnerable location (i.e., the site where leakage is most likely to have significant impacts due to factors such as the geology, hydrology, population demographics, etc.) against acceptance criteria coupled with confirmatory checks before reactors enter the 60-year short-term storage period that the sites are not more vulnerable. An alternative to this bounding evaluation would be a regulatory requirement that all licensees conduct site-specific evaluations prior to their reactors enter the 60-year short-term storage period.

VI. THE WC DGEIS RELIES ON INCORRECT ASSUMPTIONS ABOUT THE COVERAGE AND APPLICABILITY OF MONITORING REQUIREMENTS

6.1 In concluding that spent fuel pool leaks will be detected in a timely manner, the WC DGEIS relies on the current existence and continuing applicability of a robust set of regulatory requirements for monitoring spent fuel pool water levels and monitoring the groundwater at the site for radioactive contamination, as well as maintenance of spent fuel pools. These assumptions are simply wrong. The requirements are neither robust nor continuing. Even during the more vigilant period of reactor operation, the key requirement on which NRC relies—monitoring of spent fuel pool water levels—applies only in very limited circumstances. And there is no requirement in NRC regulations at all for regular groundwater monitoring during reactor operation and after the reactor permanently shuts down. While the nuclear industry has developed a voluntary groundwater monitoring program, such voluntary measures could be terminated at any time, at the discretion of the industry. And while NRC inspectors have audited the implementation of the voluntary measures at reactors that are presently operating, they did not audit the measures at the reactors that have already permanently shut down and have no stated plans to conduct further audits anywhere. Therefore, the NRC has no basis for relying on these voluntary measures during the 60-year short-term storage period. Thus, a close look shows that the assumption in the WC DGEIS about strong regulatory oversight—an essential underpinning of the NRC's risk and impact prediction for spent fuel pool leaks—is tenuous at best and an illusion at worst.

A. Limited Spent Fuel Pool Water Level Monitoring Requirements

6.2 According to the WC DGEIS, during the short-term storage period:

> *Significant short-term water loss from a spent fuel pool is likely to be identified due to licensee monitoring of spent fuel pool water levels.* (NRC 2013b, page E-9).

But this conclusion is undermined by gaps in the NRC's regulatory requirements governing spent fuel pool water level monitoring.

6.3 When the NRC issues an operating license for a nuclear power reactor, an appendix to the license contains the technical specifications. The technical specifications establish the minimum complement of equipment needed for safety, the testing and inspections required to assure reliability of this equipment, and the remedial measures to be taken when necessary equipment is unavailable.

6.4 The NRC developed Standard Technical Specifications for reactors designed by the different vendors (e.g., Westinghouse, Combustion Engineering, Babcock & Wilcox, and General Electric). Many owners have formally obtained NRC permission to tailor the Standard Technical Specifications to their reactors. In any case, the custom technical specifications for the remaining reactors are comparable in technical content; the primary difference being in the organization and presentation of that technical content.

6.5 The minimum complement of equipment is defined by Limiting Conditions for Operation (LCOs) and applicability statements. For example, an LCO might require two safety pumps to be available when the reactor is operating but only one safety pump when the reactor is shut down.

6.6 LCO 3.7.8 of the NRC's Standard Technical Specifications covers the minimum water level necessary for safety in the boiling water reactors manufactured by General Electric:

> *LCO 3.7.8 The spent fuel pool water level shall be > [23]*[9] *ft over the top of irradiated fuel assemblies seated in the spent fuel storage pool racks*. (NRC 2012b, page 3.7.8-1)

6.7 The associated applicability statement defines when the water level must satisfy this LCO:

> *APPLICABILITY: During movement of irradiated fuel assemblies in the spent fuel storage pool.* (NRC 2012b, page 3.7.8-1)

6.8 Thus, there is a regulatory requirement that the water level be above a certain level in the spent fuel pool *only* when irradiated fuel assemblies are being moved within the pool.

6.9 The reason for this minimum spent fuel pool level and when it is applicable is described in the Bases document developed by the NRC for the General Electric Standard Technical Specifications:

> *BACKGROUND The minimum water level in the spent fuel storage pool meets the assumptions of the iodine decontamination factors following a fuel handling accident*. (NRC 2012c, page B 3.7.8-1)

> *LCO: The specified water level preserves the assumptions of the fuel handling accident analysis. As such, it is the minimum required for fuel movement within the spent fuel storage pool*. (NRC 2012c, page B 3.7.8-1)

> *APPLICABILITY: This LCO applies during movement of irradiated fuel assemblies in the spent fuel storage pool since the potential for a release of fission products exists.* (NRC 2012c, page B 3.7.8-1)

6.10 The minimum spent fuel pool water level requirement protects against radiation released during a fuel handling accident such as when an irradiated fuel assembly drops onto other irradiated fuel assemblies damaging fuel rods and releasing radioactive gases and particles. This exclusive role for the required water level is reinforced by the measures mandated in the Standard Technical Specifications should the requirement not be met:

> *ACTIONS A. Spent fuel storage pool water level not within limit.*

[9] The number in brackets is a convention used within the Standard Technical Specifications to denote a value determined by reactor-specific calculations. For the majority of reactors, the bracketed value will be retained—for some reactor, the site-specific value may be slightly higher or lower as dictated by individual designs.

> *REQUIRED ACTION A.1 Suspend movement of irradiated fuel assemblies in the spent fuel storage pool*. (NRC 2012c, page 3.7.8-1)

6.11 It is, therefore, not required that the water level in the spent fuel pool be restored to above the minimum level or even that a declining water level be halted—all that is required is that the movement of irradiated fuel assemblies within the spent fuel pool be halted.

6.12 For the minimum spent fuel pool water level requirement specified by LCO 3.7.8 to be satisfied, another provision in the Standard Technical Specifications requires that the instrumentation used to measure the level be functional. Specifically, the definition of OPERABLE[10] in Section 1.1, Definitions, of the Standard Technical Specifications states:

> *A system, subsystem, division, component, or device shall be OPERABLE or have OPERABILITY when it is capable of performing its specified safety function(s) and when all necessary attendant instrumentation, controls, normal or emergency electrical power, cooling and seal water, lubrication, and other auxiliary equipment that are required for the system, subsystem, division, component, or device to perform its specified safety function(s) are also capable of performing their related support function(s).* (NRC 2012b, page 1.1-4)

6.13 This definition of OPERABLE applied to LCO 3.7.8 means that REQUIRED ACTION A.1 is invoked whenever the measured water level in the spent fuel pool drops within [23] feet of irradiated (spent) fuel assemblies in the pool's storage racks or whenever the water level instrumentation is unavailable to provide the measured level.

6.14 The relationship between the definition of OPERABLE and the APPLICABILITY statement in LCO 3.7.8 means that the instrumentation used to measure the water level in the spent fuel pool is only required to be available when irradiated (spent) fuel assemblies are being moved in the spent fuel pool. At all other times, the spent fuel pool water level instrumentation can be unavailable (i.e., non-functional) without invoking any out-of-service deadlines or required compensatory actions.

6.15 The NRC's regulatory requirements for water level inside spent fuel pools at pressurized water reactors are comparable:

> *LCO 3.7.15 The fuel storage pool water level shall be $\geq$ 23 ft over the top of irradiate fuel assemblies seated in the storage racks*. (NRC 2012d, page 3.7.15-1)
>
> *APPLICABILITY: During movement of irradiated fuel assemblies in the fuel storage pool.* (NRC 2012d, page 3.7.15-1)
>
> *ACTIONS A. Fuel storage pool water level not within limit.*

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[10] The capitalization of this word is a convention used within the Standard Technical Specifications for terms defined within Section 1.1. This convention alerts users to the fact that the terms have explicit meanings.

> *REQUIRED ACTION: Suspend movement of irradiated fuel assemblies in the fuel storage pool.* (NRC 2012d, page 3.7.15-1)
>
> *BACKGROUND The minimum water level in the fuel storage pool meets the assumptions of iodine decontamination factors following a fuel handling accident. The specified water level shields and minimizes the general area does when the storage racks are filled to their maximum capacity. The water also provides shielding during the movement of spent fuel.* (NRC 2012e, page B 3.7.15-1)
>
> *LCO The fuel storage pool water level is required to be ≥ 23 ft over the top of irradiated fuel assemblies seated in the storage racks. The specified water level preserves the assumptions of the fuel handling accident analysis*. (NRC 2012e, page B 3.7.15-1)
>
> *APPLICABILITY The LCO applies during movement of irradiated fuel assemblies in the fuel storage pool, since the potential for a release of fission products exists*. (NRC 2012e, page B 3.7.15-2)

6.16 Limiting the applicability of the minimum water level in the spent fuel pool to only when irradiated fuel assemblies are being moved decreases the likelihood that spent fuel pool leakage will be detected. When these LCOs are not applicable (i.e., when irradiated fuel assemblies are not being moved), it is not required that the instrumentation used to monitor the spent fuel pool water level be in service. Consequently, if the spent fuel pool water level instrumentation broke, there would be no regulatory requirement to return it to service. As a practical matter, under current regulations, the water level instrumentation—and the associated audible, visual, and computer alarms that are generated when water level drops too low—could remain out of service until just before the next planned movement of irradiated fuel assemblies within the spent fuel pool. Because irradiated fuel assemblies are seldom moved within the spent fuel pools, especially within spent fuel pools at reactors that have been permanently shut down, the water level instrumentation could be legally out of service for the overwhelming majority of the time. This reality undermines reasonable assurance that a low-volume spent fuel pool leak would be readily detected.

6.17 In the procedure used when examining spent fuel pools at permanently shut down nuclear power reactors, the NRC inspectors are tasked to:

> *Review and evaluate whether the SFP instrumentation, alarms and leakage detection systems are adequate to assure the safe wet storage of spent fuel.* (NRC 1997, Section 02.02)

6.18 The NRC's Standard Technical Specifications and their Bases define "safe wet storage of spent fuel" as being when at least 23 feet of water exists above the top of the storage racks when irradiated fuel is being moved. When irradiated fuel is not being moved, no regulatory requirement governs the amount of water in the spent fuel pool or the availability of water level instrumentation. Consequently, if an NRC inspector finds the spent fuel pool water level instrumentation out of service or water level inside the pool far below normal, he or she lacks regulatory leverage to compel either condition to be remedied.

6.19 Thus, these LCOs, which are inapplicable during storage because they only apply when spent fuel is being moved, are not supportive of NRC's conclusion that spent fuel pools are being constantly monitored and maintained. The WC DGEIS cannot place much weight on equipment and conditions unless they are required to be in place.

B. Limited Spent Fuel Pool Water Level Record-keeping Requirements

6.20 The NRC presumes in the WC DGEIS that its inspectors will review records such as those prepared by plant workers for tasks like providing makeup water to the spent fuel pool to compensate for evaporation and periodically logging the spent fuel pool water level, and will detect any spent fuel pool leakage (if the workers own efforts have not already discovered leakage). An NRC inspection procedure for examining spent fuel pools at permanently shut down nuclear power reactors appears—at first blush—to support this assumption by stating:

> *The SFP water level instrumentation and alarms should ensure that any significant loss of inventory will be promptly detected by operations personnel. … Operator rounds and control room logs should provide a data base sufficient to identify spent fuel pool leakage problems*. (NRC 1997, Section 03.02)

6.21 As discussed in paragraphs 6.6 to 6.16 of this declaration, however, there are no regulatory requirements in place during the short-term storage period that ensure spent fuel pool level instrumentation will routinely be available. Consequently, the NRC's assumption that routine spent fuel pool water level monitoring and record-keeping will detect spent fuel pool leakage is invalid. Again, the WC DGEIS cannot place much weight on equipment and conditions unless they are required to be in place throughout the 60-year short-term storage period.

C. Nonexistent Spent Fuel Pool Leak Analysis Requirements

6.22 Returning to the procedure used by NRC inspectors when examining spent fuel pools at permanently shut down nuclear power reactors, the NRC states:

> *Within the scope of this inspection, the inspector should evaluate the tests or analytical calculations performed to determine SFP leakage and evaporation rates. The assumptions in these tests and calculations should be assessed and evaluated. For example, a licensee may bound their analyses by a worst-case situation and normalized environmental conditions.* (NRC 1997, Section 03.02)

6.23 But there is no regulatory requirement for licensees to ever calculate spent fuel pool evaporation rates or analyze reasonably foreseeable leakage scenarios. The WC DGEIS states:

> *The safety of spent fuel storage is established for each facility through a safety analysis report prepared by the licensee to support its application for an operating license and review by the NRC. Each safety analysis report includes a number of operational conditions and limitations important to safe spent fuel storage. These conditions and*

> *limitations are subject to regulations that restrict the changes that can be implemented without prior NRC approval*. (NRC 2013b, page E-4, lines 18-22)

6.24 The NRC developed a Standard Review Plan (NUREG-0800) to guide its staff in reviewing safety analysis reports submitted by applicants for reactor operating licenses and determining whether all applicable regulatory requirements have been met. The Standard Review Plan also aides applicants in preparing their submittals to the NRC.

6.25 The spent fuel pool is not the only source of radioactively contaminated water at nuclear power plants. In fact, its water contains significantly lower concentrations of radioactivity than contained in other systems and components. For example, the liquid waste management system (LWMS) collects, stores, and processes highly radioactive liquids. Applicants for operating licenses evaluate the postulated failure of a large LWMS tank that results in most if not all its radioactive contents being released as described in Section 11.6 of the NRC's Standard Review Plan:

> *As a result, a gross failure of the LWMS is considered highly unlikely, e.g., such as a failure involving the near total loss of the system's inventory of radioactive materials. However, the malfunction of a tank and its components, a valve misalignment, tank overflow, or an operator error appear more likely and are assumed to be types of failures warranting an evaluation of their consequences. Although no specific types of system failures have been designated as being representative, it was considered that for the safety evaluation of the LWMS, the type of malfunction analyzed should be limited to the postulated failure of a tank or pipe rupture, located outside of containment. The evaluation considers the impact of the failure on the nearest potable water supply, and the use of water for direct human consumption or indirectly through animals (livestock watering), crops (agricultural irrigation), and food processing (water as an ingredient).* (NRC 2007, page BTP 11-6-2)

6.26 Note that a LWMS tank failure and its potential consequences to the environment are required to be analyzed despite this scenario being "considered highly unlikely" by the NRC.

6.27 The Tennessee Valley Authority evaluated the postulated release of radioactively contaminated water from LWMS tanks at its Browns Ferry Nuclear Plant (BFNP) in Alabama. TVA reported:

> *In order to assess the impact of a liquid radwaste spill on the nearest potable water supply surrounding the BFNP site, a study was conducted to determine if the limits of 10CFR20, Appendix B, Table 2, Column 2 will be exceeded. The results of the study involving a postulated release of liquid radwaste from the worst offending tank indicates that the limits of 10CFR20 will not be exceeded. The worst offending tank identified is the waste collector tank with a maximum operating volume of 38,000 gallons and maximum activity of 1.4E+8 microcuries.*[11] (TVA 2003, page 9.2-7)

[11] 1.4E+8 is scientific notation for 140,000,000.

6.28 TVA reported the results from its study for each LWMS tank in Table 9.2-4 of the Browns Ferry Updated Final Safety Analysis Report (shown below). The table reflects the waste collector tank holding the largest amount of radioactivity, thus posing the greatest hazard.

BFN-18

Table 9.2-4
(Sheet 1)

RADIOACTIVITY CONTENTS OF TANKS AND SYSTEMS NOT DESIGNED TO WITHSTAND TORNADO, MAXIMUM PROBABLE FLOOD OR DESIGN BASIS EARTHQUAKE

Vessel or System Name	Number of Tanks	Maximum Activity Per Tank or System (μCi) Total	Isotopic Distribution, Percent of Total Activity (b) Sr-89	Sr-90	Sr-91	Mo-99	1-131	1-133	1-135	Cs-134	Cs-137	Ba-140	Ce-144	Np-239	CO-58	CO-60
Waste Surge Tank	1	2.3×10^5	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Waste Sample Tank	4	2.1×10^5	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Floor Drain Sample Tank	2	1.2×10^5	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Laundry Drain Tank	2	3.6×10^4	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Waste Collector Tank	1	1.4×10^8	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
**Floor Drain Collector Tank	1 9.5×10^6	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1	
Cleanup Backwash Receiver Tank (a)	3	5.0×10^9	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Condensate Backwash Receiver Tank (a)	3	1.0×10^8	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Spent Resin Tank (a)	1	2.0×10^9	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Waste Backwash Receiver Tank (a)	1	2.0×10^8	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Chemical Waste	1	1.4×10^5	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Condensate Storage Tank	5	2.0×10^6	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Condensate Transfer System	-	6.0×10^4	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Condensate Filter/ Demineralizer Tanks (a)	27	1.0×10^9	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Fuel Pool Filter/ Demineralizer Tanks (a)	4	2.0×10^8	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Waste Demineralizer Tank (a)	1	3.0×10^8	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Evaporator Feed Tank	1	5.0×10^5	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Waste Filter Tank (a)	1	1.0×10^6	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1
Floor Drain Filter Tank (a)	1	9.0×10^5	0.7	0.2	8.6	18.3	8.6	14.3	6.4	0.1	0.2	18.3	0.1	18.6	1.0	0.1

6.29 Studies of postulated releases from LWMS tanks serve two important purposes. First, the results demonstrate compliance with federal regulations on discharges of radioactivity to the environment. Second, they define the boundaries for future plant activities.

6.30 As discussed in paragraphs 3.2 to 3.4 above, postulated losses of water inventory from the reactor vessel must be postulated and evaluated, regardless of the low likelihood of occurrence. As discussed in paragraphs 6.25 to 6.28 above, postulated losses of water inventory from LWMS tanks must be postulated and evaluated, again regardless of their likelihood. These evaluations define the respective hazards that federal regulations require protection against. Their results essentially form the answer keys when determining whether a reactor's design and procedures comply with federal regulations. Their results also establish boundaries for subsequent reactor operation. Before a license modifies the plant or revises its procedures, 10 CFR §50.59, Changes, tests and experiments, requires that the proposed activity be evaluated against the established boundaries. If an activity significantly increases the consequences or likelihood of a previously evaluated event, it cannot happen unless the NRC explicitly approves it.

6.31 Neither the NRC's Standard Review Plan nor any of the literally dozens of safety analysis reports submitted by plant owners analyze either a long-term, low-volume leak from a spent fuel pool or the rapid and complete loss of spent fuel pool water into the environment. The failure to analyze a spent fuel pool leak means that neither of the two purposes described in paragraphs 6.29 and 6.30 above is met. First, because the hazard is not defined, the adequacy of purported protective measures intended to manage the risk cannot be objectively assessed. Second, because a hazard evaluations results are not available to establish boundaries, there is no assurance that adequate protection will be sustained throughout the 60-year short-term storage period.

6.32 To illustrate the necessary role performed by hazard evaluations, consider a hypothetical case in which a spent fuel pool leak was postulated and evaluated. Suppose the results from that evaluation showed that a leak of up to X gallons per day could not cause significant impacts and that a leak of X gallons per day or greater could not cause significant impacts as long as it was detected within Y days. These results define how much water could be released via what specific pathways to facilitate objective determination whether NRC and EPA radiation protection standards will be met.

6.33 The results from the hypothetical hazard evaluation described in paragraph 6.32 above establish boundaries that provide assurance that risk continues to be properly managed into the future. For example, suppose the basis for concluding that leaks of up to X gallons per day not resulting in significant impacts relied on the combination of migration time required for leaked water to reach a source of drinking water and the filtering of radionuclides from the plume before it reached that source. The subsequent discovery that leaked water could enter an underground conduit and reach a drinking water source, effectively bypassing the delay and filtering functions of the geology/hydrology, would necessitate a re-evaluation to determine if the study's conclusion remained valid or required revision. As another example, suppose the means of detecting the X gallons per day or larger leak within Y days relies on weekly sampling from a close-in groundwater monitoring well. Before the frequency of sampling this well was relaxed to monthly or before this well was removed from service and replaced by a well three times more distant, an evaluation would need to conclude that a leak of X gallons per day or greater will still be detectable within Y days—otherwise, proper management of the risk of significant impacts is invalidated.

6.34 Absent the proper foundation afforded by a hazard evaluation, it is speculative to conclude that spent fuel pool leaks of 100 gallons per day will be detected before causing significant impacts. And even if such speculation was valid today, the conditions enabling that conclusion to remain valid throughout the short-term period are not explicitly defined. Consequently, owners could inadvertently undermine its validity by taking steps such as relaxing sampling frequencies, relocating wells, or removing water level instrumentation.

6.35 Risk management requires a hazard and its protections to both be defined as explicitly as possible. Doing so enables the risk to be properly managed now and into the future. By explicitly defining the hazard, one can determine when changing conditions increase the hazard, thus allowing protection levels to be increased accordingly. By explicitly defining protections credited against the hazard, one can make informed decisions whether proposed changes to the protections retain the necessary safety margins.

6.36 But there is simply no regulatory requirement that licensees analyze a postulated leak of any rate (small, medium, or large) of radioactive water from the spent fuel pool for any duration (short or long) for its postulated consequences to the environment. Neither the spent fuel pool leak hazard nor protections against it are explicitly defined. The conclusions expressed in the

WC DGEIS that spent fuel pool leaks will be detected before causing significant impacts are therefore speculative and subjective.

6.37 In addition, the WC DGEIS provides no argument that a spent fuel pool leak is more "highly unlikely" than a LWMS tank failure. In fact, the WC DGEIS is silent regarding the relative likelihood of these two scenarios. Yet LWMS tank leaks must be analyzed for its potential consequences to the environment while spent fuel pool leaks need not. This discrepancy is not justified.

D. Nonexistent Groundwater Monitoring and Inspection Requirements

6.38 The NRC in the WC DGEIS assumes that leaks of 100 gallons per day and greater from the spent fuel pool will be readily detected, corrected, and mitigated to prevent significant impacts. The NRC further assumes that groundwater monitoring will back up in-plant leakage detection processes so as to detect spent fuel pool leaks before significant impacts occur:

> *In addition to spent fuel pool design and operational controls, licensees are required, as described in Section E.1.2, to perform groundwater monitoring at nuclear power plant sites, which makes it unlikely that leakage from the spent fuel pool would remain undetected long enough for any contamination to migrate offsite. In addition, a groundwater-monitoring program based on a site characterization that conforms to standards (e.g., ANSI/ANS 2.17–2010) and a configuration of monitoring wells that takes into account the most likely leakage pathway (i.e., the spent fuel pool) would further reduce the likelihood that a leak would remain undetected long enough for contamination to migrate offsite.* (NRC 2013b, page E-10, lines 15-22)

6.39 The foundation for this WC DGEIS assumption exists in the procedure used by NRC inspectors when examining spent fuel pools at permanently shut down nuclear power reactors:

> *The inspector should also review data from the licensee's environmental monitoring program, if applicable, to determine if there are indications of SFP leakage into the environment*. (NRC 1997, Section 03.02)

6.40 But the environmental monitoring program is an illusion. There are no regulatory requirements for groundwater monitoring either at operating reactors or reactors during the 60-year short-term storage period:

> *Existing NRC regulations do not explicitly mandate routine onsite ground-water monitoring in the Restricted Area during facility operations*. (NRC 2006a, page 5)

6.41 Although the WC DGEIS cites a recent Decommissioning Planning Rule that "requires all licensees to establish operational practices to minimize site contamination and perform reasonable subsurface radiological surveys" (NRC 2013b, page B-18, lines 17-18), in reality the rule allows licensees to choose whether or not to conduct groundwater monitoring:

> *The amendments in this final rule require licensees, to the extent practical, to conduct their operations to minimize the introduction of residual radioactivity into the site, particularly in the subsurface soil and groundwater. There are a variety of monitoring methods to evaluate subsurface characteristics, and these are highly site specific with respect to their effectiveness. One or more licensees <u>may find</u> that compliance with the amendments will mean the installation of groundwater monitoring wells and surface monitoring devices at their sites.* (Federal Register 2011, page 35561) (emphasis added)

6.42 Rather than enforceable, reliable, dependable regulatory requirements, the WC DGEIS instead relies on a voluntary industry program for groundwater monitoring:

> *For nuclear power plants licensed before August 20, 1997, which includes all currently operating reactors, NRC has found that, in general, groundwater monitoring conducted in accordance with the Groundwater Protection Initiative developed by the Nuclear Energy Institute, a nuclear industry consortium, is adequate to comply with these regulations. … However, licensees may choose to develop groundwater-monitoring programs with additional elements than those recommended by the Groundwater Protection Initiative. For nuclear power plants licensed after August 20, 1997, licensees are subject to the additional requirements of 10 CFR 20.1406(a)-(b), of which "monitoring and routine surveillance programs are an important part of minimizing potential contamination".* (NRC 2013b, page E-5, lines 38 to page E-6, line 9)

***

> *The Nuclear Energy Institute developed its Groundwater Protection Initiative in 2006 in response to leaks containing radioactive material at several plants. The initiative is described in NEI 07-07, "Industry Ground Water Protection Initiative – Final Guidance Document"... All power reactor licensees have committed to follow the initiative, which identifies actions to improve licensee response to inadvertent releases, including releases from spent fuel pools that may result in low, but detectable, levels of plant-related radioactive materials in subsurface soils and water.* (NRC 2013b, page E-6, lines 10-16)

6.43 But the NRC's reliance on such voluntary measures directly contradicts NRC's conclusion that:

> *A strong regulatory framework that includes both regulatory oversight and licensee compliance is important to the continued safe storage of spent fuel*. (NRC 2013b, page B-15, lines 27-28)

6.44 The NRC's insistence on a strong regulatory program as the basis for its environmental findings is reasonable. The industry's Groundwater Protection Initiative is a voluntary measure that may be retracted or relaxed by the nuclear industry at any time without NRC review and approval. In addition, as discussed below in Section VII, it is currently not being routinely inspected by the NRC at either operating or permanently shut down nuclear power plants. As such, the WC DGEIS cannot credit this non-mandatory, non-inspected program with detecting and correcting leaks during the 60-year short-term storage period.

VII. THE WC DGEIS FAILS TO ACCOUNT FOR THE SIGNIFICANT REDUCTION IN REGULATORY REQUIREMENTS AND OVERSIGHT THAT OCCURS AFTER A REACTOR CEASES OPERATION

7.1 In reaching its conclusion that spent fuel leaks cannot have significant impacts, the WC DGEIS assumes the continued effectiveness of current monitoring requirements, oversight procedures, and other measures that are in place while the reactor is operating, rather than looking ahead to the fewer requirements, procedures, and other measures that will remain in place after reactors permanently shut down. As stated in the WC DGEIS:

> *For the purposes of the analyses in this draft GEIS, the NRC assumes that regulatory control of radiation safety will remain at the same level of regulatory control as currently exists today*. (NRC 2013b, page 1-15, lines 3-5)

***

> *The analyses in this draft GEIS are based on current technology and regulations.* (NRC 2013b, page 1-17, line 21)

***

> *Even though the reactor is no longer operating during the short-term storage timeframe, a licensee is still bound by the terms and conditions of its operating license until the license is terminated. As a result, the NRC assumes that spent fuel pool maintenance requirements that are in place during the operating period of the reactor will remain in place during the short-term timeframe and will stay in place even if the license is modified during the short-term timeframe.* (NRC 2013b, page E-4, lines 13-17)

7.2 This assumption is blatantly wrong. There is extensive evidence that the scope of regulatory requirements and associated regulatory oversight significantly shrinks after a nuclear power reactor permanently shuts down. This declaration presents some examples, although much more evidence exists.

7.3 For instance, standard NRC communications with licensees about safety problems and concerns are typically not sent to licensees of permanently shut down reactors, even when they contain relevant information. On March 3, 2004, the NRC issued Information Notice 2004-05 regarding the leak from the spent fuel pool at Salem that reached the soil. The NRC sent this warning notice to:

> *All holders of operating licenses for nuclear power reactors (except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel)* (NRC 2004, page 1)

7.4 Owners of reactors that have permanently shut down nuclear power reactors and who have certified to the NRC that all irradiated fuel has been removed from the reactor vessel did not formally receive the warning from the NRC about spent fuel pool leakage. If information is power, the NRC leaves these owners powerless to prevent similar leaks from their spent fuel pools.

7.5 The NRC's failure to send such warnings to owners of permanently shut down reactors has implications beyond merely keeping individual storage sites in the dark. Operating experience programs adopted throughout the nuclear power industry in the wake of the March 1979 accident at Three Mile Island are used to review incoming correspondence such as NRC's Information Notices and screen them for applicability to the site. Applicable documents are routed to appropriate departments for review and action. Applicable documents are thus formally incorporated into training programs and procedures. But the NRC's decision to exclude owners of permanently shut down nuclear power reactors about a spent fuel pool leakage problem robs them of the operating experience opportunity to capture this information in appropriate in-plant procedures and programs—the very procedures and programs the NRC improperly takes full credit for in the WC DGEIS.

7.6 The NRC also fails to require licensees of permanently shut down reactors to implement safety upgrades, even those upgrades directly related to spent fuel pool safety. For instance, on March 12, 2012, the NRC issued three orders requiring licensees to implement lessons it learned from the March 2011 accident at Fukushima in Japan. One of the orders issued that day required the installation of reliable instrumentation to monitor the water level inside spent fuel pools:

> *The lack of information on the condition of the spent fuel pools contributed to a poor understanding of possible radiation releases and adversely impacted effective prioritization of emergency response actions by decision makers.* (NRC 2012f, attachment 1, page 3)
>
> ***
>
> *During the events in Fukushima, responders were without reliable instrumentation to determine water level in the spent fuel pool.* (NRC 2012f, attachment 1, page 6)
>
> ***
>
> *…the Commission has determined that all power reactor licensees and CP [construction permit] holders must have a reliable means of remotely monitoring wide-range spent fuel pool levels to support effective prioritization of event mitigation and recovery actions in the event of a beyond-design-basis external event.* (NRC 2012f, attachment 1, page 7)

7.7 This NRC order to install reliable spent fuel pool water level instrumentation was issued to:

> *All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status* (NRC 2012f, page 1)

7.8 A search performed on August 27, 2013, of ADAMS, the NRC's online electronic library of publicly available agency records, failed to identify any such order issued by the NRC on or after March 12, 2012, for the permanently shut down Zion nuclear power reactors.

7.9 The NRC confirmed its intention not to impose these safety upgrades on permanently shut down reactors after the Crystal River Unit 3 reactor in Florida shut down in early 2013. Its owner had received the March 2012 order from the NRC to install reliable spent fuel pool water level instrumentation. The owner asked the NRC to rescind the order because the reactor would not resume operation (Duke 2013). The NRC granted the request and approved the removal of (or lack of installation of) reliable spent fuel pool instrumentation from this permanently shut down reactor (NRC 2013c).

7.10 After the Kewaunee reactor in Wisconsin shut down later in 2013, its owner also requested that the NRC rescind its order requiring reliable spent fuel pool water level instrumentation to be installed (Dominion 2013).

7.11 Another example of the regulatory requirement shrinkage involves groundwater monitoring. According to the WC DGEIS:

> *In April 2011, the NRC evaluated industry performance in "Summary of Results from Completion of NRC's Temporary Instruction on Groundwater Protection, TI-2515/173 Industry Groundwater Protection Initiative." ... This report was based on inspections conducted between August 2008 and August 2010 at all nuclear power plant sites*. (NRC 2013b, page E-7, lines 1-4)

7.12 The WC DGEIS is correct that TI-2515/173 was written to apply to <u>all</u> nuclear power reactors:

> *This Temporary Instruction (TI) applies to all holders of operating licenses for nuclear power reactors, including those plants which have permanently ceased operations*. (NRC 2008)

7.13 But the statement in the WC DGEIS that NRC's report was based on inspections of groundwater monitoring "at all nuclear power plant sites" is patently false. Instead, inspections were only performed at <u>some</u> nuclear plants sites; namely, the sites with operating nuclear power reactors. Sites with only permanently shut down nuclear power reactors were <u>not</u> inspected between August 2008 and August 2010 as is clearly evident from Tables 1, 2, 3, and 4 from NRC 2008 found in Appendix A.

7.14 These tables clearly show that, while the NRC inspected the voluntary programs implemented under the Groundwater Protection Initiative at operating nuclear power plants, it did not inspect the programs implemented at permanently shut down plants like Zion and Humboldt Bay.[12] The WC DGEIS cannot place weight on voluntary measures that have never been inspected by the NRC.

[12] A search of the NRC's ADAMS library on August 29, 2013, failed to produce any publicly available records indicating that the NRC had, or plans to, conduct groundwater protection initiative inspections using the Groundwater Protection Initiative, TI-2515/173, at permanently shut down nuclear power reactors.

7.15 Regarding its inspections at operating nuclear power plants that someday will permanently shut down, the NRC's position is that:

> *Licensees that have implemented a groundwater monitoring program consistent with the Nuclear Energy Institute Groundwater Protection Initiative are considered to have an adequate program for the purposes of the Decommissioning Planning Rule.* (NRC 2013b, page 3-10, line 37 to page 3-20, line 1)

7.16 Based on the successful results from the one-time Groundwater Protection Initiative inspection at operating nuclear power plants, the NRC apparently considers the voluntary groundwater monitoring program to be adequate over the entire 60-year short-term storage period at shutdown plants in the WC DGEIS. This assumption is illogical and contrary to the NRC's experience periodically inspecting mandatory—not voluntary—regulatory requirements at operating nuclear power plants.

7.17 The industry's Groundwater Protection Initiative is a voluntary measure that is currently not being routinely inspected by the NRC at either operating or permanently shut down nuclear power plants. As such, the WC DGEIS cannot credit this non-mandatory, non-inspected program with detecting and correcting leaks during the 60-year short-term storage period.

7.18 Further evidence of lessened regulatory oversight after a reactor permanently shuts down is provided by the NRC's Reactor Oversight Process (ROP). Under the ROP, the NRC conducts routine and reactive inspections at operating nuclear power plants to verify compliance with regulatory requirements or identify non-compliances warranting correction. Appendix B lists the ROP's baseline inspection procedures and the associated frequencies with which they are conducted. The baseline inspections examine a wide range of areas, from fire protection to radiation protection to maintenance to security, over a three-year period. The NRC conducts some baseline inspections every quarter. The least frequent baseline inspection is conducted at least once every three years.

7.19 Recent ROP inspection results as posted on the NRC's website on August 28, 2013, are contained in Appendix C. The numerous green, white, yellow, red, and greater-than-green inspection findings clearly demonstrate that plant owners do not always comply with regulatory requirements, even in areas routinely examined by NRC inspectors. All results labeled with any colored box indicate noncompliance with regulatory requirements. The NRC cannot assume in the WC DGEIS that owners will conform to voluntary measures (such as the Groundwater Protection Initiative) when their track record demonstrates repetitive non-compliance with mandatory regulatory requirements.

7.20 Similarly, the scope of the Maintenance Rule—on which the NRC relies for its finding of no possibility of significant impact (see WC DGEIS, page E-5, lines 1-13)—shrinks after a nuclear reactor permanently shuts down. Decades ago, the NRC promulgated the Maintenance Rule to establish regulatory requirements for maintenance and testing of safety related components (NRC 1991). But the rule does not provide protection against spent fuel pool leaks:

> *The maintenance rule, 10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," requires monitoring the performance or condition of structures, systems, or components (SSCs). For licensees who have submitted the certifications for cessation of operation and for permanent fuel removal specified in 10 CFR 50.82(a)(1), this section applies only to the extent the licensee monitors the performance or condition of the SSCs associated with the storage, control, and maintenance of spent fuel in a safe condition and in a manner sufficient to provide reasonable assurance that such SSCs are capable of fulfilling their intended functions (see 10 CFR 50.65(a)(1)).* (NRC 2000, page 1.184-12)

7.21 As described in paragraphs 6.3 to 6.15 of this declaration, the safety analysis reports and technical specifications establish "spent fuel in a safe condition" as entailing protection against a fuel handling accident. The safety analysis reports and technical specifications do not impart protection against long-term, low-volume leaks from the spent fuel pool as part of "spent fuel in a safe condition." Thus, licensees can and do legally omit structures, systems, and components needed to detect and mitigate spent fuel pool leaks (e.g., water level instrumentation, water makeup pumps, leakage detection systems, etc.) from the scope of their maintenance rule programs. The WC DGEIS simply cannot take credit for measures its regulations allow licensees to remove. The WC DGEIS must only credit measures that regulations compel licensee to retain.

A. Zion – A Case Study

7.22 The permanently shut down nuclear power reactors at the Zion nuclear plant in Illinois illustrate regulatory requirement shrinkage:

> *In March 1998, Com Ed certified per 10CFR50.82 that the company had permanently ceased power operation and that all fuel was in the Spent Fuel Pool. This is a permanent, non-revocable certification that changed the Zion Station licensing basis.* (ComEd 1998, attachment B, page 1)
>
> ***
>
> *The most significant effect of this licensing basis change was to eliminate nuclear safety functions for the majority of the structures, systems, and components (SSC's). Those SSC's, which had only performed a reactor safety function (i.e., SSC's that do not support spent fuel or radiation protection function), need no longer be maintained under nuclear grade controls.* (ComEd 1998, attachment B, page 1)

7.23 The scope of maintaining "spent fuel in a safe condition" at Zion was also redefined to narrow its scope:

> *Radioactive Release from a Subsystem or Component: All accidents, with the exception of the Fuel Handling accident in the Fuel Building, were deleted. … Added section with new accident analyses for Spent Fuel Pool Accident, loss of Spent Fuel Pool Cooling, and HIC Drop Accident.* (ComEd 1998, attachment B, page 15)

***

> *However, two aspects of the pool design would allow the inventory to be significantly reduced in the event of a failure. These are,*
>
> 1. *A seal failure of a fuel transfer canal removable weir gate, and*
> 2. *A rupture of the spent fuel cooling water pump return line.* (ComEd 1998, page 5-4)

7.24 Any worker or NRC inspector seeking to ascertain whether "spent fuel in a safe condition" is reasonably assured at Zion need only evaluate whether protections against a fuel handling accident and a significant reduction in spent fuel pool water inventory are adequate. As described in VI of this declaration, protection against a fuel handling accident is defined to be maintaining the water level at least 23 feet above the spent fuel storage racks when irradiated fuel assemblies (or the HIC cask) are being moved; otherwise, any spent fuel pool water level is acceptable. As described in ComEd 1998, protection against a significant reduction in spent fuel pool water inventory involves the fuel transfer canal's weir gate seal and the spent fuel pool cooling water pump discharge piping. Protection against a long-term, low-volume spent fuel pool leak is neither directly nor indirectly associated with these regulatory requirements.

7.25 The WC DGEIS cannot credit regulatory requirements that are entirely silent on the matter to provide protection against long-term, low-volume spent fuel pool leaks during the 60-year short-term storage period.

B. Dresden – A Case Study

7.26 Dresden Unit 1 in Illinois provides another important example of the breakdown in monitoring programs and regulatory oversight after reactors permanently shut down. This example undermines the NRC's assumption stated in the WC DGEIS that:

> *Even though the reactor is no longer operating during the short-term storage timeframe, a licensee is still bound by the terms and conditions of its operating license until the license is terminated. As a result, the NRC assumes that spent fuel pool maintenance requirements that are in place during the operating period of the reactor will remain in place during the short-term timeframe and will stay in place even if the license is modified during the short-term timeframe.* (NRC 2013b, page E-4, lines 13-17)

7.27 The NRC is, or should be, aware of past events such as that at Dresden rendering this assumption tenuous at best, outright invalid at worst. On January 25, 1994, workers discovered about 55,000 gallons of water on the floor of the basement of the reactor building for the Unit 1 reactor at the Dresden nuclear plant in Illinois. Its owner had permanently shut down the reactor on October 31, 1978. The NRC dispatched a special inspection team to Dresden to investigate this event. The NRC's team discovered (NRC 1994a):

- The owner stopped providing heating for the reactor building in 1989. The lack of heating led to cold temperatures inside the building that froze the water inside a pipe of the service water system causing it to burst. Leakage from this ruptured pipe was found on the basement floor. The lack of heating could also have frozen and ruptured the fuel transfer tube, allowing the spent fuel pool water to drain down and expose the top several feet of irradiated fuel in the storage racks. Had this occurred, the drained water would have reduced shielding and created high radiation levels onsite.

- The owner had turned off the spent fuel pool cooling and cleanup system in 1983. By 1987, the water quality inside the spent fuel pool degraded to the point where an influx of microorganisms had developed. Records showed that the conductivity of the spent fuel pool water was two times the limit in the operating license.

- The poor quality of the spent fuel pool water could have adversely affected the seating surfaces and gaskets for the spent fuel pool gate.

- The owner had no spent fuel pool leak detection program, nor did the owner have a water inventory program that might have detected leakage from the spent fuel pool via increased makeup additions to it.

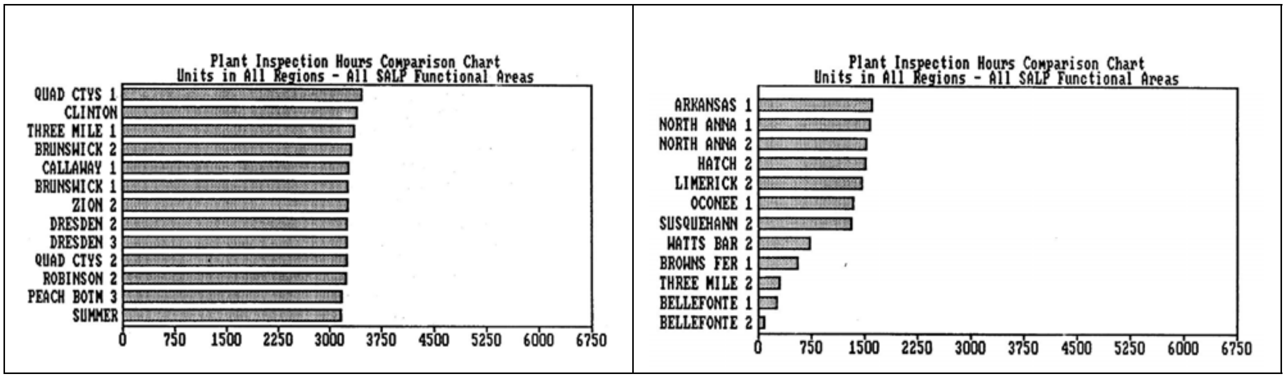
7.28 According to the NRC:

> *The inspection team concluded that the layup of the plant and storage of spent fuel at Dresden 1 was not well managed or maintained for a period of years and that weaknesses existed in the site quality audit and inspection programs. Further, safety reviews of changes to Dresden 1 systems such as termination of heating and ventilation for the containment were apparently not performed or not adequately reviewed to determine the safety consequences of the changes. Interviews with personnel at the Dresden site (which includes two operating units in addition to Dresden 1) showed that, in part, the weaknesses identified above were based on an incorrect belief that Dresden 1 could not cause a serious safety problem because it was permanently shut down. This belief resulted in audits and safety evaluations that were not rigorously implemented or that did not include the Dresden 1 systems and programs.* (NRC 1994a, page 3)

The NRC imposed a $200,000 civil penalty on the plant's owner for this event (NRC 1994a).

7.29 This event exposes the reality that the NRC's WC DGEIS fails to address the significant reduction in regulatory requirements that occurs after a reactor permanently shuts down. The NRC assumes in the WC DGEIS that all spent fuel pool maintenance measures will apply and be met during the short-term storage period. Yet, the NRC fined the owner of Dresden Unit 1 for inappropriate actions like turning off the spent fuel pool cooling and cleanup system 12 years prior to this event and allowing the water quality inside the spent fuel pool to violate operating license requirements for many years. The WC DGEIS is deficient by assuming this event is isolated and never to be repeated and not identifying reliable means to prevent recurrence.

7.30 The Dresden event also reveals the significant reduction in regulatory oversight that occurs after a reactor permanently shuts down. At the time of this event, the Dresden nuclear plant had two operating reactors and one permanently shut down reactor. Because of the operating reactors, the NRC had inspectors assigned full-time to the plant site supplemented by inspectors from its regional and headquarters offices. Clearly, those inspectors devoted almost all of their time and attention to the operating reactors; otherwise, they might have noticed that the owner turned off the Unit 1 spent fuel pool cooling and cleanup system 12 years earlier or had discontinued heating the Unit 1 reactor building 5 years earlier. Had Dresden Unit 1 not been adjacent to two operating reactors, the NRC would not have full-time inspectors assigned to the plant site.



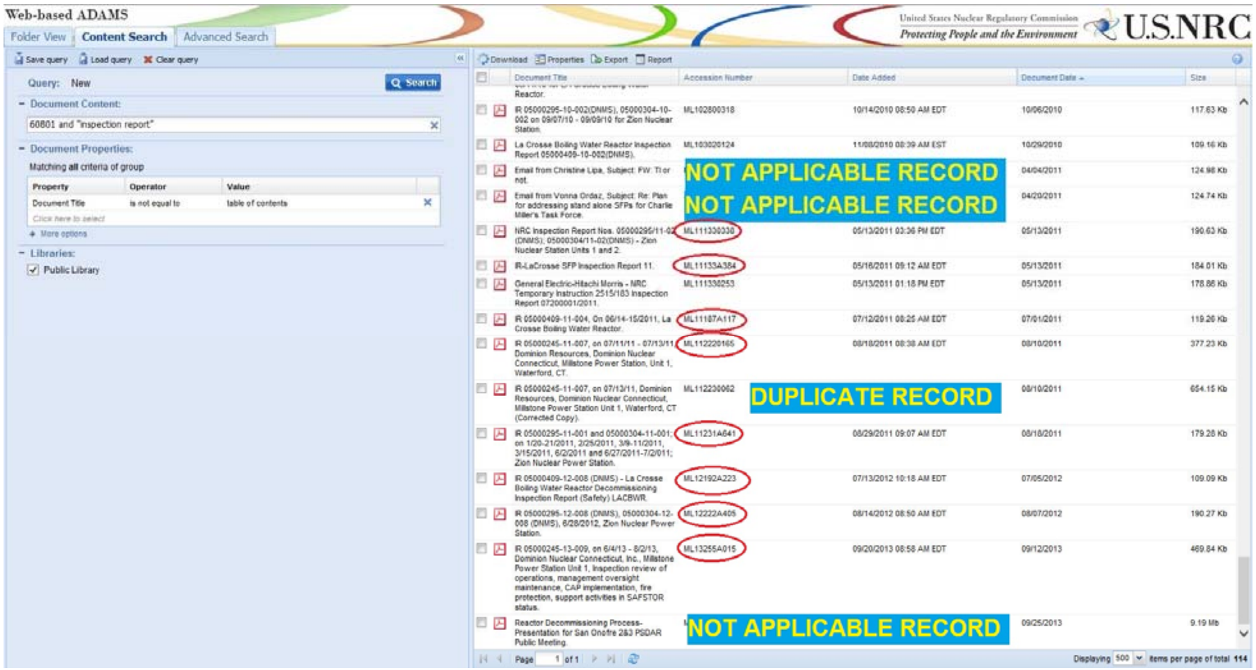
Source: NRC FOIA/PA-92-0537

7.31 The NRC inspection effort at Dresden is not unique. Shown above are the NRC inspection hours applied to various reactors in 1992. The Three Mile Island nuclear plant had one operating reactor and one permanently shut down reactor. Its Unit 1 reactor received nearly 3,700 inspection-hours of NRC attention while the permanently shut down Unit 2 reactor received about one-tenth of that attention, a scant 300 inspection-hours or so. In 1992, the Unit 1 reactor at the Browns Ferry nuclear plant had been shut down since March 1985 – not permanently shut down, but not expected to restart anytime soon (it did not resume operating until early 2007). NRC inspectors devoted less than 750 hours of attention to it during 1992. The permanently shut down Unit 1 reactor at Dresden was not even on the NRC's charts: the Dresden Units 2 and 3 reactors received over 3,000 NRC inspection-hours.

7.32 NRC Inspection Manual Chapter 0305, "Operating Reactor Assessment Program," is the agency's overall guidance document outlining the frequency and scope of the inspections it conducts at nuclear power reactors. On October 18, 2013, the NRC revised Manual Chapter 0305 to add this sentence:

> *A power reactor is no longer subject to this manual chapter after a licensee submits a written certification to cease operation in accordance with 10 CFR 50.82(a)(1)(ii).* (NRC 2013a)

7.33 NRC Inspection Manual Chapters 0350, "Oversight of Reactor Facilities in a Shutdown Condition Due to Significant Performance and/or Operational Concerns," and 0351, "Implementation of The Reactor Oversight Process at Reactor Facilities in an Extended Shutdown Condition for Reasons Other Than Significant Performance Problems," cover nuclear power reactors that have been shut down for lengthy periods, but which are expected to eventually resume operations. These manual chapters do not apply to permanently shut down reactors. A review of the Inspection Manual Chapters[13] and associated NRC Inspection Procedures[14] identified only one procedure applicable to permanently shut down nuclear power reactors (NRC 1997a). It focused on spent fuel pools. This sole procedure was developed in response to the 1994 event at Dresden Unit 1. According to the NRC, it is "estimated to require 32 onsite inspection hours semi-annually" (NRC 1997a).



Source: NRC ADAMS Website, accessed 11-04-2013

7.34 And it appears that the NRC's "semi-annual" spent fuel pool inspection expectations are actually being halfway met. According to the NRC's online electronic library, ADAMS, the NRC conducted this spent fuel pool inspection of the spent fuel pools at the permanently shut down Zion nuclear plant and documented its findings in reports dated May 13, 2011, August 18, 2011, and August 7, 2012 – three inspections over the past three years. And for the reasons described in Section VI of this declaration, even these infrequent NRC inspections provide little assurance that spent fuel pool leaks will be detected and corrected in a timely manner.

7.35 In summary, the NRC's WC DGEIS does not consider the reality that permanently shut down reactors receive less management attention (as evidenced by the Dresden Unit 1 event) and significantly less NRC oversight (as evidenced by the Dresden Unit 1 event and the inspection hour tabulation). This reality invalidates the NRC's assumptions that licensee programs and NRC's oversight will continue at the same levels after reactors shut down as existed when the reactors operated.

7.36 To meaningfully assess the impacts of spent fuel pool leaks in the WC DGEIS, the NRC must rely on regulatory requirements that will remain in place over the entire 60-year short-term

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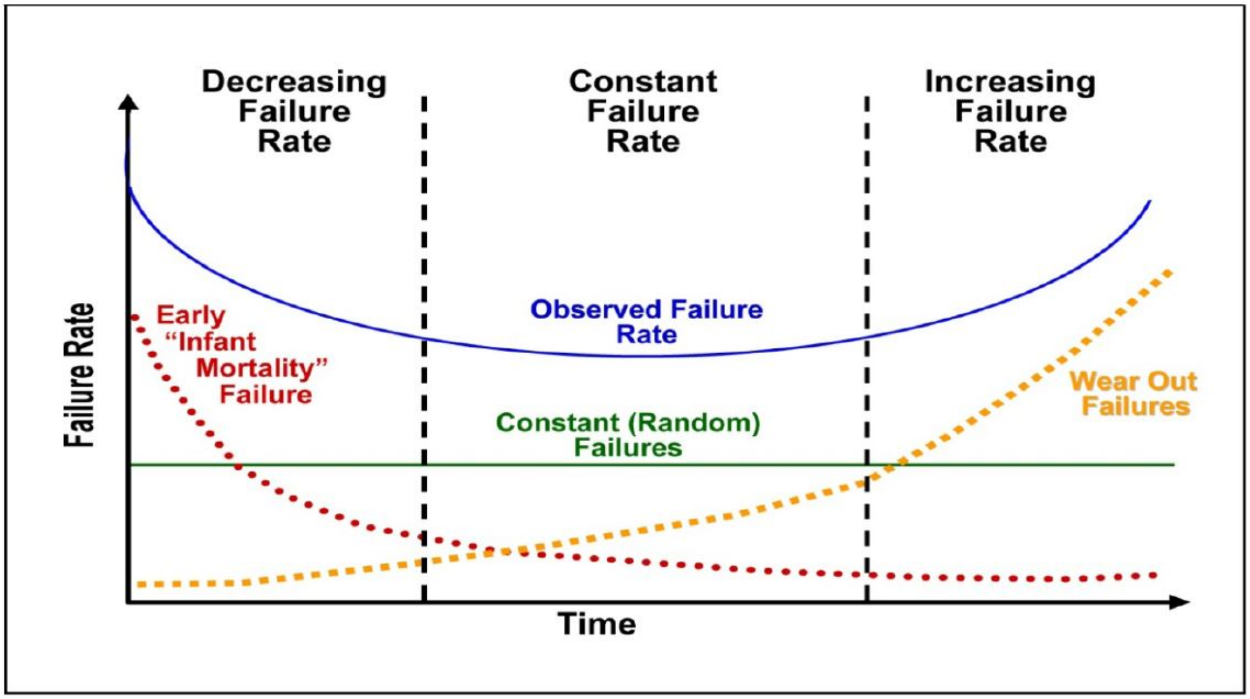
[13] See http://www.nrc.gov/reading-rm/doc-collections/insp-manual/manual-chapter/

[14] See http://www.nrc.gov/reading-rm/doc-collections/insp-manual/inspection-procedure/

storage period and not on regulatory requirements that are inapplicable or significantly reduced in scope after reactors permanently shut down. Only if the WC DGEIS achieves this can it provide reasonable assurance that spent fuel pool leaks will be detected before the leaked materials exceed public health regulatory limits and cause noticeable impacts to groundwater resources.

C. Reduction in Aging Management Protections

7.37 The WC DGEIS also fails to properly consider the significant reduction in scope for aging management regulatory requirements and associated supporting analyses that happens when nuclear power plants permanently shut down. Spent fuel pools and the piping and components connected to them are subject to aging degradation. Aging degradation does not magically cease when reactor operation ceases but continues on throughout the 60-year short-term storage phase. As depicted below in what is commonly called the "bathtub curve" due to its shape, aging degradation can cause the failure rate to increase:



Source: NRC 2013f

7.38 The NRC has approved renewed operating licenses for the majority of the nuclear power reactors operating today.[15] The NRC's license renewal rule (10 CFR. Part 54) enables the NRC to renew the original 40-year operating license for up to 20 additional years. The NRC will renew an operating license only after determining that the aging management program for in-scope passive systems, structures, and components is adequate:

[15] See "Completed Application" list at http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html

> *For each structure and component identified in paragraph (a)(1) of this section, demonstrate that the effects of aging will be adequately managed so that the intended function(s) will be maintained consistent with the CLB [current licensing basis] for the period of extended operation.* (10 CFR. §54.21(a)(3))

As described in Section A2 of the NRC's Generic Aging Lessons Learned Report (NRC 2012a), the spent fuel pool and associated equipment are within the scope of the license renewal rule and therefore require adequate aging management programs during the period of extended operation.

7.39 But the period of extended operation only covers the duration of reactor operation, not to the end of the 60-year short-term storage period as clearly illustrated in Figure 2.4 of the WC DGEIS:

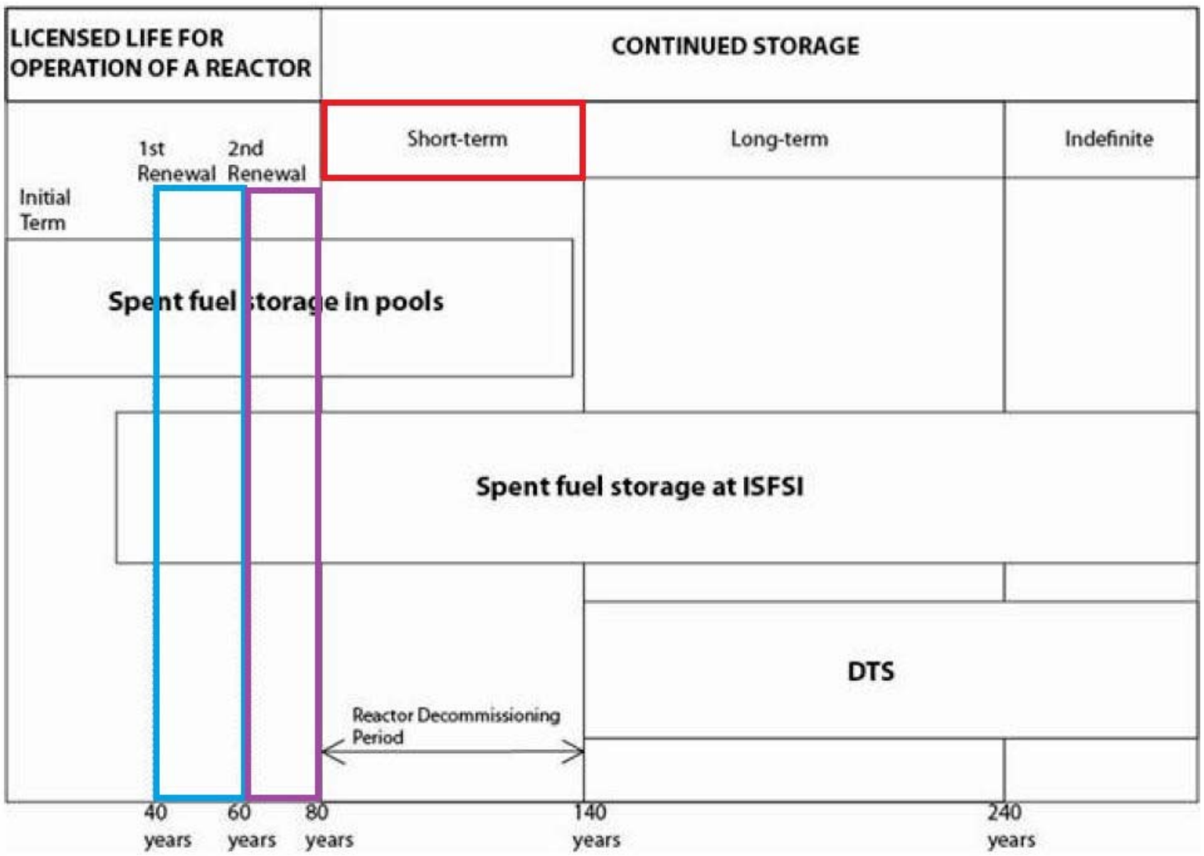


Figure 2-4. Continued Storage Timeline

7.40 The applicant for a renewed operating license develops aging management programs for in-scope systems, structures, and components—including the spent fuel pool and associated equipment—that provide reasonable assurance that required margins will be maintained over the duration of extended reactor operation. Once the period of extended operation ends and the short-term storage period begins, no regulations require licensees to continue their aging management programs.

7.41 The short-term storage period of 60 years equals the operating lifetime of a nuclear power reactor obtaining only one renewal – the 40-year initial term plus the 20-year period of extended operation. The aging management programs prepared by the applicants and approved by the NRC only consider the 20-year period of extended operation. While the efficacy of these programs does not automatically expire along with the operating licenses, the fact remains that neither the plant owners nor the NRC have formally evaluated aging degradation mechanisms and reliable barriers against excessive degradation over the 60-year short-term storage period assumed in the WC DGEIS.

7.42 The bathtub curve shows that aging degradation will eventually cause the failure rate to increase. Regulatory requirements such as the maintenance rule and the aging management programs mandated by the license renewal rule guard against problems caused by structures, systems, and components being operated deep into the Increasing Failure Rate portion on the right end of the bathtub curve. In other words, these mandated measures require that equipment affected by aging degradation be repaired or replaced before safety margins are compromised. The lack of comparable regulatory requirements during the 60-year short-term storage period increases the likelihood that unchecked aging degradation causes problems.

7.43 In summary, the WC DGEIS must consider the significant reduction in the scope of regulatory requirements and oversight that occurs after reactors permanently shut down rather than the inflated levels that exist while the reactors operate.

VIII. THE WC DGEIS FAILS TO CONSIDER SOME SIGNIFICANT IMPACTS FROM A SPENT FUEL POOL LEAK

8.1 The WC DGEIS is also inadequate because it fails altogether to consider a number of credible environmental impacts related to spent fuel pool leaks.

A. Offsite Contamination Below Standards and Onsite Contamination Excluded

8.2 The WC DGEIS fails to consider environmental impacts other than contamination in excess of NRC and EPA standards. (NRC 2013b, page E-18, lines 31-32). It also excludes onsite contamination. As a result, the WC DGEIS fails to consider numerous instances in which onsite contamination resulted in costly cleanups, which were required regardless of whether the licensee had failed to comply with NRC standards. In other words, compliance with NRC standards was insufficient protection against significant impacts.

8.3 For instance, the leak from the Salem spent fuel pool is not significant under the WC DGEIS criterion even though millions of dollars have been spent remediating tritium contamination in the groundwater. As described in Section IV.C above, water leaked from the spent fuel pool at the Salem nuclear plant prompted the State of New Jersey to compel its owner to remediate the site to recover the radioactively contaminated water. Over 28 million gallons of water have been drawn from the soil around the plant, treated, and either re-used by the plant or legally discharged (Arcadis 2013). Salem's leaking spent fuel pool did not result in any measured level of radioactivity in drinking water that exceeded federal standards, but it resulted in a sizeable cleanup cost. Spent fuel pool leaks in the future could pose financial burdens on stockholders, ratepayers, or taxpayers—a factor that NRC seems to have overlooked in the WC DGEIS.

8.4 Similarly, an onsite leak at the Oyster Creek nuclear plant in New Jersey costs millions of dollars to remediate. In April 2009, radioactively contaminated water leaked from an underground pipe at the Oyster Creek nuclear plant in New Jersey. The State of New Jersey ordered the plant's owner to clean up the leak. New Jersey Department of Environmental Protection Deputy Commissioner Iren Kropp was quoted as saying "They don't get a court hearing. They have to act and do exactly what we say" under the state's Spill Act. A company manager estimated the costs to exceed $13 million (Bates 2010). While this leak came from an underground pipe rather than the spent fuel pool, the contaminated water carried a hefty price tag even though it did not migrate offsite. The NRC fails to consider such onsite contamination consequences in the WC DGEIS.

8.5 And as discussed above in Section IV.D, Indian Point suffered a 50 gallon per day leak from the Unit 2 spent fuel pool that the owner believes to have lasted for over two years. This and other leaks discovered from the Unit 1 and Unit 2 spent fuel pools led to extensive and costly investigatory and assessment efforts at the site. Again, the WC DGEIS gives no indication that NRC considered such onsite contamination consequences.

8.6 While the source was an effluent pipe used to discharge radioactively contaminated water to the Kankakee River rather than the spent fuel pool, a leak discovered in 2005 at the Braidwood nuclear plant in Illinois had significant impact even though it did not result in any measured radionuclide concentrations in offsite groundwater used for drinking or in drinking wells in excess of EPA and NRC regulatory limits. Among the consequences from this leak:

- Exelon Corporation, Braidwood's owner, agreed to purchase one property and reimburse 14 other property owners for devaluations stemming from the leak (Dow Jones, 2005).
- The NRC's Chairman described the leak in his four-page transmittal letter for a monthly report to Congressional oversight committee Chairs and Ranking Members (NRC 2006c, page 2). Thus, leakage resulting in no offsite contamination above regulatory limits—considered insignificant in the WC DGEIS—was considered significant enough to promptly report it to the U.S. Congress.
- The Illinois Attorney General and the Will County State's Attorney jointly filed a lawsuit against Exelon on eight counts related to the leaks (Illinois Attorney General, 2006).
- Exelon agreed to provide bottled water to about 420 homeowners near the Braidwood nuclear plant (Associated Press, 2006).
- Exelon, the Illinois Attorney General, and the Will County State's Attorney settled the leak lawsuit on May 11, 2006. Per the agreement, Exelon agreed to reimburse the State of Illinois and Will County for all their costs related to the leak, to implement several remediation measures, and to take other measures intended to prevent future leaks (Twelfth Circuit Court, 2006).

8.7 In summary, the Salem, Oyster Creek and Indian Point cases clearly demonstrated that leaks contaminating the plant's property can have significant impacts. And the Braidwood case clearly demonstrates that leaks contaminated offsite properties below regulatory limits can also have significant impacts. The WC DGEIS cannot summarily dismiss this reality.

B. Social and Economic Impacts

8.8 The WC DGEIS does not properly consider the social and economic effects of contamination in nearby communities. These effects can be significant.

8.9 For example, during a workshop on groundwater protection conducted by the NRC on April 20, 2010, Bill Buscher of the State of Illinois Environmental Protection Agency pointed out that the millions of gallons of radioactively contaminated water that leaked from the Braidwood nuclear plant and migrated offsite and into people's drinking wells had serious implications even though the measured tritium concentrations were within the federal standards for drinking water. Buscher explained that several nearby residents were approaching retirement age and had planned to sell their properties and use the proceeds to relocate to live out their golden years. But the specter of radioactive contamination sent real estate prices spiraling downward. It is not clear from the WC DGEIS that the NRC considers potential property devaluations caused by spent fuel pool leaks.

C. Licensee Longevity

8.10 The WC DGEIS assumes that companies owning permanently shut down reactors are immortal. As of 2003, the companies comprising the Standard & Poor 500 stock index (S&P 500) had been publicly traded for an average of 25 years, with this average trending towards shorter values.[16] The NRC assumes in the WC DGEIS that spent fuel pools could be around for up to 140 years (40 year original operating license period along with two 20-year license extensions followed by up to 60 years of short-term storage after reactor operation permanently ceases). The NRC thus assumes that the owner, or licensee, responsible for maintaining the spent fuel pool and monitoring against leaks will endure for 5.6 times longer than the average lifetime of the S&P 500 companies. The NRC apparently failed to consider, from a socioeconomic perspective, the fact that an owner no longer receiving revenue from a permanently retired generating plant may not survive for six decades. The WC DGEIS needs to either explain how bankruptcy, changes in ownership, takeover by the state, and other ownership issues cannot occur during the 60-year short-term storage period or explain how the spent fuel pool leak risk will be properly managed during and following such ownership issues.

[16] Per August 25, 2010, posting to http://www.investopedia.com/stock-analysis/2010/the-average-lifespan-of-sp-500-companies-xom-aapl-pg-ibm-jnj0825.aspx

IX. Conclusions

9.1 The WC DGEIS concedes that long-term, low-volume spent fuel pool leaks could exceed public health regulatory limits and impact groundwater resources. Although the WC DGEIS concludes that any such leaks are very unlikely to happen, it fails to provide solid, reliable support for this conclusion.

9.2 The WC DGEIS does not show that the NRC has considered all relevant spent fuel pool leaks. For instance, the NRC did not consider the leaks that occurred from the spent fuel pools at the Brookhaven National Laboratory and the Yankee Rowe nuclear plant. The BNL spent fuel pool leaked radioactively contaminated water into the ground for up to 12 years. Four tests for leakage from the spent fuel pool over a seven year period failed to detect the leak. And numerous monitoring wells already existing or added to the site failed to detect the leaked water for many years or attributed leak indications other sources. But this event was not included among the past events NRC considered for the WC DGEIS. Likewise, the NRC failed to consider in the WC DGEIS the two million gallons that leaked from the Yankee Rowe nuclear plant.

9.3 In the WC DGEIS, NRC assumes that spent fuel pool leaks of 100 gallons per day or more would be readily detected before causing significant impacts. In making this assumption, the NRC relies on the availability of spent fuel pool leakage detection system and groundwater monitoring measures. But the WC DGEIS fails to properly consider that spent fuel pool water level instrumentation is not required to be functioning except during the very rare occasions when irradiated fuel is being moved within the pool and that groundwater monitoring measures are entirely voluntary. Thus, the NRC relies on measures that quite simply may be non-existent. In addition, the WC DGEIS fails to explain how leakage far in excess of 100 gallons remained undetected at Yankee Rowe until two million gallons of radioactively contaminated water had escaped into the soil.

9.4 In the WC DGEIS, the NRC fails to justify its conclusion that spent fuel pool leaks of less than 100 gallons per day either will be detected in a timely manner or will cause no significant impact if undetected for an extended period. The BNL and Indian Point leaks contradict the NRC's conclusion because each involved releases of tens of thousands of gallons, but at rates of less than 50 gallons per day. The WC DGEIS dismisses leaks smaller than 100 gallons per day, regardless of their duration, but without explicitly defining the hazard and protections credited against it (as discussed in paragraphs 6.31 to 6.37), this dismissal is speculative and subjective.

9.5 In the WC DGEIS, the NRC fails to identify how the spent fuel pool leaks listed in Table E-4 were detected. By not identifying the means of detecting these past leaks, the WC DGEIS fails support its assumption that leaks will be readily detectable. Instead, the WC DGEIS leaves open the possibility that the leaks were only detected through sheer luck. The WC DGEIS must explicitly identify the means by which past leaks were detected and ensure that regulatory requirements will retain these means throughout the 60-year short-term storage period. Otherwise, the NRC has no basis for a finding of reasonable assurance that the methods on which it relies will detect future leaks.

9.6 In the WC DGEIS, the NRC fails to recognize that both regulatory requirements and its oversight regime are significantly scaled back when nuclear power reactors cease operation. For example, the aging management measures supporting renewal of reactor operating licenses only apply during the period of extended reactor operation—not the six decades of spent fuel pool storage that follow. And evidence shows that the NRC's inspection effort is drastically reduced, to almost drive-by inspection efforts, after a reactor permanently shuts down.

9.7 For the WC DGEIS, the NRC fails to properly consider impacts from leaks causing offsite contamination below federal health standards and onsite contamination. The Braidwood event, for example, reveals that leaks resulting in offsite contamination cause significant impacts while the Salem and Oyster Creek events reveal that leaks resulting in onsite contamination can also entail significant impacts.

9.8 The NRC lacks the regulatory backstop needed to validate assumptions made for the WC DGEIS about spent fuel pool leakage detection capabilities and leak impacts. Consequently, the conclusion in the WC DGEIS that spent fuel pool leaks cannot have significant impacts may not be relied upon.

9.9 The WC DGEIS must be revised to explicitly and properly:

- Identify the regulatory requirements in place throughout the short-term storage period that provide reasonable assurance that spent fuel pool leakage of X[17] gallons per day or greater will be detected before causing significant impacts.

- Demonstrate by analysis applicable to all sites, or require site-specific analyses, showing that spent fuel pool leakage of less than X gallons per day of infinite duration cannot cause significant impacts.

9.10 Absent the failures and deficiencies identified in this declaration being adequately remedied, the WC DGEIS cannot support rulemaking and policies allowing irradiated fuel to be stored in spent fuel pools for up to 60 years following cessation of reactor operation. Past spent fuel pool leaks raise serious questions about safety and environmental risks from future leaks. Those questions must have sound and well-supported answers before the NRC approves the storage of spent fuel in pools for 60 years following reactor operation. Otherwise, post-operational spent fuel storage is nothing more than a six-decade gamble.

I declare that the foregoing facts are true to the best of my knowledge and that the opinions expressed above are based on my best professional judgment.

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Date: 12/13/2013

[17] In the WC DGEIS, the NRC assumed an X value of 100. Correcting the many deficiencies, errors, and shortcomings identified by this declaration may result in a final X value higher or lower than 100.

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Appendix A

Source: NRC 2011b

Table 1

Number of Program Elements Rated Incomplete in Region 1 (for 2008-2010)

The 11 Objectives in NEI 07-07 are listed at the right.	Readiness Potential (2008-2010)*	Hydrology and Geology	Site Risk Assessment	On-Site Groundwater Monitoring	Remediation Process	Record Keeping	Stakeholder Briefings	Voluntary Communications	30-Day Reports	Annual Reports	Self Assessments	NEI Program Assessments
Region 1		1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	3.1	3.2
Beaver Valley	1											
Calvert Cliffs	1											
FitzPatrick	3		4	4	3							
Ginna	2	3	3	2								
Hope Creek	1											
Indian Point	1											
Limerick	1											
Millstone	1											
Nine Mile Point	1											1
Oyster Creek	2		1	1	3						1	1
Peach Bottom	1		2	2								1
Pilgrim	1											
Salem	1											
Seabrook	1											
Susquehanna	1											
Three Mile Island	2		1	1	2	1						1
Vermont Yankee	3	3	6	1						1	3	1

* Sites with a readiness potential of "1" should have the highest potential to effectively manage

Haddam Neck, Maine Yankee, Saxton and Yankee-Rowe are sites with permanently shut down nuclear power reactors that did not receive a TI-2515/173 inspection between 2008 and 2010.

Appendix A

Table 2

Number of Program Elements Rated Incomplete in Region 2 (for 2008-2010)

The 11 Objectives in NEI 07-07 are listed at the right.	Readiness Potential (2008-2010)*	Hydrology and Geology	Site Risk Assessment	On-Site Groundwater Monitoring	Remediation Process	Record Keeping	Stakeholder Briefings	Voluntary Communications	30-Day Reports	Annual Reports	Self Assessments	NEI Program Assessments
Region 2		1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	3.1	3.2
Browns Ferry	1											
Brunswick	1											
Catawba	1											
Crystal River	1											
Farley	1						3					
Harris	1											
Hatch	1		1									
McGuire	1											
North Anna	1											
Oconee	1											
Robinson	1											
Saint Lucie	1											
Sequoyah	1											
Summer	1											
Surry	1											
Turkey Point	1											
Vogtle	1											
Watts Bar	1							1				

Appendix A

Table 3

Number of Program Elements Rated Incomplete in Region 3 (for 2008-2010)

The 11 Objectives in NEI 07-07 are listed at the right.	Readiness Potential (2008-2010)*	Hydrology and Geology	Site Risk Assessment	On-Site Groundwater Monitoring	Remediation Process	Record Keeping	Stakeholder Briefings	Voluntary Communications	30-Day Reports	Annual Reports	Self Assessments	NEI Program Assessments
Region 3		1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	3.1	3.2
Braidwood	1											
Byron	1				2		1					
Clinton	1											
D.C. Cook	1											
Davis-Besse	1				1							1
Dresden	1			3	1							
Duane Arnold	1											
Fermi	1											
Kewaunee	2		2		2	1	3					
La Salle	1		1									
Monticello	1						2					
Palisades	1		3		1							
Perry	2	1	1	1	1			3				
Point Beach	1											
Prairie Island	1											
Quad Cities	1			2								

Big Rock Point, Elk River, Fort St. Vrain, Hallam, La Crosse, Zion[18] are sites with permanently shut down nuclear power reactors that did not receive a TI-2515/173 inspection between 2008 and 2010.

[18] As of March 29, 2012, Zion still stored irradiated fuel in its spent fuel pool per NRC webpage http://www.nrc.gov/info-finder/decommissioning/power-reactor/zion-nuclear-power-station-units-1-2.html

Appendix A

Table 4

Number of Program Elements Rated Incomplete in Region 4 (for 2008-2010)

The 11 Objectives in NEI 07-07 are listed at the right.	Readiness Potential (2008-2010)*	Hydrology and Geology	Site Risk Assessment	On-Site Groundwater Monitoring	Remediation Process	Record Keeping	Stakeholder Briefings	Voluntary Communications	30-Day Reports	Annual Reports	Self Assessments	NEI Program Assessments
Region 4		1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	3.1	3.2
Arkansas Nuclear	3		5	1				1		2		
Callaway	3		4	3	3							
Columbia	2		5									
Comanche Peak	1											
Cooper	3	4	7		3					2		
Diablo Canyon	3		7		3			4			1	
Fort Calhoun	1											
Grand Gulf	1											
Palo Verde	1							4				
River Bend	3	2	6	3	1					1	1	
San Onofre	1											
South Texas	1											
Waterford	3	2	6	3	1						1	
Wolf Creek	1											

Humboldt Bay, Rancho Seco, Trojan are sites with permanently shut down nuclear power reactors that did not receive a TI-2515/173 inspection between 2008 and 2010.

Appendix B

BASELINE INSPECTION PROCEDURES

IP/IA No.	Title	Frequency[1]
71111 Reactor Safety – Initiating Events, Mitigating Systems, Barrier Integrity		
71111.01	Adverse Weather Protection	A
	(Reserved)	
	(Reserved)	
71111.04	Equipment Alignment	Q/A
71111.05AQ	Fire Protection Annual/Quarterly	Q/A
71111.05T	Fire Protection (Triennial)	T
71111.05TTP	Fire Protection – NFPA 805 (Triennial)	T
71111.06	Flood Protection Measures	A
71111.07	Heat Sink Performance	A/T
71111.08	Inservice Inspection Activities	R
	(Reserved)	
	(Reserved)	
71111.11	Licensed Operator Requalification Program and Licensed Operator Performance	Q/B
71111.12	Maintenance Effectiveness	A
71111.13	Maintenance Risk Assessment and Emergent Work Control	A
	(Reserved)	
71111.15	Operability Determinations and Functionality Assessments	A
	(Reserved)	
71111.17	Evaluations of Changes, Tests, or Experiments and Permanent Plant Modifications	T
71111.18	Plant Modifications	A
71111.19	Post –Maintenance Testing	A
71111.20	Refueling and Other Outage Activities	R
71111.21	Component Design Bases Inspection	T
71111.22	Surveillance Testing	A
	(Reserved)	
71114 Reactor Safety – Emergency Preparedness		
71114.01	Exercise Evaluation	B
71114.02	Alert Notification System Testing	B

Issue Date: 03/08/13 Att 3-1 2515 Appendix A

Source: NRC 2013e

Appendix C

NRC Inspection Findings at Operating Nuclear Power Plants as posted August 28, 2013, at
http://www.nrc.gov/NRR/OVERSIGHT/ASSESS/pim_summary.html
NRC findings in order of increasing safety significance: Green, White, Yellow, Red
(Security-related White, Yellow, and Red are shown as blue Greater-than-Green (GTG))

2Q/2013 ROP Inspection Findings Summary

This summary provides the color designation of the most significant inspection findings over the previous 4 quarters.

The Commission has decided that certain information about findings pertaining to security cornerstone will not be publicly available to ensure that potentially useful information is not provided to a possible adversary; while other information will be available. Therefore, the cover letters to security inspection reports may be viewed.

Plants	Initiating Events	Mitigating Systems	Barrier Integrity	Emergency Preparedness	Occupational Radiation Safety	Public Radiation Safety	Security
Arkansas Nuclear 1	No Finding	Green	Green	No Finding	No Finding	No Finding	No Finding
Arkansas Nuclear 2	Green	Green	Green	No Finding	Green	No Finding	No Finding
Beaver Valley 1	No Finding	Green	No Finding	No Finding	No Finding	No Finding	GTG
Beaver Valley 2	Green	Green	No Finding	No Finding	No Finding	No Finding	GTG
Braidwood 1	No Finding	Green	Green	No Finding	No Finding	No Finding	Green
Braidwood 2	No Finding	Green	Green	No Finding	No Finding	No Finding	Green
Browns Ferry 1	No Finding	Red (1)	No Finding	Green	No Finding	No Finding	Green
Browns Ferry 2	No Finding	Green	No Finding	Green	No Finding	No Finding	Green
Browns Ferry 3	Green	Green	No Finding	Green	No Finding	No Finding	Green
Brunswick 1	Green	Green	Green	Green	No Finding	No Finding	No Finding
Brunswick 2	Green	Green	Green	Green	No Finding	No Finding	No Finding
Byron 1	No Finding	Green	Green	No Finding	No Finding	No Finding	No Finding
Byron 2	No Finding	Green	Green	No Finding	No Finding	No Finding	No Finding
Callaway	Green	Green	Green	No Finding	Green	No Finding	Green
Calvert Cliffs 1	Green	Green	Green	No Finding	No Finding	No Finding	Green
Calvert Cliffs 2	No Finding	Green	Green	No Finding	No Finding	No Finding	Green
Catawba 1	No Finding	Green	Green	No Finding	No Finding	No Finding	No Finding
Catawba 2	No Finding	Green	Green	No Finding	No Finding	No Finding	No Finding
Clinton	Green	Green	Green	No Finding	Green	No Finding	No Finding
Columbia Generating Station	Green	Green	Green	White (2)	Green	No Finding	Green
Comanche Peak 1	Green	Green	Green	No Finding	No Finding	No Finding	Green
Comanche Peak 2	Green	Green	Green	No Finding	No Finding	No Finding	Green
Cooper	Green	Green	No Finding	Green	Green	No Finding	No Finding
Crystal River 3	No Finding	No Finding	No Finding	No Finding	No Finding	No Finding	No Finding

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(Security-related White, Yellow, and Red are shown as blue Greater-than-Green (GTG))

D.C. Cook 1	Green	Green	No Finding	No Finding	No Finding	No Finding	No Finding
D.C. Cook 2	Green	Green	No Finding	No Finding	No Finding	No Finding	No Finding
Davis-Besse	Green	Green	Green	No Finding	No Finding	No Finding	GTG
Diablo Canyon 1	Green	Green	Green	No Finding	No Finding	No Finding	Green
Diablo Canyon 2	Green	Green	Green	No Finding	No Finding	No Finding	Green
Dresden 2	No Finding	White (1)	No Finding	No Finding	No Finding	No Finding	No Finding
Dresden 3	No Finding	White (1)	No Finding	No Finding	No Finding	No Finding	No Finding
Duane Arnold	Green	Green	Green	No Finding	Green	Green	No Finding
Farley 1	Green	Green	No Finding	No Finding	Green	No Finding	Green
Farley 2	Green	Green	No Finding	No Finding	Green	No Finding	Green
Fermi 2	Green	Green	No Finding	No Finding	No Finding	No Finding	Green
FitzPatrick	Green	Green	No Finding	No Finding	No Finding	No Finding	No Finding
Fort Calhoun	Red (1)	Yellow (1)	Green	Green	Green	Green	GTG
Ginna	Green	Green	Green	No Finding	No Finding	No Finding	Green
Grand Gulf 1	Green	Green	Green	No Finding	Green	No Finding	Green
Harris 1	Green	Green	No Finding	No Finding	No Finding	No Finding	Green
Hatch 1	Green	Green	Green	Green	No Finding	No Finding	No Finding
Hatch 2	Green	Green	Green	Green	No Finding	No Finding	No Finding
Hope Creek 1	No Finding	Green	Green	No Finding	No Finding	No Finding	No Finding
Indian Point 2	Green	Green	No Finding	No Finding	No Finding	No Finding	Green
Indian Point 3	No Finding	Green	No Finding	No Finding	No Finding	No Finding	Green
La Salle 1	Green	Green	No Finding	No Finding	Green	No Finding	No Finding
La Salle 2	Green	Green	No Finding	No Finding	Green	No Finding	No Finding
Limerick 1	Green	Green	No Finding	No Finding	No Finding	No Finding	No Finding
Limerick 2	Green	Green	No Finding	No Finding	No Finding	No Finding	No Finding
McGuire 1	Green	Green	No Finding	No Finding	No Finding	No Finding	No Finding
McGuire 2	Green	Green	No Finding	No Finding	No Finding	No Finding	No Finding
Millstone 2	No Finding	Green	No Finding	Green	No Finding	No Finding	Green
Millstone 3	Green	Green	Green	Green	No Finding	No Finding	Green
Monticello	Green	Green	No Finding	No Finding	No Finding	Green	Green
Nine Mile Point 1	Green	No Finding	Green	No Finding	No Finding	No Finding	Green
Nine Mile Point 2	Green	Green	No Finding	No Finding	Green	Green	Green

Appendix C

NRC Inspection Findings at Operating Nuclear Power Plants as posted August 28, 2013, at
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NRC findings in order of increasing safety significance: Green, White, Yellow, Red
(Security-related White, Yellow, and Red are shown as blue Greater-than-Green (GTG))

North Anna 1	No Finding	Green	No Finding	Green	No Finding	No Finding	No Finding
North Anna 2	Green	Green	No Finding	Green	No Finding	No Finding	No Finding
Oyster Creek	No Finding	Green	Green	No Finding	No Finding	No Finding	No Finding
Oconee 1	No Finding	Green	No Finding	No Finding	No Finding	No Finding	No Finding
Oconee 2	No Finding	Green	No Finding	No Finding	No Finding	No Finding	No Finding
Oconee 3	No Finding	Green	No Finding	No Finding	No Finding	No Finding	No Finding
Palisades	Green	Green	No Finding	No Finding	Green	No Finding	Green
Palo Verde 1	No Finding	Green	Green	Green	No Finding	No Finding	Green
Palo Verde 2	Green	Green	Green	Green	No Finding	No Finding	Green
Palo Verde 3	No Finding	Green	Green	Green	No Finding	No Finding	Green
Peach Bottom 2	No Finding	Green	Green	No Finding	No Finding	No Finding	Green
Peach Bottom 3	No Finding	No Finding	No Finding	No Finding	No Finding	No Finding	Green
Perry 1	Green	Green	Green	Green	White (2)	No Finding	Green
Pilgrim 1	Green	Green	No Finding	No Finding	No Finding	No Finding	Green
Point Beach 1	Green	White (2)	Green	No Finding	Green	No Finding	No Finding
Point Beach 2	Green	White (1)	Green	No Finding	Green	No Finding	No Finding
Prairie Island 1	Green	Green	No Finding	White (1)	No Finding	No Finding	Green
Prairie Island 2	Green	Green	Green	No Finding	No Finding	No Finding	Green
Quad Cities 1	Green	Green	No Finding	No Finding	No Finding	No Finding	No Finding
Quad Cities 2	Green	Green	No Finding	No Finding	No Finding	No Finding	No Finding
River Bend 1	Green	Green	Green	No Finding	Green	No Finding	Green
Robinson 2	No Finding	Green	Green	No Finding	No Finding	No Finding	No Finding
Saint Lucie 1	Green	Green	No Finding	No Finding	No Finding	Green	Green
Saint Lucie 2	No Finding	Green	No Finding	No Finding	No Finding	Green	Green
Salem 1	Green	Green	Green	No Finding	No Finding	No Finding	No Finding
Salem 2	Green	Green	No Finding	No Finding	No Finding	No Finding	No Finding
San Onofre 2	Green	Green	No Finding	Green	No Finding	Green	Green
San Onofre 3	Green	Green	No Finding	Green	No Finding	Green	Green
Seabrook 1	Green	Green	No Finding	Green	Green	No Finding	No Finding
Sequoyah 1	No Finding	White (1)	No Finding	No Finding	No Finding	No Finding	No Finding
Sequoyah 2	Green	White (1)	Green	No Finding	No Finding	No Finding	No Finding

Appendix D

Curriculum vitae of David A. Lochbaum
PO Box 15316
Chattanooga, TN 37415
(423) 468-9272, office
(423) 488-8318, cell

EDUCATION

June 1979 Bachelor of Science in Nuclear Engineering, The University of Tennessee at Knoxville

EXPERIENCE SUMMARY

03/10 to date *Director – Nuclear Safety Project*
Union of Concerned Scientists

Responsible for directing UCS's nuclear safety program, for monitoring developments in the nuclear industry, for serving as the organization's spokesperson on nuclear safety issues, for initiating action to correct safety concerns, for authoring reports and briefs on safety issues, and for presenting findings to the Nuclear Regulatory Commission, the US Congress, and state and local officials.

03/09 to 03/10 *Reactor Technology Instructor*
U.S. Nuclear Regulatory Commission
Technical Training Center

Responsible for providing initial qualification and re-qualification training on boiling water reactor technology for NRC employees. Activities included revising chapters of the training manual, conducting classroom and control room simulator training sessions, maintaining the test question database, administering examinations, and assisting the development of an interactive 3-D model of the reactor pressure vessel and its internals.

10/96 to 02/09 *Director - Nuclear Safety Project*
Union of Concerned Scientists

Responsible for directing UCS's nuclear safety program, for monitoring developments in the nuclear industry, for serving as the organization's spokesperson on nuclear safety issues, for initiating action to correct safety concerns, for authoring reports and briefs on safety issues, and for presenting findings to the Nuclear Regulatory Commission, the US Congress, and state and local officials.

11/87 to 09/96 *Senior Consultant*
Enercon Services, Inc.

Responsible for developing the conceptual design package for the alternate decay heat removal system, for closing out partially implemented modifications, reducing the backlog of engineering items, and providing training on design and licensing bases issues at the Perry Nuclear Power Plant.

Responsible for developing a topical report on the station blackout licensing bases for the Connecticut Yankee plant.

Responsible for vertical slice assessment of the spent fuel pit cooling system and for confirmation of licensing commitment implementation at the Salem Generating Station.

Responsible for developing the primary containment isolation devices design basis document, reviewing the emergency diesel generators design basis document, resolving design document open items, and updating design basis documents for the FitzPatrick Nuclear Power Plant.

Responsible for the design review of balance of plant systems and generating engineering calculations to support the Power Uprate Program for the Susquehanna Steam Electric Station.

Responsible for developing the reactor engineer training program, revising reactor engineering technical and surveillance procedures and providing power maneuvering recommendations at the Hope Creek Generating Station.

Responsible for supporting the lead BWR/6 Technical Specification Improvement Program and preparing licensing submittals for the Grand Gulf Nuclear Station.

03/87 to 08/87 *System Engineer*
General Technical Services

Responsible for reviewing the design of the condensate, feedwater and raw service systems for safe shutdown and restart capabilities at the Browns Ferry Nuclear Plant.

08/83 to 02/87 *Senior Engineer*
Enercon Services, Inc.

Responsible for performing startup and surveillance testing, developing core monitoring software, developing the reactor engineer training program, and supervising the reactor engineers and Shift Technical Advisors at the Grand Gulf Nuclear Station.

10/81 to 08/83 *Reactor Engineer / Shift Technical Advisor*
Tennessee Valley Authority
Browns Ferry Nuclear Plant

Responsible for performing core management functions, administering the nuclear engineer training program, maintaining ASME Section XI program for the core spray and control rod drive systems, and covering STA shifts at the Browns Ferry Nuclear Plant.

06/81 to 10/81 *BWR Instructor*
General Electric Company
BWR/6 Training Center

Responsible for developing administrative procedures for the Independent Safety Engineering Group (ISEG) at the Grand Gulf Nuclear Station.

01/80 to 06/81 *Reactor Engineer / Shift Technical Advisor*
Tennessee Valley Authority
Browns Ferry Nuclear Plant

Responsible for directing refueling floor activities, performing core management functions, maintaining ASME Section XI program for the RHR system, providing power maneuvering recommendations and covering STA shifts at the Browns Ferry Nuclear Plant.

06/79 to 12/79 *Junior Engineer*
Georgia Power Company
Edwin I. Hatch Nuclear Plant

Responsible for completing pre-operational testing of the radwaste solidification systems and developing design change packages for modifications to the liquid radwaste systems at the Edwin I. Hatch Nuclear Plant. Also qualified as a station nuclear engineer and covered shifts during startups, control rod pattern exchanges, and other power maneuvers.

OTHER QUALIFICATIONS

January 2010 Certified as a boiling water reactor technology instructor at the U.S. Nuclear Regulatory Commission

April 1982 Certified as a Shift Technical Advisor at the TVA Browns Ferry Nuclear Plant

May 1980 Certified as an Interim Shift Technical Advisor at the TVA Browns Ferry Nuclear Plant

Member, American Nuclear Society (since 1978).

INSTITUTE FOR RESOURCE AND SECURITY STUDIES
27 Ellsworth Avenue, Cambridge, Massachusetts 02139, USA

Declaration of 19 December 2013
by Gordon R. Thompson:

Comments on the US Nuclear Regulatory Commission's
Waste Confidence Generic Environmental Impact Statement,
Draft Report for Comment (September 2013)

I, Gordon R. Thompson, declare as follows:

I. Introduction

(I-1) I am the executive director of the Institute for Resource and Security Studies (IRSS), a nonprofit, tax-exempt corporation based in Massachusetts. Our office is located at 27 Ellsworth Avenue, Cambridge, MA 02139. IRSS was founded in 1984 to conduct technical and policy analysis and public education, with the objective of promoting peace and international security, efficient use of natural resources, and protection of the environment. My professional qualifications are discussed in Section II, below.

(I-2) I have been retained by a group of environmental organizations to prepare this declaration.[1] This declaration provides comments invited by the US Nuclear Regulatory Commission (NRC).[2] NRC has invited comments on a September 2013 draft version of a generic environmental impact statement (GEIS) that addresses the subject of "waste confidence".[3] In the remainder of this declaration I refer to that document as the "draft GEIS". The stated objective of the draft GEIS is to:[4] "examine the potential environmental impacts that could occur as a result of the continued storage of spent

[1] These organizations include: Alliance to Halt Fermi 3, Beyond Nuclear, Blue Ridge Environmental Defense League, Center for a Sustainable Coast, Citizens Allied for Safe Energy, Citizens' Environmental Coalition, Don't Waste Michigan, Ecology Party of Florida, Friends of the Coast, Friends of the Earth, Georgia Women's Action for New Directions, Green States Solutions, Hudson River Sloop Clearwater, Missouri Coalition for the Environment, NC WARN, Nevada Nuclear Waste Task Force, New England Coalition, No Nukes Pennsylvania, Northwest Environmental Advocates, Nuclear Energy Information Service, Nuclear Information and Resource Service, Nuclear Watch South, Physicians for Social Responsibility, Public Citizen, Promoting Health and Sustainable Energy, Radiation and Public Health Project, Riverkeeper, SEED Coalition, San Clemente Green, San Luis Obispo Mothers for Peace, Sierra Club Nuclear Free Campaign, Snake River Alliance, Southern Alliance for Clean Energy, and Vista 360.
[2] NRC, 2013a.
[3] NRC, 2013b.
[4] NRC, 2013b, page iii.

nuclear fuel (spent fuel) at at-reactor and away-from-reactor sites until a repository is available."

(I-3) NRC states that it has prepared the draft GEIS to support a proposed rule.[5] The proposed rule is the most recent of a sequence of formal NRC findings, over several decades, about waste confidence. In this context, the term "waste" refers to spent nuclear fuel (SNF) or other forms of high-level radioactive waste (HLW) arising from the operation of commercial nuclear reactors.

(I-4) In a declaration dated 2 January 2013, I set forth 22 recommendations for the scope of the draft GEIS, together with information and analysis to support those recommendations.[6] Hereafter, I refer to that declaration as the "Thompson scoping declaration". It accompanies this declaration as Exhibit #1. In the present declaration, I incorporate by reference the information, analysis, and recommendations provided in the Thompson scoping declaration.

(I-5) This declaration addresses selected issues. Absence of discussion of an issue in this declaration does not imply that I view the issue as insignificant, or that I have no professional opinion on the manner in which the issue has been addressed in the draft GEIS.

(I-6) The issues discussed in this declaration are outlined in Section III, below. These issues all pertain to the concept of radiological risk, whose definition is discussed in Section IV, below. In this declaration the term "radiological risk" refers to the potential for harm to humans as a result of unplanned exposure to ionizing radiation. The consequences of this exposure could be direct or indirect. In the context of the draft GEIS, the set of direct and indirect consequences constitutes a set of environmental impacts.

(I-7) When spent fuel is discharged from a reactor of the type now used in the USA, it is initially stored under water in a pool adjacent to the reactor. The fuel assemblies are held upright in racks sitting on the floor of the pool. At each commercial reactor in the USA, the adjacent pool is now equipped with high-density, closed-frame racks. The nuclear industry began installing these racks in the 1970s, to replace the low-density, open-frame racks previously used. The high-density racks offered a comparatively cheap option for storing a growing nationwide inventory of spent fuel.

(I-8) At each commercial reactor in the USA, fuel takes the form of long, narrow tubes made of zirconium alloy (i.e., zircaloy), containing uranium oxide pellets. A group of these tubes makes up a fuel assembly. The zircaloy tubes are often referred to as fuel "cladding". Zircaloy has the property that at a comparatively high temperature (e.g.,

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[5] NRC, 2013c.
[6] Thompson, 2013b.

about 900 °C) it can begin reacting exothermically (i.e., with production of heat) with either air or steam.

(I-9) Spent fuel generates internal heat from decay of radioactive isotopes. When the fuel is under water in a normally functioning pool, the decay heat enters the surrounding water, which is in turn cooled by pumping it through heat exchangers. However, if the water level were to fall below the top of the fuel, the fuel temperature would begin to rise. This temperature rise would be exacerbated by storage of spent fuel in high-density, closed-frame racks, as is now universally practiced in the USA. The fuel temperature could continue rising to the point at which an exothermic reaction of zircaloy with air or steam would begin. That reaction could then accelerate, in a runaway process. In this manner, loss of water from a pool could lead to a self-propagating exothermic reaction of zircaloy cladding with air or steam. That phenomenon is often referred to as a "pool fire". Conditions determining the onset and progression of a pool fire would include the timing of water loss and the level of decay heat production in the fuel. The level of decay heat production declines with increasing age of the fuel after discharge from a reactor.

(I-10) As part of its consideration of radiological risk, the draft GEIS considers the potential for a pool fire. Later in this declaration, I show that the draft GEIS is deficient in its examination of both the probability and the consequences of a pool fire. In examining these matters, the draft GEIS cites a number of studies that NRC has performed in the context of pool fires.

(I-11) In June 2013, NRC published a draft version of a pool-fire study that is not cited in the draft GEIS. That study is titled "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a US Mark I Boiling Water Reactor".[7] Hereafter, I refer to that study as "NRC's draft consequence study". It accompanies this declaration as Exhibit #2. In a declaration dated 1 August 2013, I provided a critical review of NRC's draft consequence study, with recommendations for further NRC investigation in this area.[8] Hereafter, I refer to that declaration as the "Thompson draft consequence declaration". It accompanies this declaration as Exhibit #3. In the present declaration, I incorporate by reference the information, analysis, and recommendations provided in the Thompson draft consequence declaration. NRC's draft consequence study was re-published in final form in October 2013, with no substantial change.[9] Thus, my critical review of the draft study had no effect on the final study. I assume that the technical parts of the draft and final versions are identical. Thus, the Thompson draft consequence declaration applies equally to both.

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[7] Barto et al, 2013a.
[8] Thompson, 2013a.
[9] The October 2013 version is: Barto et al, 2013b. It was published as an enclosure under the SECY memo: Satorius, 2013a. That memo stated: "None of the comments or responses [i.e., on the draft version of the study] has necessitated making substantial changes to the report." (See: Satorius, 2013a, page 3.)

(I-12) The draft GEIS assumes that spent fuel will be stored initially in pools and subsequently in dry casks. The potential for a pool fire has been mentioned above. There is also a potential for a "cask fire". Such an event could occur if a malevolent actor gains access to a dry cask containing spent fuel and attacks the cask in a manner that produces a self-propagating reaction between air and zircaloy fuel cladding. Later in this declaration, I address the probability and consequences of a cask fire.

(I-13) As mentioned in paragraph I-6, above, the issues discussed in this declaration all pertain to radiological risk. Accordingly, I focus my comments on the draft GEIS on selected portions of that document. Portions of the draft GEIS that I address include, but are not limited to:

- Section 4.18 – Environmental Impacts of Postulated Accidents
- Section 4.19 – Potential Acts of Sabotage or Terrorism
- Appendix F – Spent Fuel Pool Fires

(I-14) As mentioned in paragraph I-2, above, this declaration has been prepared on behalf of a group of environmental organizations. This declaration complements three other declarations – by Arjun Makhijani, David Lochbaum, and Mark Cooper – prepared on behalf of the same group of environmental organizations.

(I-15) This declaration has the following narrative sections:

I. Introduction
II. My Professional Qualifications
III. Issues Discussed in this Declaration
IV. Definition of Radiological Risk
V. Estimation of Radiological Risk
VI. Malevolent Acts and Radiological Risk
VII. The Future Risk Environment
VIII. Linkage of Pool Risk and Reactor Risk
IX. Risk Implications of Nuclear-Power Scenarios
X. Pool Fire: Probability and Consequences
XI. Cask Fire: Probability and Consequences
XII. Risk-Reducing Options
XIII. Conclusions

(I-16) In addition to the above-named narrative sections, this declaration has four appendices that are an integral part of the declaration. Appendix A contains tables and figures that support the narrative. Appendix B is a bibliography. Documents cited in the narrative or in Appendix A are listed in Appendix B unless otherwise identified. Appendix C is a list of exhibits that accompany this declaration. Each exhibit is a document that is listed in Appendix B. My curriculum vitae is provided in Appendix D.

II. My Professional Qualifications

(II-1) As stated in paragraph I-1, above, I am the executive director of the Institute for Resource and Security Studies. In addition, I am a senior research scientist at the George Perkins Marsh Institute, Clark University. My curriculum vitae is provided here in Appendix D.

(II-2) I received an undergraduate education in science and mechanical engineering at the University of New South Wales, in Australia, and practiced engineering in Australia in the electricity sector. Subsequently, I pursued graduate studies at Oxford University and received from that institution a Doctorate of Philosophy in mathematics in 1973, for analyses of plasma undergoing thermonuclear fusion. During my graduate studies I was associated with the fusion research program of the UK Atomic Energy Authority. My undergraduate and graduate work provided me with a rigorous education in the methodologies and disciplines of science, mathematics, and engineering.

(II-3) My professional work involves technical and policy analysis in the fields of energy, environment, sustainable development, human security, and international security. Since 1977, a significant part of my work has consisted of analyses of the radiological risk posed by commercial and military nuclear facilities. These analyses have been sponsored by a variety of non-governmental organizations and local, state and national governments, predominantly in North America and Western Europe. Drawing upon these analyses, I have provided expert testimony in legal and regulatory proceedings, and have served on committees advising US government agencies.

(II-4) To a significant degree, my work has been accepted or adopted by relevant governmental agencies. During the period 1978-1979, for example, I served on an international review group commissioned by the government of Lower Saxony (a state in Germany) to evaluate a proposal for a nuclear fuel cycle center at Gorleben. I led the subgroup that examined radiological risk and identified alternative options with lower risk.[10] One of the risk issues that I personally identified and analyzed was the potential for a pool fire. In examining that potential, I identified partial loss of water from a pool as a more severe condition than total loss of water. I identified a variety of events that could cause loss of water from a pool, including aircraft crash, sabotage, neglect, and acts of war. Also, I identified and described alternative SNF storage options with lower risk; these lower-risk options included design features such as spatial separation, natural cooling, and underground vaults. The Lower Saxony government accepted my findings about the risk of a pool fire, and ruled in May 1979 that high-density pool storage of spent fuel was not an acceptable option at Gorleben.[11] That ruling accompanies this declaration as Exhibit #4. As a direct result of that ruling, policy throughout Germany

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[10] Beyea et al, 1979.
[11] Albrecht, 1979.

has been to use dry storage in casks, rather than high-density pool storage, for away-from-reactor storage of SNF.

(II-5) Since 1979, I have been based in the USA. During the subsequent years, I have been involved in a number of NRC regulatory proceedings related to the radiological risk posed by storage of SNF. In that context I have prepared a number of declarations and expert reports. For example, in 2009 I prepared a report that critiqued proposed NRC findings on waste confidence.[12] That report accompanies this declaration as Exhibit #5. Also, I co-authored a 2003 journal article, on SNF radiological risk, that received considerable attention from relevant stakeholders.[13] That article accompanies this declaration as Exhibit #6. The findings in that article were generally confirmed by a subsequent report by the National Research Council.[14] That report accompanies this declaration as Exhibit #7. As a result of my cumulative experience, I am generally familiar with: (i) US practices for managing SNF; (ii) the radiological risk posed by those practices; (iii) NRC regulation of that risk; and (iv) alternative options for reducing that risk. Also, I am familiar with the US effort since the 1950s to implement final disposal of SNF and HLW, and have written a review article on that subject.[15] That article accompanies this declaration as Exhibit #8.

(II-6) I have performed a number of studies on the potential for commercial or military nuclear facilities to be attacked directly or to experience indirect effects of violent conflict. A substantial part of that work relates to the radiological risk posed by storage of SNF or HLW. For example, in 2005 I was commissioned by the UK government's Committee on Radioactive Waste Management (CORWM) to prepare a report on reasonably foreseeable security threats to options for long-term management of UK radioactive waste.[16] That report accompanies this declaration as Exhibit #9. The time horizon used in that report was, by CORWM's specification, 300 years.

(II-7) On behalf of the Nautilus Institute, I prepared a handbook that analysts in various countries could use to support their assessment of radiological risk arising from management of spent fuel.[17] That handbook accompanies this declaration as Exhibit #10.

III. Issues Discussed in this Declaration

(III-1) The primary purpose of this declaration is to provide comments on the draft GEIS, regarding selected issues. These issues all pertain to radiological risk, with a focus on the potential for a pool fire or a cask fire. The definition of radiological risk may appear to be an academic matter, but it has substantial practical implications. I discuss this matter in Section IV, below, explaining why I reject the definition employed in the

[12] Thompson, 2009.
[13] Alvarez et al, 2003.
[14] National Research Council, 2006.
[15] Thompson, 2008.
[16] Thompson, 2005.
[17] Thompson, 2013c.

draft GEIS. In addressing radiological risk in this declaration, I focus on the potential for an unplanned release of radioactive material, especially an atmospheric release. Within that focus, I consider two categories of initiating event for the release: (i) accidents; and (ii) attacks. Accidents would involve events such as equipment failure, human error, or natural forces (e.g., earthquake). Attacks would involve deliberate, malevolent acts or the collateral effects of such acts. Accidents and attacks have features in common. Therefore, they should be considered in parallel, which is the approach I take in this declaration.

(III-2) Analysts who examine the radiological risk associated with potential attacks affecting nuclear facilities have a double duty. First, they owe the public an accurate, general picture of the risk. Second, they should refrain from publishing information that could directly assist a potential attacker. This declaration is designed to meet both requirements. Also, this declaration does not purport to provide an assessment of radiological risk. Instead, it comments on the risk assessment provided in the draft GEIS. From that perspective this declaration is, I believe, accurate and reasonably complete. At the same time, this declaration does not provide information that could directly assist an attack on a particular nuclear facility. Accordingly, this declaration is appropriate for general distribution.

(III-3) After radiological risk is properly defined, one can identify quantitative and qualitative indicators that, taken together, describe the risk in a particular situation. Then, analysts can seek to estimate values for those indicators. The resulting set of values constitutes a risk assessment. Section V, below, discusses approaches that can be used to estimate the values of relevant indicators. In that discussion I describe the strengths and limitations of probabilistic risk assessment (PRA), which provides the basis for the draft GEIS's estimation of radiological risk.

(III-4) Section VI, below, provides some background discussion on the contribution of malevolent acts (i.e., attacks) to radiological risk. Section VII provides some background discussion on the "risk environment", a term that refers to the array of societal, technical, and natural factors that, taken together, have significant influence on the radiological risk posed by a particular facility. Those discussions inform this declaration's critique, in Sections X and XI and elsewhere, of risk assessment in the draft GEIS.

(III-5) The potential for a pool fire can be affected by the potential for a radioactive release from a nearby, operational reactor, and vice versa. In other words, the radiological risks associated with a pool and with a nearby reactor can be linked. Section VIII discusses the nature and significance of this linkage, and its neglect in the draft GEIS. The linkage is discussed further in Section X.

(III-6) The development of waste-related radiological risk over future decades would be affected by the nature and scale of activity in the country's nuclear-power sector during that period. Section IX discusses the risk implications of nuclear-power scenarios, and NRC's neglect of this issue in the draft GEIS.

(III-7) Section X provides a critical review of the assessment of pool-fire risk in the draft GEIS, in terms of probability and consequences. Section XI discusses the probability and consequences of a cask fire, and NRC's neglect of this threat in the draft GEIS.

(III-8) Section XII discusses options for reducing waste-related radiological risk, and NRC's neglect of these options in the draft GEIS.

(III-9) Conclusions are presented in Section XIII.

IV. Definition of Radiological Risk

(IV-1) In this declaration, I define the general term "risk" as the potential for an unplanned, undesired outcome. Risk, so defined, is an inevitable part of human existence. However, many aspects of risk can be managed. That is especially true when the risk arises from a technological project. In such a case, the first step in risk management is to understand, as deeply as possible, the risk arising from the project. The second step is to identify and characterize a range of options for reducing the risk. The remaining steps are to choose, implement, and follow up a set of risk-reducing options.

(IV-2) Table IV-1 shows some categories of risk that could be posed by a commercial nuclear facility. I define radiological risk as the potential for harm to humans as a result of unplanned exposure to ionizing radiation. The exposure could arise from unplanned release of radioactive material, or from line-of-sight exposure to unshielded radioactive material or a criticality event. In this declaration I focus on exposure arising from an unplanned release, especially an atmospheric release. That mode of exposure would typically dominate the radiological risk posed by storage of SNF or HLW, at least during the first few centuries of storage.

(IV-3) By defining radiological risk as "the potential for harm", I do not mean to imply that any single indicator can adequately describe this risk. To the contrary, assessment of radiological risk requires the compiling of a set of qualitative and quantitative information about the likelihood and characteristics of the unplanned exposure and resulting harm. The required information can be expressed as values of qualitative and quantitative indicators.

(IV-4) NRC has articulated several, inconsistent definitions of risk. The definition in the NRC Glossary is, on its face, similar to my definition. Other NRC definitions, discussed below, deviate from the NRC Glossary to the point where they become fundamentally flawed. The NRC Glossary defines risk as:[18]

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[18] NRC website, http://www.nrc.gov/reading-rm/basic-ref/glossary/risk.html, accessed on 21 October 2013.

> "The combined answer to three questions that consider (1) what can go wrong, (2) how likely it is, and (3) what its consequences might be. These three questions allow the NRC to understand likely outcomes, sensitivities, areas of importance, system interactions, and areas of uncertainty, which can be used to identify risk-significant scenarios."

(IV-5) In the draft GEIS, the concept of risk is first introduced using a definition close to, but not identical with, the definition in NRC's Glossary. The Executive Summary of the draft GEIS says:[19]

> "NRC's concept of risk combines the *probability* of an accident with the *consequences of that accident.* In other words, the NRC examines the following questions:
> - What can go wrong?
> - How likely is it?
> - What would be the consequences?"

(IV-6) Later in the draft GEIS, the definition of risk deviates further from NRC's Glossary and becomes fundamentally flawed. In Section 4 of the draft GEIS, this later definition is embedded in an instructive paragraph. The paragraph is:[20]

> "The consequences of a severe (or beyond-design-basis) accident, if one occurs, could be significant and destabilizing. The impact determinations for these accidents, however, are made with consideration of the low probability of these events. The environmental impact determination with respect to severe accidents, therefore, is based on the **risk, which the NRC defines as the product of the probability and the consequences of an accident**. This means that a high-consequence low-probability event, like a severe accident, could still result in a small impact determination, if the risk is sufficiently low."

(IV-7) Through this deviation, NRC has ended up with a particular, limited definition of risk, as the arithmetic product of a numerical indicator of harmful consequences and a numerical indicator of the probability that those consequences will occur.[21] I refer to that definition hereafter as the "arithmetic" definition of risk. The arithmetic definition is flawed from several perspectives, as discussed below. It is, however, used extensively in the nuclear industry.

(IV-8) The above-quoted paragraph from the draft GEIS suggests a powerful motive for use of the arithmetic definition of risk. Consider the following situation. The consequences of a potential event could be severe; indeed, they could be "significant and

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[19] NRC, 2013b, page xxx.
[20] NRC, 2013b, pages 4-68 and 4-69 (emphasis added).
[21] Often, the arithmetic product is calculated for each of a range of scenarios, and these products are summed across the scenarios to yield an overall "risk".

destabilizing", to use the words of the draft GEIS. Yet, if the event has, allegedly, a sufficiently low probability, then its "risk", arithmetically defined, would be very low. A devotee of the arithmetic definition could then argue that no action is required to mitigate the risk. In that way, the cost of mitigating actions would be avoided.

(IV-9) In the context of radiological risk in the commercial nuclear sector, the arithmetic definition of risk is flawed from at least four overlapping perspectives:

- First, numerical estimates of consequences and probability are typically incomplete and highly uncertain.
- Second, significant aspects of consequences and probability are not susceptible to numerical estimation.
- Third, larger consequences can be qualitatively different than smaller consequences.
- Fourth, devotees of the arithmetic definition typically argue that equal levels of "risk", as they define it, should be equally acceptable to citizens. Their argument may be given a scientific gloss, but is actually a statement laden with subjective values and interests. An informed citizen could reject their argument on reasonable grounds.

(IV-10) I address the first and second of these four perspectives in Section V, below, and elsewhere in this declaration. I address the third and fourth perspectives in the remainder of Section IV, and elsewhere in this declaration.

(IV-11) The third perspective is that larger consequences can be qualitatively different than smaller consequences. There is ample evidence to support this proposition. For example, analysts at the French government's Institut de Radioprotection et de Surete Nucleaire (IRSN) have found a qualitative difference between larger and smaller radiological consequences. The IRSN analysts estimated the costs (i.e., economic damage) that would arise from an accidental, atmospheric release of radioactive material from the Dampierre nuclear generating station in France. They considered two types of release – a "controlled" (smaller) and a "massive" (larger) release. A paper summarizing their findings was presented at the 2012 Eurosafe conference.[22] That paper accompanies this declaration as Exhibit #11.

(IV-12) The IRSN analysts concluded that the costs arising from a massive release would differ "profoundly" from the costs arising from a controlled release, in terms of both qualitative and quantitative factors. Indeed, they described the massive release as "an unmanageable European catastrophe". Their paper concluded with the statement: [23]

> "Safety decisions may also be informed by this picture, in particular if it is realized that the most severe cases actually carry huge stakes for the nation and

[22] Pascucci-Cahen and Patrick, 2012.
[23] Pascucci-Cahen and Patrick, 2012.

> therefore that their lower probability may not balance their catastrophic potential."

(IV-13) To illustrate the potential for qualitative difference between larger and smaller consequences, consider the IRSN description of a massive release as "an unmanageable European catastrophe". Underlying that description is the potential for major socio-political impacts that would, in Europe, have substantial trans-boundary dimensions. The European Union might not survive the political stress arising from this event.

(IV-14) There is strong evidence that the 1986 Chernobyl accident was a principal cause of the dissolution of the Soviet Union. Political unrest related to the accident was noted in a 1987 paper by the US Central Intelligence Agency. That paper accompanies this declaration as Exhibit #12. The paper's concluding statement was:[24]

> "As public dissatisfaction grows, the Chernobyl' accident may provide a focal point around which disgruntled citizens can organize, and Moscow may discover that Chernobyl' is a continuing irritant with a potential for social and ethnic tensions for years to come."

(IV-15) Public dissatisfaction did indeed grow, and the Warsaw Pact and the Soviet Union dissolved in 1991. Mikhail Gorbachev, the last head of state of the Soviet Union, confirmed in a 2006 essay that the Chernobyl accident was a principal cause of the Union's dissolution. That essay accompanies this declaration as Exhibit #13. Gorbachev's essay began with the statement:[25]

> "The nuclear meltdown at Chernobyl 20 years ago this month, even more than my launch of *perestroika*, was perhaps the real cause of the collapse of the Soviet Union five years later. Indeed, the Chernobyl catastrophe was an historic turning point: there was the era before the disaster, and there is the very different era that has followed."

(IV-16) The full array of consequences of a large, atmospheric release of radioactive material from a nuclear facility in the United States is difficult to predict. The nature and scale of those consequences would vary according to the characteristics of the release and other factors. It is clear, however, that there are unresolved socio-political tensions in this country. Thus, the consequences of a large release could include substantial political stress. It is unlikely that aggrieved citizens would be comforted if they learned that NRC had determined, at a prior time, that the release was a low-risk event.

(IV-17) As mentioned above, the arithmetic definition of risk is used extensively in the nuclear industry, despite its flaws. It is also used in other contexts. One manifestation of this definition is the "probability-threshold position" on risk. Supporters of that position

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[24] CIA, 1987.
[25] Gorbachev, 2006.

argue that levels of risk below some numerical threshold can be ignored. That position means, in effect, that risks below the threshold are assigned a value of zero. The threshold might be, for example, an average probability of human fatality of $1x10^{-6}$ per annum. The probability-threshold position has been critiqued in a paper by the philosopher Kristin Shrader-Frechette.[26] That paper accompanies this declaration as Exhibit #14. Shrader-Frechette found that arguments for the probability-threshold position are fundamentally flawed.

(IV-18) Devotees of the arithmetic definition of risk often claim that their position is "scientific" and "rational". It is neither. The arithmetic definition is laden with subjective values and interests, and is prone to abuse. It is given a scientific gloss because it is expressed in numbers. However, the neatness of its numerical expression is achieved by ignoring significant factors that are not susceptible to numerical assessment. Ignoring such factors is the antithesis of a scientific approach. Moreover, the arithmetic definition pre-empts important ethical considerations, such as the tolerability of large consequences. Accordingly, the Thompson scoping declaration offered the following recommendation, which I continue to endorse:[27]

> "**Recommendation #21:** In considering radiological risk, the proposed EIS [i.e., the draft GEIS] should repudiate the arithmetic definition of risk."

V. Estimation of Radiological Risk

(V-1) For many societal hazards, such as automobile accidents, there is a rich body of data on actual incidents. In these cases, statistical methods can be used to predict probability. Also, in cases where the consequences are well defined, as is true for most automobile accidents, statistics can be used to predict consequences.

(V-2) The hazard of interest in this declaration is an unplanned release of radioactive material from a commercial nuclear facility. More specifically, the unplanned release contemplated here would be substantially larger than the authorized, routine release from a facility over a period of a year or so. There is, fortunately, a limited body of experience with unplanned releases of this nature. Thus, statistics cannot be used to predict probability or consequences.

(V-3) In the absence of reliable statistics, other approaches to radiological risk assessment must be taken. Three approaches are discussed here:

- Probabilistic risk assessment
- Direct experience
- Insurers' judgment

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[26] Shrader-Frechette, 1985.
[27] Thompson, 2013b, Sections IX and X.

(V-4) The great majority of experience with radiological risk assessment for commercial nuclear facilities is for reactors. Thus, I provide here a discussion of reactor risk assessment. This discussion shows the strengths and limitations of PRA, which provides the basis for estimation of radiological risk in the draft GEIS. Moreover, spent-fuel-pool risk is strongly linked with reactor risk, as shown in Section VIII, below.

(V-5) Figures V-1 through V-3 show PRA findings for two commercial reactors – a pressurized-water reactor (PWR) at the Surry site, and a boiling-water reactor (BWR) at the Peach Bottom site. Figures V-1 and V-2 show the estimated probability of an accident involving substantial damage to the reactor core. Such damage would involve melting of some or all of the fuel in the core. The probability is expressed as core damage frequency (CDF) per reactor-year (RY). Figure V-3 shows the estimated conditional probability (i.e., probability given core damage) of various types of containment failure. A failure of containment would lead to a release of radioactive material to the atmosphere. The earlier the failure, the larger the release, other factors being equal.

(V-6) The findings shown in Figures V-1 through V-3 are from NRC's NUREG-1150 study.[28] That study was the high point of PRA practice worldwide. The study was well funded, involved many experts, was conducted in an open and transparent manner, was done at Level 3 (i.e., with estimation of offsite consequences), considered internal and external initiating events, explicitly propagated uncertainty through its chain of analysis, was subjected to peer review, and left behind a large body of published documentation. While there are deficiencies in the NUREG-1150 findings, these could be corrected by fresh analysis and the use of new information. The process of correction is possible because the NUREG-1150 study was conducted openly and left a documentary record.

(V-7) PRA practice in the USA has degenerated since the NUREG-1150 study. Now, PRAs or similar studies are conducted mostly by the nuclear industry, with limited transparency. NRC formerly sponsored independent reviews of industry PRAs, but no longer does so. Recent NRC work on PRA has not attained the scope, quality of review, and other aspects of NUREG-1150 that are mentioned in paragraph V-6.

(V-8) The first reactor PRA was the NRC's Reactor Safety Study (RSS).[29] NRC set up a group of experts, chaired by the physicist Harold Lewis, to review the RSS. Their report accompanies this declaration as Exhibit #15. In their report, the review group succinctly described the challenge of developing a credible PRA as follows:[30]

> "RSS was faced with the problem of estimating the probability of occurrence of an extremely rare event – core melt – in a system of great complexity, a nuclear power reactor. Since the event has never occurred in a commercial reactor, there

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[28] NRC, 1990.
[29] NRC, 1975.
[30] Lewis et al, 1978, page 6.

> are no direct experimental data on which to base an estimate. The only datum that exists is the observation that there have been no core melts [as of 1978] in several hundred reactor-years of light water power reactor operation, and this fact provides at best an upper bound on the probability to be estimated. Therefore, it is necessary to resort to a theoretical calculation of the probability. But since the system is so complex, a complete and precise theoretical calculation is impossibly difficult. It is consequently necessary to invoke simplified models, estimates, engineering opinion, and in the last resort, subjective judgments."

(V-9) The preparation of a "complete and precise theoretical calculation" of core damage frequency remains "impossibly difficult" today, just as it was when Lewis and his colleagues wrote in 1978. This difficulty is intrinsic to the complexity of a reactor and the large number of potential failure modes. The difficulty is compounded when PRA analysts move from estimation of CDF (Level 1) to estimation of radioactive release (Level 2) and to estimation of offsite consequences (Level 3). At Level 2 there are many phenomenological uncertainties and variabilities. At Level 3 there is great variation in a variety of factors, such as atmospheric characteristics, and basic difficulties in characterizing indirect consequences. Thus, the radiological risk posed by a reactor is much more uncertain than other technological risks that are readily susceptible to actuarial analysis (e.g., automobile accidents).

(V-10) The complexity of a reactor is not the only reason why PRA findings are uncertain. Another reason is that a PRA examines an idealized system. The idealized system is properly designed, properly built, properly operated, and composed of independent components that typically fail randomly. PRA analysts have recognized that component failures may not always be independent. In response, they have developed analytic techniques to account for "common mode" failures that are attributable to influences (e.g., an earthquake, or a maintenance error) that can simultaneously affect more than one component. Although these techniques are useful, they leave some significant threats unaddressed.

(V-11) Three exemplary threats show how the idealized system examined in a PRA can be an incomplete representation of reality. First, a PRA cannot account for gross errors in design, construction, or operation. Second, it cannot account for malevolent acts. Third, it cannot account for deficiencies in institutional culture and practice. Each threat is significant. All three threats can lead to common mode failures. PRA's inability to account for malevolent acts is notable because a malevolent human intellect can identify weak points in a system, and can exploit destructive forces that are latent in the system.

(V-12) Reactor core-melt accidents have occurred at the Three Mile Island (TMI) site in 1979, the Chernobyl site in 1986, and the Fukushima #1 site in 2011. In each instance, retrospective investigations identified dominant risk factors that were non-quantifiable and could not have been accounted for in a PRA. These factors reflected, in differing ways, substantial deficiencies in institutional culture and practice. The three instances are discussed in the following three paragraphs.

(V-13) A commission, chaired by John Kemeny, was established by US President Carter to investigate the TMI accident. The commission's report accompanies this declaration as Exhibit #16. The commission concluded that systemic deficiencies in human behavior and organization were the dominant causes of the accident. To illustrate, their report included the statement:[31]

> "We are convinced that if the only problems were equipment problems, this Presidential Commission would never have been created. The equipment was sufficiently good that, except for human failures, the major accident at Three Mile Island would have been a minor incident. But, wherever we looked, we found problems with the human beings who operate the plant, with the management that runs the key organization, and with the agency that is charged with assuring the safety of nuclear power plants."

(V-14) Two Harvard University physicists, one of whom had previously worked in a reactor physics group in the USSR, published a paper in 1992 that examined the Chernobyl accident. Their paper accompanies this declaration as Exhibit #17. The abstract of their paper stated:[32]

> "The Chernobyl accident was the inevitable outcome of a combination of bad design, bad management and bad communication practices in the Soviet nuclear industry. We review the causes of the accident, its impact on Soviet society, and its effects on the health of the population in the surrounding areas. It appears that the secrecy that was endemic in the USSR has had profound negative effects on both technological safety and public health."

(V-15) The National Diet (i.e., parliament) of Japan established an independent commission to investigate the Fukushima accident. The executive summary of their report accompanies this declaration as Exhibit #18. The commission's principal conclusion was:[33]

> "The TEPCO Fukushima Nuclear Power Plant accident was the result of collusion between the government, the regulators and TEPCO, and the lack of governance by said parties. They effectively betrayed the nation's right to be safe from nuclear accidents. Therefore, we conclude that the accident was clearly "manmade". We believe that the root causes were the organizational and regulatory systems that supported faulty rationales for decisions and actions, rather than issues related to the competency of any specific individual."

[31] Kemeny et al, 1979, page 8.
[32] Shlyakhter and Wilson, 1992.
[33] Diet, 2012, page 16.

(V-16) The combined experience of these three incidents strongly suggests that a non-quantifiable factor, which cannot be accounted for in a PRA, will be a major or dominant risk factor underlying the next core melt at a commercial nuclear reactor. Thus, reliance on PRA to estimate the probability of the next core melt would be neither reasonable nor prudent.

(V-17) One might expect that responsible authorities would learn from these three incidents, and ensure that hitherto neglected risk factors are considered in future assessments of radiological risk. However, a paper by the sociologist John Downer shows that entrenched institutional cultures in the nuclear industry can suppress learning and promote the continuation of favored narratives. Downer's paper accompanies this declaration as Exhibit #19. The paper's conclusion begins with the statement:[34]

> "The disaster-punctuated history of nuclear power ought to speak for itself about the limitations of risk assessments, but our narratives obfuscate that history by rationalizing it away. For experience can only "show" if we are willing to "see," and the lessons of Fukushima, like those of the accidents that preceded it, will always be opaque to us if our narratives consistently interpret it as exceptional. So it is that even as the dramas of Fukushima linger, and in some ways intensify, the Ideal of Mechanical Objectivity survives with its misleading impression that expert calculations can objectively and precisely reveal the "truth" of nuclear risks. This has critical policy implications."

(V-18) Another approach to assessing radiological risk is to examine direct experience. In the case of a reactor, the most relevant experience consists of incidents in which a reactor core suffered severe damage. The next most relevant experience consists of incidents in which the core could have suffered severe damage if the incident had continued to develop. NRC categorizes incidents of the second type as accident sequence precursors (ASPs).

(V-19) Testimony to the US Senate by Thomas Cochran, soon after the Fukushima accident, listed twelve incidents involving severe damage to fuel in the core of a power reactor.[35] Cochran's testimony accompanies this declaration as Exhibit #20. His list of incidents excludes similar incidents at non-power reactors. For example, it excludes the core fire and radioactive release experienced in 1957 by a reactor at the Windscale site in the UK. That reactor was used to produce plutonium and other materials for nuclear weapons.

(V-20) Of the twelve core-damage incidents at power reactors, five have both: (i) occurred at a Generation II commercial reactor; and (ii) involved substantial fuel melting. These five incidents were at TMI Unit 2 (a PWR) in 1979, Chernobyl Unit 4 (an RBMK) in 1986, and Fukushima #1 Units 1 through 3 (BWRs) in 2011. These incidents occurred

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[34] Downer, 2013, page 17.
[35] Cochran, 2011.

in a worldwide fleet of commercial reactors. About 430 reactors are currently operable, although none of Japan's 50 nominally operable reactors is actually operating at present. Currently-operating reactors and previous reactors in the worldwide fleet had accrued 14,760 RY of operating experience as of February 2012.[36] Thus, about 15,500 RY of experience will be accrued through 2013.

(V-21) These five core-melt incidents provide a data set that is comparatively sparse and therefore does not provide a statistical basis for a high-confidence estimate of CDF. Nevertheless, this data set does provide a reality check for PRA estimates of CDF. From this data set – five core-melt incidents over a worldwide experience base of about 15,500 RY – one observes a CDF of $3.2x10^{-4}$ per RY (1 event per 3,100 RY). This value can be regarded as a "simple" estimate of CDF.

(V-22) A PRA analyst employed by NRC, Raymond Gallucci, has written a paper that develops CDF estimates based on direct experience.[37] Gallucci's paper accompanies this declaration as Exhibit #21. The paper considers both reactor core-melt and ASP experience, leading to a "simple" CDF estimate of $6.0x10^{-4}$ per RY (1 event per 1,700 RY). The paper does not adopt that estimate. Instead, it makes some analytic assumptions, and ultimately concludes that CDF, worldwide and in the USA, is in the range $0.7x10^{-4}$ to $4.0x10^{-4}$ per RY (between 1 event per 14,300 RY and 1 event per 2,500 RY). I question the assumptions underlying this downward adjustment of the "simple" CDF estimate. However, Gallucci's analysis deserves careful consideration in view of his professional expertise. On another note, Gallucci ends his paper by expressing his personal willingness to tolerate a CDF of the level that he has identified. On that matter, his opinion has no more weight than the opinion of any citizen.

(V-23) As shown in the preceding paragraphs, direct experience suggests a CDF as high as $6.0x10^{-4}$ per RY. The lowest value in the range suggested by Gallucci is $0.7x10^{-4}$ per RY. It is instructive to compare these numbers with the CDF estimates shown in Figures V-1 and V-2. The only CDF estimates in those figures that approach direct-experience levels are the upper-bound (95th percentile) levels of earthquake-caused CDF using Livermore seismic estimates. Thus, direct experience indicates that NUREG-1150 substantially under-estimated CDF. This finding does not mean that NUREG-1150 was a bad study. On the contrary, as stated above, NUREG-1150 was the high point of PRA practice. My finding simply confirms that PRA cannot account for all of the factors that determine the probability component of radiological risk.

(V-24) CDF estimates are typically presented as the number of incidents per RY. These estimates could also be presented as the cumulative number of incidents across a fleet of reactors, during a calendar year or some other time interval. At present, there are 100

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[36] See: World Nuclear Association (WNA) website, http://www.world-nuclear.org/. Data on cumulative reactor-years worldwide were obtained from the WNA website on 17 February 2012. The WNA website no longer provides such data.

[37] Gallucci, 2012.

licensed commercial reactors in the USA. Thus, a CDF of $3.2x10^{-4}$ per RY would be equivalent to a nationwide core-damage probability of $3.2x10^{-2}$ per calendar year (i.e., 3.2 percent per year). If that probability were sustained over decades, the occurrence of one or more core-damage incidents would become almost certain.

(V-25) Estimating the probability of core damage is just one step in assessing the radiological risk posed by a commercial reactor. Another step is to estimate the potential release of radioactive material to the environment. Figure V-3 illustrates a part of that step – estimating the conditional probability of failure of containment, given core damage. Additional steps include estimation of the movement of radioactive material in the environment, and estimation of the resulting consequences. As mentioned above, assessment of radiological risk involves the compiling of a set of qualitative and quantitative information about both probability and consequences.

(V-26) Direct experience provides some evidence regarding the release of radioactive material, its movement in the environment, and its impacts. Table V-1 shows estimated amounts of the radioactive isotope Cs-137 that were released to the atmosphere during the Chernobyl and Fukushima accidents. Figure V-4 shows the distribution of Cs-134 and Cs-137 isotopes deposited on Japan after being released to the atmosphere during the Fukushima accident. Table V-2 shows an estimate, by the US Department of Energy, of radiation dose commitment from the Chernobyl release.

(V-27) A paper by Sornette et al reveals the limitations of PRA findings by comparing them with lessons from direct experience.[38] That paper accompanies this declaration as Exhibit #22. The paper considers monetized losses from nuclear-facility incidents, using two sources of information. One source is a reactor PRA. The other source is a compilation of data on actual incidents at nuclear facilities. Figure V-5 of this declaration reproduces a figure from Sornette et al. That figure shows that the PRA substantially under-estimates the probability of a monetized loss. The under-estimation grows as losses become larger. In other words, the PRA findings show a thin-tail probability distribution, whereas the empirical data show a fat-tail distribution.

(V-28) Two approaches to radiological risk assessment are discussed above – PRA, and direct experience. A third approach is to examine the judgment of nuclear-facility insurers. Such an examination is set forth in Tables V-3 and V-4. Table V-3 shows insurance premiums for the Darlington nuclear generating station in Canada, to cover liability for bodily injury or property damage at offsite locations. Table V-4 calculates an "implied probability of event", which represents the insurers' assessment of the probability of a claim up to the liability limit, arising from an accident at Darlington.[39] (Events caused by malevolent acts are not considered in Table V-4.) If, for example, the liability limit is $1 billion, the implied probability of a claim up to that limit ranges from $6.4x10^{-4}$ to $1.0x10^{-3}$ per RY.

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[38] Sornette et al, 2013.
[39] A claim up to the liability limit means that monetized impact exceeds the liability limit.

(V-29) The calculations presented in Table V-4 show that, in the judgment of the Canadian nuclear insurers, the probability distribution of the monetized impact of an accident at Darlington is close to the distribution shown by the "Empirical Records" curve in Figure V-5. Evidently, the insurers are not persuaded by PRA findings, which show much lower probabilities. In 2012, Ontario Power Generation, the owner/operator of the Darlington station, published the findings of a PRA it conducted for the station.[40] Those findings accompany this declaration as Exhibit #23. Findings of a previous PRA for Darlington were published in 1987.[41] The 2012 PRA estimated the probability of a large, atmospheric release as 9.5×10^{-6} per RY, while the 1987 PRA estimated that probability as 8.2×10^{-7} per RY. The Canadian nuclear insurers have access to these PRA studies, but choose to set premiums at much higher levels than the PRAs would imply.

(V-30) At this point in Section V, I have shown that reactor PRAs typically yield estimates of probability (i.e., the probability of accident outcomes) that are substantially lower than is implied by direct experience and insurers' judgment. This finding carries over to PRAs for non-reactor facilities, because it arises from limitations in the art of PRA itself. Those limitations are significant for the draft GEIS, because the draft GEIS relies upon PRA findings for estimation of radiological risk.

(V-31) In 1989 I was a co-author of a critical review of the state of the art of PRA.[42] The findings of that review remain generally valid today. One of the review's conclusions, with some reframing and updating to match the context of this declaration, provides a useful way to summarize the role of PRA in radiological risk assessment. The reframed and updated conclusion, which refers to a commercial reactor or to various other types of nuclear facility, is:

Actual probability of event = (PRA finding)x(Reality factor #1) + (Reality factor #2)

Where the variables in this equation are as follows:

- "Actual probability of event" refers to the real-world numerical probability of an outcome such as: reactor core damage; release of a specified amount of radioactive material; contamination of a specified area of land above a specified dose threshold; or accrual of a specified collective dose to people offsite.
- "PRA finding" refers to a PRA estimate of the probability of the outcome in question – this could be a mean, median, or other representation of a probability distribution.
- "Reality factor #1" is a number, typically greater than 1, that represents influences that are within the paradigm of PRA but are not properly accounted for in contemporary PRAs – these influences include: complexity; inadequate data; and deficiencies in institutional culture and practice.

[40] OPG, 2012.
[41] Ontario Hydro, 1987.
[42] Hirsch et al, 1989.

- "Reality factor #2" is a number that represents influences outside the paradigm of PRA – these influences include: gross errors in design, construction, or operation; and malevolent acts.

And the following observations apply:

- Experience suggests that Reality factor #1 for severe accidents may have a value that exceeds 1 by several orders of magnitude (i.e., factors of 10).
- Reality factor #2 has two numerical components: (i) a retrospective component that can be determined empirically based on the occurrence of events; and (ii) a prospective component that will remain unknown for the foreseeable future.
- Both Reality factors may vary significantly in response to variations in the future risk environment, as discussed in Section VII, below.
- This version of the equation is applicable when the values of "PRA finding" and "Actual probability of event" are both less than 1. At higher values, the term "probability" would be replaced by the term "frequency".

(V-32) The two Reality factors cannot be fully estimated by PRA techniques, although they may have components that can be estimated in that way. In cases where there is a record of direct experience – such as the occurrence of reactor core damage or the occurrence of ASPs – one can infer a range of values for the Reality factors, drawing upon PRA findings. If there is no record of direct experience of a hypothesized event, PRA findings can provide a kernel of information that can be adjusted by Reality factors that are judged appropriate to the situation. Thus, PRA findings can be valuable items of information. They are, however, only a guide to the assessment of probability, and are not definitive statements of that probability.

VI. Malevolent Acts and Radiological Risk

(VI-1) The draft GEIS makes assertions about the environmental impacts of malevolent acts affecting stored spent fuel. Later in Section VI, I identify those assertions. Then, in Sections X and XI, below, I critically review those assertions in the contexts of pool fires and cask fires. I begin Section VI by providing some background information about malevolent acts.

(VI-2) In the context of this declaration, it is noteworthy that NRC explicitly considered the impacts of malevolent acts in its 1979 GEIS on Handling and Storage of Spent Light Water Power Reactor Fuel, which was designated NUREG-0575.[43] Potential malevolent acts were described in Appendix J of that GEIS. Appendix J accompanies this declaration as Exhibit #24. NRC stated its rationale for considering malevolent acts as follows:[44]

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[43] NRC, 1979.
[44] NRC, 1979, Appendix J, pages J-2 and J-3.

> "The NRC staff is unable to determine the quantitative likelihood of a hypothetical malevolent act being successfully performed by an adversary group. Instead, a group of selected reference events have been assumed to occur in order to establish a range of potential effects that might be caused by deliberate acts. The consequences corresponding to these reference events were calculated on a per-fuel-element basis, thus allowing the results to be extrapolated to possibly include massive destructive acts and thereby develop an upper bound on estimates of potential consequences, regardless of the plausibility of the attempted acts."

(VI-3) To implement that rationale in NUREG-0575, NRC considered four types of "sabotage" event at a spent-fuel pool. Table VI-1 summarizes NRC's description of these types of event. One sees from Table VI-1 that NRC envisioned an attack by up to 83 adversaries. The attackers could hold the control room for about one half hour. They could use explosive charges to breach the walls of the pool building or the floor of the pool itself.

(VI-4) NUREG-0575 did not consider the environmental impact of pool fires. It dismissed the potential for a pool fire with the brief statement:[45]

> "Assuming that the spent fuel stored at an independent spent fuel storage installation is at least one year old, calculations have been performed to show that loss of water should not result in fuel failure due to high temperatures if proper rack design is employed".

(VI-5) The citation for the "calculations" mentioned in that statement was to a report prepared by Sandia Laboratories for NRC, under the designation NUREG/CR-0649.[46] That report accompanies this declaration as Exhibit #25. Careful examination of NUREG/CR-0649 shows that it did not support the interpretation placed upon it by NUREG-0575. In fact, NUREG/CR-0649 showed that partial loss of water from a spent-fuel pool could lead to a pool fire.[47] The significance of partial loss of water is discussed further in Section X, below.

(VI-6) Thus, the authors of NUREG-0575 did not properly understand the potential for a pool fire. Accordingly, they failed to understand that the malevolent acts they postulated in Appendix J could, with slight adjustment, readily initiate a pool fire, as discussed in Section X, below. Nevertheless, NRC did postulate this set of malevolent acts in its 1979 GEIS. To my knowledge, NRC has never repudiated its postulation of these acts.

(VI-7) Since the 1970s, I have written numerous reports, declarations, and other documents that address malevolent acts as potential contributors to the radiological risk posed by reactors, spent-fuel-storage facilities, and other nuclear facilities. Documents in

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[45] NRC, 1979, page 4-21.
[46] Benjamin et al, 1979.
[47] See, for example, the "blocked inlets" curve in Figure 26 (at page 77) of: Benjamin et al, 1979.

this category that are mentioned up to this point in this declaration include: (i) a January 2013 declaration[48] (Exhibit #1); (ii) an August 2013 declaration[49] (Exhibit #3); (iii) a February 2009 report[50] (Exhibit #5); (iv) a November 2005 report[51] (Exhibit #9); and (v) a January 2013 handbook[52] (Exhibit #10). Here, I introduce two additional documents I have written that address malevolent acts at nuclear facilities. One document is a November 2007 report that discusses continued operation of the Indian Point nuclear power plants.[53] That report accompanies this declaration as Exhibit #26. The second document is a January 2003 report that discusses threats to spent fuel as a neglected issue of homeland security.[54] That report accompanies this declaration as Exhibit #27. Each of the documents listed in this paragraph cites numerous documents prepared by diverse authors.

(VI-8) An August 2012 report prepared at the Congressional Research Service provides a succinct overview of policy, law, and regulation in the United States regarding the threat of malevolent acts at nuclear facilities.[55] That report accompanies this declaration as Exhibit #28. A February 2012 report on the future of nuclear power in the United States, by authors including former NRC chair John Ahearne, contains an instructive chapter on the threat of malevolent acts.[56] That report accompanies this declaration as Exhibit #29. Also instructive is a 2007 journal article by staff of the US Environmental Protection Agency, on the sabotage vulnerability of nuclear power plants.[57] That article accompanies this declaration as Exhibit #30. Computer models have been developed to help assess the vulnerability of nuclear facilities to malevolent acts, as discussed in a 2006 journal article by Morris et al.[58] That article accompanies this declaration as Exhibit #31.

(VI-9) For convenience, this declaration includes some tables and figures that appear in one or more of the documents listed in paragraph VI-7, above. I refer here to Tables VI-2 through VI-5, and Figures VI-1 through VI-4. These tables and figures provide clear evidence that reactors and spent-fuel-storage facilities are vulnerable to attack, including attack by non-State actors. I could explain this evidence in detail, but choose not to provide that explanation in a document that is intended for general distribution.

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[48] Thompson, 2013b.
[49] Thompson, 2013a.
[50] Thompson, 2009.
[51] Thompson, 2005.
[52] Thompson, 2013c.
[53] Thompson, 2007.
[54] Thompson, 2003.
[55] Holt and Andrews, 2012.
[56] Ahearne et al, 2012.
[57] Honnellio and Rydell, 2007.
[58] Morris et al, 2006.

(VI-10) The documents listed in paragraphs VI-7 and VI-8, the numerous citations within those documents, and the tables and figures identified in paragraph VI-9, provide a thoroughly documented basis for the following conclusions:

1. A reactor, spent-fuel-storage facility, or other nuclear facility in the United States could be attacked by a State or by a non-State actor.
2. A non-State actor could acquire the capability to execute an attack that releases to the environment a large amount of radioactive material from a reactor core or from stored spent fuel.
3. Storage of spent fuel at high density in a pool adjacent to an operating reactor is advantageous to an attacker, because this arrangement would help the attacker to obtain a large, radioactive release from the reactor and the pool.
4. The amount of radioactive material that would be released by an attack could exceed the amount that would be released by an accident.
5. NRC requires licensees to implement only a "light" defense of a nuclear facility, namely a defense that is designed to resist attacks within the lower end of the spectrum of severity of potential attacks.
6. NRC does not require any defense against attack from the air, although a non-State actor could execute such an attack.
7. Licensees routinely lobby NRC to reduce the scale of threat against which licensees are required to mount a defense.
8. Measures deployed by licensees to mitigate the effects of potential accidents would be ineffective in many scenarios of potential attack.
9. The probability of a successful attack cannot be estimated by statistical methods or by analytic arts such as probabilistic risk assessment.
10. In light of human history, observation of the contemporary world, and consideration of possible societal trends, a prudent decision maker would conclude that a successful attack on a reactor or spent-fuel-storage facility in the United States over the coming decades is as likely to occur as are major national challenges that are planned for, such as severe natural disasters or engagement in wars.
11. Options are available to reduce radiological risk arising from potential attacks.
12. The attack-related risk of storing spent fuel could be dramatically reduced by re-equipping spent-fuel pools with low-density, open-frame racks, and by otherwise storing spent fuel in protected dry casks.
13. Requiring licensees to implement options that substantially reduce the attack-related risk at nuclear facilities would enhance protective deterrence as a national strategy, with substantial benefits.

(VI-11) The draft GEIS addresses the potential for malevolent acts in its Section 4.19, titled Potential Acts of Sabotage or Terrorism. The Executive Summary of the draft GEIS addresses this potential in its Section ES.13.1.19, also titled Potential Acts of Sabotage or Terrorism. In its Section 4.19, the draft GEIS has separate sub-sections that address attacks on spent-fuel pools, and attacks on independent spent fuel storage installations (ISFSIs). The draft GEIS summarizes its findings on the potential for malevolent acts as follows:[59]

> "The NRC finds that even though the environmental consequences of a successful attack on a spent fuel pool beyond the licensed life for operation of a reactor are large, the very low probability of a successful attack ensures that the environmental risk is SMALL. Similarly, for an operational ISFSI during continued storage, the NRC finds that both the probability and consequences of a successful attack are low, and therefore, the environmental risk is SMALL. Therefore, the storage of spent fuel during continued storage will not constitute an unreasonable risk to the public health and safety from acts of radiological sabotage, theft, or diversion of special nuclear material. The environmental impacts of terrorism are an area of particular controversy."

(VI-12) In addressing an attack on a spent-fuel pool, this statement in the draft GEIS acknowledges that the consequences of an attack could be "large". In Section X, below, I provide further evidence about the meaning of that term. Then, the statement asserts that the probability of a successful attack is "very low". Elsewhere, the draft GEIS says that this probability is "numerically indeterminable".[60] I agree with the latter statement, but do not agree that the probability is very low. As summarized in paragraph VI-10, above, there is an extensive, thoroughly documented body of evidence showing that a successful attack on a reactor or pool is as likely to occur as are major national challenges that are planned for, such as severe natural disasters or engagement in wars.

(VI-13) The draft GEIS notes that, after loss of cooling at a pool, some days would pass before water boiled away to the point where fuel would be exposed. For a pool containing PWR fuel, the draft GEIS cites boil-away times exceeding 4 to 11 days, depending upon the age of the fuel. The draft GEIS asserts that such a time period would allow the implementation of mitigating actions that would prevent a pool fire.[61] In Section VIII, below, I show that NRC has neglected to consider pool-reactor risk linkage that could hinder or preclude mitigating actions. Pool-reactor risk linkage could preclude mitigating actions during either an accident or an attack. Also, a malevolent actor could preclude mitigating actions directly, and/or could cause a loss of water by mechanisms other than boil-away. I address these matters in Section X, below.

(VI-14) The draft GEIS asserts that additional security measures implemented after the 11 September 2001 attacks reduced the probability of a pool fire.[62] Presumably, the draft GEIS is referring to attack-induced pool fires. However, even with the additional security measures, NRC requires licensees to implement only a light defense of a nuclear

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[59] NRC, 2013b, Executive Summary, page xiiv. A briefer statement to the same general effect appears at: NRC, 2013b, pp 4-89 to 4-90.
[60] NRC, 2013b, page 4-85.
[61] NRC, 2013b, Appendix F, page F-11.
[62] NRC, 2013b, Appendix F, page F-11.

facility. The conclusions that I set forth in paragraph VI-10, above, take account of that defense.

(VI-15) As discussed in paragraphs VI-11 and VI-12, above, the draft GEIS identifies "large" but vaguely specified consequences of an attack-induced pool fire, and "very low" but numerically indeterminable probability. The draft GEIS proceeds to multiply these indicators together in some unspecified manner, concluding that the risk of an attack on a pool is "SMALL". In effect, the draft GEIS uses the "arithmetic" definition of risk that I discuss in Section IV, above. That definition is fundamentally flawed for the reasons I set forth in Section IV. In this instance, application of the arithmetic definition is additionally flawed because the indicators that are multiplied together are nebulous.

(VI-16) In addressing an attack on an ISFSI, the statement in the draft GEIS that is quoted in paragraph VI-11 asserts that both the probability and consequences of a successful attack are "low". I discuss this probability and these consequences in Section XI, below. That discussion addresses, among other matters, the role of protective deterrence. The statement quoted in paragraph VI-11 goes on to assert that the risk of a successful attack on an ISFSI is "SMALL". That assertion reflects use of the arithmetic definition of risk. As stated in paragraph VI-15, above, that definition is fundamentally flawed, and its application in the draft GEIS is additionally flawed because the indicators that are multiplied together are nebulous.

VII. The Future Risk Environment

(VII-1) The draft GEIS examines storage of spent fuel over three timeframes.[63] The "short-term storage" timeframe is for 60 years beyond licensed life for reactor operations. The "long-term storage" timeframe is for 100 years beyond the short-term timeframe. The "indefinite storage" timeframe extends into the indefinite future.

(VII-2) Assessing radiological risk over such long timeframes poses a daunting challenge to risk assessors. A competent risk assessor would immediately acknowledge that the risk environment could change substantially during the short- and long-term timeframes, and even more so during the indefinite timeframe. In this declaration, the term "risk environment" refers to the array of societal, technical, and natural factors that, taken together, have significant influence on risk. Over a period of decades and centuries, these factors, and their interactions with each other, could change substantially. Moreover, the risk environment could change non-uniformly across the United States.

(VII-3) Section V of the Thompson scoping declaration discussed the future risk environment. That discussion culminated in my recommendation:[64]

[63] NRC, 2013b, page 1-12.
[64] Thompson, 2013b, Section V and Section X.

> "**Recommendation #7:** Risk assessment in the proposed EIS should be supported by a set of indicators that express the dynamic aspects of the potential risk environment across the time period and suite of scenarios considered in the EIS."

(VII-4) A report from Argonne National Laboratory examines the challenge of safeguarding spent fuel during very long-term storage (VLTS), which it defines as above-ground, interim, dry storage for a period of more than 50 years.[65] That report accompanies this declaration as Exhibit #32. The challenges identified in the report arise partly from potential changes in the risk environment. Thus, the report illustrates the significance of a potentially changing risk environment for the assessment of radiological risk. The report makes the following statement:[66]

> "Safeguarding a VLTS facility with nuclear material for 50, 100, or 200 years will present many challenges. First of all, the integrity of the fuel or cask may deteriorate. The radioactive signature of the fuel will also change. As the fuel cools, it may become more attractive for diversion. Even though the State has the means to handle very radioactive spent fuel, cooler spent fuel will still be more attractive to divert because it is easier to handle and reprocess. Keeping data on the facility for that long may also be a challenge. If the past 50 years are any indication of the future, it is difficult to predict what the safeguards challenges and needs will be in just the next 50 years."

(VII-5) The draft GEIS does consider one aspect of potential change in the risk environment over coming decades. In its Section 4.18, it discusses the influence of climate change on design-basis accidents or severe accidents at spent-fuel pools or at dry cask storage facilities (i.e., ISFSIs). It acknowledges various potential outcomes of climate change, such as increased intensity and frequency of severe weather events, sea level rise, increased storm surges, shoreline retreat, and inland flooding. It assumes, however, that mitigating actions could prevent significant increase in radiological risk as a result of climate change, that NRC will continue to exist and will require the necessary mitigating actions, and that licensees will be willing and able to implement these actions.

(VII-6) Section 1.8.3 of the draft GEIS, titled Analysis Assumptions, sets forth a highly optimistic view of the future conditions that will affect stored spent fuel. It assumes that institutional controls will remain operative into the indefinite future, arguing that this assumption "avoids unreasonable speculation regarding what might happen in the future regarding Federal actions to provide for the safe storage of spent fuel".[67] It further assumes that each ISFSI will be replaced on a 100-year cycle, into the indefinite future.

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[65] Kollar et al, 2013.
[66] Kollar et al, 2013, page 6.
[67] NRC, 2013b, page 1-14.

(VII-7) For the reasons set forth in Section V of the Thompson scoping declaration, the highly optimistic assumptions used in the draft GEIS are neither reasonable nor prudent. Moreover, assuming static conditions is speculative in the extreme, and shows a profound ignorance of human history. Given the long timeframes envisioned in the draft GEIS, the only reasonable approach is to consider a broad range of scenarios. Section VI of the Thompson scoping declaration discussed this approach. That discussion yielded three recommendations, each of which is pertinent to radiological risk, as follows:[68]

> "**Recommendation #8:** The scenarios considered in the proposed EIS should cover a range of potential outcomes regarding the role of nuclear power, including: (i) shrinkage in the number of operating reactors, with potential shutdown of all reactors by the middle of the 21st century; (ii) expansion in the number of operating reactors; and (iii) introduction of new technology."
>
> "**Recommendation #9:** The scenarios considered in the proposed EIS should cover future societies exhibiting a range of variation in prosperity, technological capability, and the quality of governance."
>
> "**Recommendation #10:** The scenarios considered in the proposed EIS should cover a range of potential future outcomes regarding the propensity for violent conflict, and should cover situations in which stored SNF or HLW would experience attacks involving States or non-State actors."

(VII-8) The draft GEIS does not implement any of my Recommendations #7 through #10. Instead, the draft GEIS takes the unreasonable, imprudent, and highly speculative position that the risk environment will remain unchanged into the indefinite future.

VIII. Linkage of Pool Risk and Reactor Risk

(VIII-1) The radiological risk posed by a spent-fuel pool is significantly increased if that pool is located near an operational reactor, and vice versa. This linkage of pool risk and reactor risk is discussed below. Before embarking on that discussion, however, I explain why this linkage is significant in the context of the draft GEIS.

(VIII-2) The hazard posed by a nuclear fuel assembly begins at the moment when the assembly first undergoes nuclear fission, which occurs inside a reactor. That moment would be the logical starting point for any GEIS that addresses spent fuel. A less logical, but perhaps plausible, starting point would be the moment when the fuel assembly is discharged from a reactor and placed in a nearby pool. The draft GEIS uses a much later and entirely illogical starting point. The draft GEIS considers the environmental impacts of storing spent fuel during a period that begins when the reactor that discharged the fuel is no longer licensed for operation.

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[68] Thompson, 2013b, Section VI and Section X.

(VIII-3) By adopting this later starting point, the draft GEIS excludes from consideration a set of significant environmental impacts that arise in earlier phases of the life of a fuel assembly. That exclusion is illogical. It deserves examination from a legal perspective, but that examination is outside the scope of this declaration.

(VIII-4) For the remainder of this declaration, I adopt the starting point used in the draft GEIS. That adoption does not mean that I endorse this starting point. Discussion in the following paragraphs shows that, even if one adopts the starting point used in the draft GEIS, linkage of pool risk and reactor risk is a significant factor in the radiological risk of storing spent fuel.

(VIII-5) Let us consider spent fuel that has been discharged from a reactor that is no longer operational, and that is currently in the pool into which it was discharged. Let us designate the US inventory of this spent fuel, at any given time, as "draft GEIS fuel in pools" (DGFIP). It turns out, as shown below, that a significant fraction of DGFIP could be located near operational reactors. This finding could hold for a significant period even if nuclear power continues to decline as a US energy source. The same finding could hold for a much longer period if nuclear power revives as a US energy source. Both outcomes for nuclear power are encompassed by the draft GEIS. Later in this declaration, I discuss the implications of nuclear-power scenarios for the radiological risk of storing spent fuel. That discussion is in Section IX, below.

(VIII-6) Currently, 100 commercial reactors are licensed to operate in the United States, at 62 sites. At 35 of these sites, there are multiple (i.e., two or three) licensed reactors.[69] During future decades, all of the currently licensed reactors will shut down permanently. However, there is no NRC requirement or expectation that all of the reactors at a particular site will permanently shut down at the same moment. Thus, there could be, and probably will be, significant periods when a significant fraction of DGFIP is located near operational reactors. Moreover, there are 9 sites where two reactors share a single pool, and 8 other sites where the pools serving two adjacent reactors are connected by a transfer canal.[70] At these 17 sites, any fuel in a pool is intimately associated with two adjacent reactors.

(VIII-7) If nuclear power revives as a US energy source, where might a new fleet of reactors be constructed? This question has been addressed by nuclear industry consultant Karl Fleming in a paper supporting his presentation to NRC commissioners in July 2011. That paper accompanies this declaration as Exhibit #33. The paper states:[71]

> "It is likely that most if not all of the next fleet of new reactors will be built on one or more of the existing licensed reactor sites in view of the additional costs

[69] NRC, 2013d. There are 25 sites with multiple PWRs, and 10 sites with multiple BWRs. There are 13 sites with one PWR, and 14 sites with one BWR.
[70] Satorius, 2013b, Enclosure 1, Table 72.
[71] Fleming, 2011.

> and effort that will be required to approve new sites."

(VIII-8) Thus, if nuclear power revives, a significant fraction of DGFIP could be located near new operational reactors, for a period of many years. That finding, combined with my finding in paragraph VIII-6 for the case of continued decline of nuclear power, shows that a significant fraction of DGFIP could be located near operational reactors for a significant period, regardless of future trends in US nuclear power.

(VIII-9) At this point, I have established that pool storage of spent fuel, as considered in the draft GEIS, could occur, and probably will occur, at locations near operational reactors. It follows that the draft GEIS should have carefully considered the potential linkage of pool risk and reactor risk.

(VIII-10) PRA practice has neglected linkage of risk among multiple reactors at a site. That neglect is summarized in Karl Fleming's paper, discussed above. The paper says:[72]

> "Our current state of knowledge about the risks from accidents is derived from PRAs. For the most part PRAs on multi-unit sites have been performed on individual reactors separately. In fact, some multi-unit sites have performed a PRA only for one of the sited reactors, arguing that symmetry considerations justify a single reactor PRA. In order to meet expectations for PRA quality, as defined in the various PRA standards, such PRAs must address certain multi-unit dependencies in the modeling of risks that involve damage to a single reactor. The capability to use equipment from one reactor to back up failures on another is typically considered, however the probability that resources are consumed by concurrent reactor accidents is almost always ignored."

(VIII-11) In a 2013 journal article, Schroer and Modarres proffer an event classification schema for applying PRA to multiple reactors at a site.[73] That article accompanies this declaration as Exhibit #34. At the time of publication, co-author Suzanne Schroer was a member of the NRC staff. The article says:[74]

> "Currently, multi-unit nuclear power plant PRAs consider the risk from each unit separately and do not consider combination events between the units. To gain an accurate view of the site's risk profile, the CDF for the site rather than the unit must be considered. This paper has presented a classification system that utilizes existing single-unit PRAs and combines them into a multi- unit PRA. Six main commonality classes that can cause multiple units to be dependent have been presented: initiating events, shared connections, identical components, proximity dependencies, human dependencies, and organizational dependencies. A seventh

[72] Fleming, 2011.
[73] Schroer and Modarres, 2013.
[74] Schroer and Modarres, 2013, page 49.

> class, independent events, was only marginally discussed because it does not address dependencies between the units."

(VIII-12) From the two preceding paragraphs and the documents cited therein, one sees that linkage of risk among multiple reactors at a site has been long neglected, but is beginning to receive some attention from NRC and licensees. Linkage of pool risk and reactor risk at a site has been similarly neglected, but has not been properly addressed by NRC or licensees.

(VIII-13) Although NRC has not properly addressed the linkage of pool risk and reactor risk, NRC has taken a small, initial step in that direction. This step was taken in a pool-fire study that NRC published in 2013. As discussed in paragraph I-11, above, NRC published a draft version of the pool-fire study in June 2013.[75] The study was re-published in final form in October 2013, with no substantial change.[76] The October 2013 version, with its cover memo, accompanies this declaration as Exhibit #35. Hereafter, I refer to it as "NRC's consequence study". I assume that the technical parts of the June 2013 and October 2013 version are identical. Thus, the Thompson draft consequence declaration applies equally to both.

(VIII-14) NRC's consequence study took a small step toward addressing the linkage of pool risk and reactor risk in the sense that it identified aspects of that linkage. It did not proceed to analyze those aspects. The identification occurred under the rubric, Multi-Unit Considerations, via the following statement:[77]

> "<u>Observations Regarding a Concurrent Reactor Event</u>:
>
> There are four broad interplays that can be defined between the SFP [spent fuel pool] and the reactor:
>
> 1. an initiating event that directly affects both the reactor and the SFP
> 2. a reactor accident that prevents accessibility to the SFP for a prolonged period of time (e.g., due to high radiation fields), leading to a SFP accident
> 3. a reactor accident that includes ex-containment energetic events (e.g., a hydrogen combustion event) or other ex-containment interplays (e.g., steaming through the drywell head that affects refuel floor combustible gas mixtures) and creates a hazard to the SFP (e.g., by causing debris to fall in to the pool) or otherwise changes the SFP event progression
> 4. an SFP accident that prevents accessibility to key reactor systems and components for a prolonged period of time or which creates a hazard for

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[75] Barto et al, 2013a.

[76] The October 2013 version is: Barto et al, 2013b. It was published as an enclosure under the SECY memo: Satorius, 2013a. That memo stated: "None of the comments or responses [i.e., on the draft version of the study] has necessitated making substantial changes to the report." (See: Satorius, 2013a, page 3.)

[77] Barto et al, 2013b, Section 2.2, pp 28-29.

equipment used to cool the reactor (e.g., the flooding of low elevations of the reactor building due to a leak in the pool or excessive condensation from continuous boiling of SFP water), leading to a reactor accident

For each of these interplays, large seismic events and severe weather SBO [station blackout] events are logically the most relevant initiators, as they are the type of initiators that are most likely to initiate an accident at the reactor and SFP, while simultaneously hampering further accessibility to key areas, key systems and components, and key resources. To the extent practicable, this study has attempted to qualitatively account for some of these effects. For example, when the reactor and SFP are hydraulically connected (during refueling), the decay heat and water volumes from both sources are considered. The study also explores these effects on mitigation (Section 8), and addresses some aspects of the uncertainty associated with this treatment (Section 9). However, explicitly modeling multiunit effects was not a focus of this study, because of the existing limitations with the available computational tools. An ongoing project described in SECY-11-0089 will attempt to more rigorously address these effects in the framework of a multiunit Level 3 PRA for Vogtle Electric Generating Plant Units 1 and 2."

(VIII-15) The four "interplays" described in this statement are far from the final word about linkage of pool risk and reactor risk, but they would provide a useful starting point for technical analysis on that linkage. These interplays could occur in situations where pool storage of spent fuel, as considered in the draft GEIS, occurs at a location near an operational reactor. Thus, the draft GEIS should have carefully considered the implications of these interplays for the environmental impacts of storing spent fuel in pools. Unfortunately, the draft GEIS failed to consider those implications.

(VIII-16) The second half of the statement quoted in paragraph VIII-14 shows clearly that NRC's consequence study does not provide credible technical analysis of the pool-reactor interplays that it identifies. Instead, it says that another project "will attempt" to address these interplays at some future date. Until that work is done properly, NRC will not be able to complete an adequate GEIS on the environmental impacts of storing spent fuel.

(VIII-17) The 2011 Fukushima accident illustrated the potential for risk linkages among facilities at a nuclear site. Figure VIII-1 shows how that potential was manifested at Unit 4. The Unit 4 reactor building suffered a violent explosion of hydrogen that reportedly originated from reactor core damage at Unit 3.[78] That hydrogen explosion, and other influences at the site, hindered mitigating actions at Unit 4. Those actions were needed to keep the Unit 4 spent-fuel pool in a safe state, because normal systems that provide cooling and makeup to the pool were disabled by the earthquake and tsunami that

[78] The reactor core of Unit 4 had been removed and placed in the adjacent pool prior to the accident.

afflicted the site. Eventually, water makeup was provided to the pool by the concrete-pumping truck that appears in Figure VIII-1. That truck was brought to the site after several other methods of providing water makeup had failed.

(VIII-18) Figure VIII-2 illustrates how intimately a spent-fuel pool can be associated with the reactor it serves. Moreover – as discussed in paragraph VIII-6, above – at 17 sites in the United States, any fuel in a pool is intimately associated with two adjacent reactors. In other instances, the association between a pool and a different, nearby reactor may not be quite so intimate. Nevertheless, physical proximity, sharing of buildings, and/or sharing of support systems could establish a strong linkage of pool risk and reactor risk. One concern is that a release of radioactive material from a reactor could create a radiation field that precludes personnel access needed to keep a nearby spent-fuel pool in a safe state. Lack of that access could lead to a pool fire.

(VIII-19) One potential manifestation of risk linkage among facilities at a nuclear site would be the occurrence of a cascading sequence of incidents. To illustrate, consider the potential impact of a large aircraft on a reactor. That event could be an accident or a malevolent act. The successful use of a large aircraft as an instrument of attack is, of course, not theoretical. It occurred in the United States three times on 11 September 2001.

(VIII-20) Morris et al describe the use of the VISAC code to analyze the impact of a large aircraft on the containment of a reactor.[79] They note that the hard parts of the aircraft – notably, the jet engine rotors – might not fully penetrate the containment. They consider, however, the entry of a small fraction (apparently, 1 percent) of the aircraft's jet fuel into the annular space between the inner and outer walls of the containment. Perusal of Figure VIII-2 shows analogous spaces in that reactor design. Vaporization and ignition of the jet fuel in this confined space would, with high conditional probability, lead to a violent fuel-air explosion. Morris et al describe VISAC analyses that show, in all cases, significant damage to the containment from this explosion, with holes in both the inner and outer walls. They go on to say:[80]

> "While the damage is significant, subsequent events are most likely responsible for most of the radioactive release predicted. It is unlikely that the staff inside the control room adjacent to the containment building will survive the smoke and toxic fumes resulting from the fire, even if they managed to survive the direct consequences of the crash of the airplane. In view of the fire engulfing the containment building and adjacent structures, it seems unlikely that the separately located auxiliary control room could be reached by the staff members originally located in the main control room. Therefore, even if those in the control room should be unaffected by the air fuel explosion, the additional fire hazard outdoors will prohibit the surviving operators from shutting down the plant in a controlled

[79] Morris et al, 2006.
[80] Morris et al, 2006, page 206.

manner from the auxiliary control room."

(VIII-21) The potential events that Morris et al describe can be viewed as stages in a cascading sequence of incidents. First, the aircraft strikes the containment. Second, some jet fuel enters a confined space. Third, a fuel-air explosion breaches the containment and causes other damage. At some point during stages 1-3, or subsequently, the control room, the auxiliary control room, and their personnel are rendered non-functional. Fourth, radioactive material is released from the reactor to the interior of the containment, or directly to the external environment. Fifth, radioactive material passes from the interior of the containment to the external environment. Sixth, the cascade could proceed to one or more pool fires, as discussed in the following paragraph.

(VIII-22) The spent-fuel pool that serves the afflicted reactor, and the cooling and water makeup systems that serve that pool, could be damaged by the aircraft impact or by the fuel-air explosion. That damage could be sufficient to initiate a zircaloy fire in the pool. A nearby spent-fuel pool, built to serve another reactor, could suffer similar damage, resulting in a zircaloy fire in that pool. Deposition of radioactive material released from the afflicted reactor would create an intense radiation field around the reactor. The radiation field could extend in all directions, because the fire accompanying this disaster would create intense turbulence in the local atmosphere. The radiation field could preclude personnel access for days or weeks, thereby precluding mitigating actions that might prevent the initiation of zircaloy fires in the affected pools. In that situation, a nearby pool that was not affected directly by the aircraft impact could boil dry, leading to a fire in that pool.

(VIII-23) NRC has never, to my knowledge, published a credible technical analysis of a cascading sequence of incidents of this type. Nor, to my knowledge, has NRC ever publicly stated that it has performed such analysis in secret. Until such analysis is done, and done properly, NRC will not be able to complete an adequate GEIS on the environmental impacts of storing spent fuel.

IX. Risk Implications of Nuclear-Power Scenarios

(IX-1) Section 1.8.6 of the draft GEIS, titled Issues Eliminated from Review in this GEIS, contains the statement:[81]

> "The NRC is evaluating the continued storage of commercial spent fuel in this draft GEIS. Thus, certain topics are not addressed because they are not within the scope of this review. These topics include:
> - noncommercial spent fuel (e.g., defense waste)
> - commercial high level waste generated from reprocessing
> - greater-than-class-C LLW
> - advanced reactors (e.g., high-temperature and gas-cooled reactors)

[81] NRC, 2013b, pages 1-23 and 1-24.

- foreign spent fuel
- nonpower reactor spent fuel (e.g., test and research reactors)
- need for nuclear power
- reprocessing of commercial spent fuel"

(IX-2) By excluding from consideration the "need for nuclear power", the draft GEIS cripples its ability to assess the environmental impacts of storing spent fuel. Nowhere in the draft GEIS is this grave deficiency corrected. The draft GEIS does not set forth any scenario for the future use of nuclear power or, more specifically, for the future creation of spent fuel. Thus, in the draft GEIS, the timeframe for creation of spent fuel spans an unknown but potentially vast range, as does the quantity of spent fuel created in that timeframe.

(IX-3) At the lower end of its range, the timeframe for creation of spent fuel will end when the last of the currently licensed reactors ceases to operate. However, since the draft GEIS sets no upper limit on the time period that it considers, the creation of spent fuel could continue ad infinitum. Thus, the upper end of the range of timeframes is undefined.

(IX-4) At the lower end of its range, the quantity of spent fuel that is created will be the quantity that is discharged from the currently licensed reactors. However, since the draft GEIS says nothing about the future use of nuclear power, it sets no upper limit to the quantity of spent fuel that will be created. Consider a simple, illustrative example. Suppose that nuclear power soon revives in the United States, leading to a tenfold increase in annual creation of spent fuel by the mid-21st century. Further suppose that this rate of creation continues for a few centuries. At the end of that period, the cumulative quantity of spent fuel that has been created would far exceed the quantity that is discharged from the currently licensed reactors.

(IX-5) If the total quantity of spent fuel that is created were at the lower end of its range, the radiological risk posed by storing this fuel would be bounded. As the inventory of fuel aged, its radiological risk would decline, other factors being equal. Moreover, the inventory would gradually move from pools to ISFSIs, which would reduce its risk. In principle, one could assess the cumulative radiological risk of storing spent fuel, from the present until the moment when the last fuel assembly in the inventory is emplaced in a repository.

(IX-6) If, however, the total quantity of spent fuel that is created is unbounded, then the radiological risk posed by storing this fuel would be similarly unbounded.[82] The draft GEIS allows for this outcome. Thus, the draft GEIS has denied itself the ability to assess the long-term radiological risk of storing spent fuel. One cannot assess a quantity that is unbounded.

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[82] This statement holds at any given time, and cumulatively.

(IX-7) In Sections VI and VII of the Thompson scoping declaration, I set forth a number of recommendations for the use of scenarios.[83] These recommendations could have helped the framers of the draft GEIS to avoid the self-crippling of the draft GEIS that I have described in the preceding paragraphs. The framers ignored my recommendations. Those recommendations would, in principle, have allowed the draft GEIS to bound the radiological risk of storing spent fuel. Moreover, those recommendations would have allowed the draft GEIS to compare the risk posed by different scenarios and different options for managing spent fuel.

X. Pool Fire: Probability and Consequences

(X-1) The draft GEIS concedes that a pool fire could occur. More precisely, it concedes that zircaloy combustion could occur in a spent-fuel pool following loss of water from the pool. Here, in Section X, I address five aspects of the draft GEIS's consideration of pool fires, with an emphasis on the probability and consequences of a pool fire. The draft GEIS's consideration of pool fires is deficient in regard to each aspect. As a result, the draft GEIS makes an incorrect determination of the environmental impact of pool fires. The five aspects are:

- Documents cited in the draft GEIS
- NRC's understanding of relevant phenomena
- Probability of a pool fire
- Consequences of a pool fire
- Determination of radiological risk and environmental impact

Documents cited in the draft GEIS

(X-2) The draft GEIS provides technical discussions of pool fires in its Sections 4.18 and 4.19 and Appendix F. To support those discussions, the draft GEIS cites a number of documents. However, some relevant documents are not cited. In paragraphs X-3 through X-6, below, I discuss three examples of documents whose omission from the citations in the draft GEIS is significant.

(X-3) In paragraph VI-2, above, I note that NRC explicitly considered the impacts of malevolent acts in its 1979 GEIS on Handling and Storage of Spent Light Water Power Reactor Fuel, which was designated NUREG-0575.[84] Potential malevolent acts were described in Appendix J of that document. NUREG-0575 is not cited in Sections 4.18 and 4.19 and Appendix F of the draft GEIS. That omission is significant because the malevolent acts postulated in Appendix J of NUREG-0575 could, with slight adjustment, readily initiate a pool fire. I discuss that matter below.

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[83] Thompson, 2013b, Sections VI, VII, and X.
[84] NRC, 1979.

(X-4) In paragraph VIII-13, above, and elsewhere in this declaration, I discuss NRC's consequence study.[85] That study, published in draft form in June 2013 and final form in October 2013, is NRC's most recent technical analysis of pool fires. Yet, that study is not cited in Sections 4.18 and 4.19 and Appendix F of the draft GEIS, which was published in September 2013. That omission is significant from several perspectives. For example, as discussed in paragraphs VIII-14 through VIII-16, above, NRC's consequence study identified an important issue that has not been considered in the draft GEIS. That issue is the linkage of pool risk and reactor risk.

(X-5) The NRC staff incorporated the findings of NRC's consequence study into a staff recommendation regarding the expedited transfer of spent fuel from pools to dry storage. The staff recommended against expedited transfer in a November 2013 document that I refer to hereafter, following NRC practice, as the "Tier 3 analysis".[86] That document accompanies this declaration as Exhibit #36. The Tier 3 analysis describes its connection to the draft GEIS as follows:[87]

> "Within this Tier 3 analysis, the staff has considered the agency's activities on the waste confidence generic environmental impact statement (GEIS) and rulemaking, and it has ensured that the availability of these documents and interactions with stakeholders are coordinated to facilitate the public's involvement in these activities. Although this Tier 3 analysis was not specifically referenced in the draft GEIS, those who prepared the draft GEIS were aware of the conclusions in this Tier 3 analysis, and the staff has coordinated this activity with the relevant sections of the draft GEIS. To facilitate the public's ability to provide input, a draft of the October 2013 SFP study was released for public review and comment on July 1, 2013. Additionally, the draft evaluation of this Tier 3 issue was released to the public on September 26, 2013, well before the draft GEIS public comment period ends on December 20, 2013."

(X-6) Omission of the Tier 3 analysis from the citations in the draft GEIS is significant because the Tier 3 analysis sets forth an NRC staff position on the radiological risk of pool fires. The draft GEIS does not address that position. Yet, according to the statement quoted in the preceding paragraph, the preparers of the draft GEIS were aware of the conclusions in the Tier 3 analysis, and the two documents were "coordinated" in some manner. Thus, the Tier 3 analysis had a substantial but undocumented influence on the draft GEIS.[88] The lack of documentation of this influence handicaps those who seek to comment on the draft GEIS.

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[85] Barto et al, 2013b.
[86] Satorius, 2013b.
[87] Satorius, 2013b, page 9.
[88] One illustration of a likely influence is the draft GEIS's assertion that air cooling of spent fuel would prevent a pool fire at a point much earlier following fuel offload from a reactor than was considered in the study NUREG-1738. (See: NRC, 2013b, Appendix F, page F-11.) The Tier 3 analysis and NRC's consequence study represent NRC's most recent analysis of pool-fire issues such as the role of air cooling, but are not cited in the draft GEIS.

NRC's understanding of relevant phenomena

(X-7) I now turn to addressing NRC's understanding of phenomena relevant to a pool fire. I show that NRC's understanding of these phenomena is deficient, and that the NRC staff seeks to close off further inquiry that could correct the deficiencies. The first phenomenon that I address is the connection between: (i) the presence of residual water in the lower part of a pool that has experienced water loss; and (ii) the initiation of zircaloy combustion. NRC failed to understand this connection for more than two decades, and that misunderstanding continues to influence NRC's current analysis on pool fires.

(X-8) As discussed in paragraph I-7, above, the pool serving each commercial reactor in the USA is now equipped with high-density, closed-frame racks. The nuclear industry began installing these racks in the 1970s, to replace the low-density, open-frame racks previously used. The high-density racks offered a comparatively cheap option for storing a growing nationwide inventory of spent fuel. Figure X-1 shows the configurations of the two types of rack.

(X-9) If water were lost from a pool equipped with high-density racks, the racks would inhibit heat transfer from the exposed fuel. Thus, spent fuel in the pool would increase in temperature, potentially leading to ignition and sustained combustion of zircaloy cladding in air or steam. To a technically trained observer, it should be obvious that ignition could be more likely if residual water were present in the pool, other factors being equal. Residual water would block the flow of air from below, thus reducing heat transfer from the exposed portion of the fuel. Figure X-2 illustrates this phenomenon. As a result, spent fuel with a comparatively high age after discharge from a reactor could burn if residual water were present. The initial phase of "burning" would, in this case, be a steam-zircaloy reaction.

(X-10) As discussed in paragraph VI-4, above, NUREG-0575 dismissed the potential for a pool fire, arguing that spent fuel aged more than one year would not burn if water were lost from a pool.[89] NUREG-0575 was published by NRC in 1979. NRC held a similar position in 1989, when it published the pool-fire study NUREG-1353.[90] That study accompanies this declaration as Exhibit #37. NUREG-1353 stated:[91]

> "A typical spent fuel storage pool with high density storage racks can hold roughly five times the fuel in the core. However, since reloads typically discharge one third of the core, much of the spent fuel stored in the pool will have had considerable decay time. This reduces the radioactive inventory somewhat. More importantly, **after roughly three years of storage, spent fuel can be air-**

[89] NRC, 1979, page 4-21.
[90] Throm, 1989.
[91] Throm, 1989, page 1-1 (emphasis added).

> **cooled**. The spent fuel need not be submerged to prevent melting, although submersion is still desirable for shielding and to reduce airborne activity."

(X-11) Thus, from 1979 to 1989, NRC failed to understand the significance of residual water for zircaloy ignition. NRC's belief that comparatively old fuel would not ignite derived from NRC's mistaken assumption that the worst case of water loss from a pool would be total, instantaneous drainage. This erroneous belief continued into 1999 and 2000, while NRC was preparing a pool-fire study that was eventually published, in February 2001, as NUREG-1738.[92] That study accompanies this declaration as Exhibit #38. Preliminary versions of NUREG-1738 were published by NRC in June 1999 and February 2000.

(X-12) In 1999 and 2000, I was a technical adviser and expert witness for Orange County, North Carolina, supporting the County's intervention in a license proceeding before NRC's Atomic Safety and Licensing Board. The proceeding addressed a proposed expansion of spent-fuel storage capacity at the Shearon Harris nuclear power plant. In a March 2000 filing in that proceeding, the NRC staff disputed my position that comparatively old fuel could ignite if water were lost from a pool. That filing accompanies this declaration as Exhibit #39. In its filing, the NRC staff stated:[93]

> "However, although Dr. Thompson states that for "scenarios which involve partial uncovery of fuel, the reaction could affect fuel aged 10 or more years," he offers no authority to support this conclusion. **Dr. Thompson's is the only opinion of which the Staff is aware that holds that fuel five years or more out of the reactor is susceptible to zircaloy fire/exothermic reaction**. *See, e.g.,* NUREG/CR-0649, Spent Fuel Heatup Following Loss of Water During Storage, at 85-87 (1979) (Exhibit B)."

(X-13) Later in 2000, NRC corrected its erroneous belief, held since 1979, that comparatively old fuel could not ignite in the event of water loss. The Thompson draft consequence declaration describes the circumstances in which NRC made this correction.[94] In brief, NRC made the correction because its representatives were required, for the first time in decades, to justify their technical position in a public setting in which they could be challenged. The correction was acknowledged in NUREG-1738, which stated:[95]

> "The analyses in Appendix 1A determined that the amount of time available (after complete fuel uncovery) before a zirconium fire depends on various factors, including decay heat rate, fuel burnup, fuel storage configuration, building ventilation rates and air flow paths, and fuel cladding oxidation rates. While the

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[92] Collins and Hubbard, 2001.
[93] NRC, 2000, page 21 (emphasis added).
[94] Thompson, 2013a, paragraphs III-12 to III-13 and III-23 to III-24.
[95] Collins and Hubbard, 2001, pages 2-1 and 2-2 (emphasis added).

> February 2000 study indicated that for the cases analyzed a required decay time of 5 years would preclude a zirconium fire, **the revised analyses show that it is not feasible, without numerous constraints, to define a generic decay heat level (and therefore decay time) beyond which a zirconium fire is not physically possible**. Heat removal is very sensitive to these constraints, and two of these constraints, fuel assembly geometry and spent fuel pool rack configuration, are plant specific. Both are also subject to unpredictable changes as a result of the severe seismic, cask drop, and possibly other dynamic events which could rapidly drain the pool. Therefore, since the decay heat source remains nonnegligible for many years and since configurations that ensure sufficient air flow for cooling cannot be assured, a zirconium fire cannot be precluded, although the likelihood may be reduced by accident management measures."

(X-14) Paragraphs X-7 through X-13, above, yield a significant finding. They show that NRC failed to understand a comparatively simple technical issue for more than two decades. NRC's misunderstanding persisted for this long period because its staff were shielded from public challenge and did not engage in the open discourse that is essential to scientific inquiry. With some limited exceptions, that situation has continued until the present.

(X-15) Before publishing NUREG-1738 in February 2001, NRC had published several studies related to pool fires. These studies, like NUREG-1353, contained erroneous statements about the potential for ignition of comparatively old fuel. They also contained other substantial deficiencies.[96] For example, NUREG-1353 did not consider storage of BWR spent fuel in high-density racks, even though such storage has been common practice for many years.[97] Yet, NRC has neither retracted nor repudiated NUREG-1353, despite its clear obsolescence. Indeed, the draft GEIS cites NUREG-1353 as a major source of information on the probability and consequences of a pool fire.[98]

(X-16) The potential for a pool fire became clear in 1979. From the beginning, the means of addressing this threat was also clear. The radiological risk of a pool fire could be dramatically reduced by abandoning the use of high-density racks in pools, and reverting to low-density, open-frame racks.[99] Figure X-1 shows the two types of rack. Since 1979, numerous parties have intervened in license proceedings and pursued other avenues, seeking to persuade NRC to order the elimination of high-density racks. A corollary of that action would be the transfer of a substantial portion of the US inventory of spent fuel from pools to dry casks. NRC has consistently and vigorously opposed the elimination of high-density racks.

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[96] Thompson, 2009, Section 5.
[97] Throm, 1989, pages 4-9 and 4-10.
[98] NRC, 2013b, Table F-1 (page F-4).
[99] In the case of BWR spent fuel, removal of channel boxes from the fuel could also be appropriate.

(X-17) Now, in its Tier 3 analysis, the NRC staff seeks to close off any further inquiry into the risk of a pool fire. The staff recommends:[100]

> "The staff's assessment concludes that the expedited transfer of spent fuel to dry cask storage would provide only a minor or limited safety benefit, and that its expected implementation costs would not be warranted. Therefore, the staff recommends that no further generic assessments be pursued related to possible regulatory actions to require the expedited transfer of spent fuel to dry cask storage and that this Tier 3 Japan lessons-learned activity be closed."

(X-18) The Tier 3 analysis relies heavily upon NRC's consequence study.[101] I provided a critical review of that study in the Thompson draft consequence declaration.[102] I concluded that NRC's consequence study is fundamentally and irredeemably flawed, and recommended:[103]

> "(VIII-7) NRC's Draft Consequence Study should be scrapped.
> (VIII-8) In addressing the pool-fire issue, NRC should focus its initial attention exclusively on establishing a solid technical understanding of phenomena directly related to a potential pool fire. To do this, NRC would start with a clean slate and use the best available modeling capability backed up by experiment. This modeling and experimental work would be done according to scientific principles. Further recommendations regarding such work are provided in Section IV, above."

(X-19) I recommend additional investigation of pool-fire phenomena because, more than three decades after the potential for a pool fire was recognized, NRC has not yet established a solid technical understanding of relevant phenomena. Thus, the NRC staff's recommendation to cease investigation of pool-fire issues is imprudent. Apparently, the NRC staff believes that acquisition of a solid understanding of pool-fire phenomena is unnecessary. The staff has not articulated a clear position on this matter. Such a position has, however, been articulated by Dr. Dana Powers, a member of NRC's Advisory Committee on Reactor Safeguards (ACRS), in a written commentary on the Thompson draft consequence declaration.[104] That commentary, with associated documents, accompanies this declaration as Exhibit #40. Dr. Powers' commentary includes the statement:[105]

> "Much of Section IV of Dr. Thompson's report is devoted to outlining an extensive study of accident phenomenology for spent fuel events. The intent seems to be to establish a very comprehensive understanding to a scientific

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[100] Satorius, 2013b, page 10.
[101] Barto et al, 2013b.
[102] Thompson, 2013a.
[103] Thompson, 2013a, Section VIII.
[104] Armijo, 2013, Enclosure 3.
[105] Armijo, 2013, Enclosure 3, page 4 (emphasis added).

> certainty in this phenomenology. Dr. Thompson does not make it clear why this should be done if, in fact, it can be shown that partial drain events are easily remediated with high confidence and that complete drain events are highly improbable. Nor does he provide a ranking of the use of resources for the purposes of studying spent fuel pools in preference to other safety issues. On the basis of results presented to ACRS thus far, it would appear that a systems engineering evaluation would suggest **the best use of available resources would be to assure that mitigation of partial drain events was assured and that complete drain events were highly improbable. This would obviate the need for a detailed understanding of accident phenomenology**. Should a decision be made to conduct confirmatory research, examination of the Dr. Thompson's list of topics might be useful starting point in the identification of possible avenues of investigation."

(X-20) Dr. Powers' statement is instructive. He and I view the pool-fire problem from opposite perspectives. His confidence regarding the efficacy of mitigating measures, and the validity of probability estimates, is such that he sees no need for a thorough understanding of relevant phenomena. In my judgment, however, there is compelling evidence that: (i) mitigation of loss of water from a pool could not be assured in many potential situations; and (ii) complete or partial loss of water from a pool has a significant probability. Moreover, the consequences of a pool fire could be severe. Accordingly, given present knowledge of pool-fire phenomena, prudence dictates a high-priority action – the rapid elimination of high-density racks from all pools. A thorough investigation of pool-fire phenomena, conducted in parallel with that action, might yield knowledge that somewhat reduces the urgency and scope of the action, thus reducing its cost. I recommend such an investigation.

(X-21) Later in Section X, I discuss the compelling evidence mentioned in the preceding paragraph. Here, I close my discussion of pool-fire phenomena by briefly discussing the influence of two factors on zircaloy ignition and combustion. The two factors are: (i) accumulation of zirconium hydrides in the cladding of high-burnup fuel; and (ii) the ballooning and burst of fuel cladding at temperatures above the normal operating level.

(X-22) In April 2000, the Chairman of ACRS wrote a letter to the Chairman of NRC, discussing some pool-fire phenomena.[106] That letter accompanies this declaration as Exhibit #41. The letter discussed a number of phenomenological issues that had not been properly considered by NRC. I focus here on one of those issues. That issue is the influence of zirconium hydrides on the ignition of exposed spent fuel. As part of its discussion of that issue, the ACRS letter said:[107]

> "We also have difficulties with the analysis performed to determine the time at which the risk of zirconium fires becomes negligible. In previous interactions

[106] Powers, 2000.
[107] Powers, 2000, page 3 (emphasis added).

with the staff on this study, we indicated that there were issues associated with the formation of zirconium-hydride precipitates in the cladding of fuel especially when that fuel has been taken to high burnups. Many metal hydrides are spontaneously combustible in air. Spontaneous combustion of zirconium-hydrides would render moot the issue of "ignition" temperature that is the focus of the staff analysis of air interactions with exposed cladding. **The staff has neglected the issue of hydrides** and suggested that uncertainties in the critical decay heat times and the critical temperatures can be found by sensitivity analyses. Sensitivity analyses with models lacking essential physics and chemistry would be of little use in determining the real uncertainties."

(X-23) Given the trend of driving nuclear fuel to ever-higher burnups, one could reasonably expect that NRC would seriously address the concern expressed by ACRS. The ACRS letter did stimulate the preparation of an NRC internal memorandum.[108] That memorandum, with its attached draft report, accompanies this declaration as Exhibit #42. The memorandum and its attached draft report discussed factors that could influence the ignition of zircaloy when exposed to air or steam. Those factors included the presence of hydrides. They also included the ballooning and burst of fuel cladding, a matter I return to below. The draft report attached to the memorandum contained the statement:[109]

> "It would be necessary to **conduct actual ignition tests on either spent fuel or pre-oxidized and hydrided cladding** to generate experimental data to understand these various effects and to determine unambiguously the potential for autoignition. For lack of such experimental data, the potential for autoignition after ballooning and burst cannot be ruled out at this time."

(X-24) Ignition tests on actual spent fuel would be problematic because the fuel's large inventory of radioactive material would have to be shielded and contained. NRC did sponsor ignition tests on pre-oxidized cladding, as described in the report NUREG/CR-6846, published in 2004.[110] That report accompanies this declaration as Exhibit #43. At the time of publication of NUREG/CR-6846, NRC had not sponsored tests on hydrided cladding. Those tests were promised at some future time, as follows:[111]

> "The effect of pre-existing hydrides, formed on the cladding surface during in-reactor operation and relevant, in particular, for high burnup operation, is being investigated under a follow-on program at the Argonne National Laboratory. This latter study will be reported separately."

(X-25) NRC's consequence study was published in 2013. In that study, the theoretical model used to represent zircaloy ignition and combustion is drawn directly from

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[108] Eltawila, 2001.
[109] Eltawila, 2001, attached draft report by Chung and Basu, page 9 (emphasis added).
[110] Natesan and Soppet, 2004.
[111] Natesan and Soppet, 2004, Foreword (by Farouk Eltawila), page xvii.

NUREG/CR-6846. The model reflects the ignition tests on pre-oxidized cladding that are mentioned in the preceding paragraph. The study notes that this model shows accelerated combustion compared with previous models, and that this effect is confirmed by experiment.[112] Thus, the tests on pre-oxidized cladding that are described in NUREG/CR-6846 were a useful step toward simulating the ignition and combustion of actual spent fuel. Moreover, this step revealed that combustion would be more vigorous than previously expected. Yet, NRC's consequence study does not mention the effects of hydrides on cladding ignition and combustion, despite ACRS's highlighting of this issue in 2000 and NRC's promise in 2004 to sponsor appropriate tests. Thus, it seems that a key aspect of the ignition and combustion behavior of actual spent fuel, arising from the presence of hydrides, has been ignored by NRC. Moreover, accumulation of hydrides increases with burnup, and there is a trend of driving nuclear fuel to ever-higher burnups.

(X-26) As discussed in paragraph X-23, above, factors that could influence the ignition of zircaloy include the ballooning and burst of fuel cladding. It is well known that cladding can balloon (i.e., swell) and ultimately burst at temperatures substantially above the normal operating temperature. During the ballooning phase, the cross-sectional area for axial fluid flow through a fuel assembly could be reduced, thereby reducing heat transfer from the fuel. At the time of burst, unoxidized cladding would be exposed to air or steam, which could promote zircaloy ignition. The MELCOR code used in NRC's consequence study lacks a capability to model the ballooning and burst of fuel cladding.[113] MELCOR has been "benchmarked" against tests involving the ignition of electrically heated structures simulating fuel assemblies, as described in the report NUREG/CR-7143.[114] That report accompanies this declaration as Exhibit #44. Apparently, the tests did not involve ballooning and burst of cladding, perhaps because the simulated fuel rods were not sealed. Thus, neither MELCOR nor these tests provides any information about the implications of cladding ballooning and burst for zircaloy ignition. NRC's consequence study alludes to secret studies that address this matter, but provides no citation.[115]

(X-27) An April 2003 accident at the Paks-2 nuclear power plant in Hungary shows how overheated nuclear fuel will balloon and then burst. The accident and a subsequent simulation are described in a 2007 conference paper that accompanies this declaration as Exhibit #45.[116] The accident occurred while fuel was undergoing chemical cleaning inside a tank submerged in the plant's spent-fuel pool. Cooling water was supplied to the tank by a pump submerged in the pool. On this occasion, the water flow was inadequate, reportedly due to design defects and operating deficiencies. As a result, a steam bubble formed in the tank and fuel temperature began to rise. The zircaloy fuel cladding experienced extensive ballooning, followed by cladding burst and zirconium-steam

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[112] Barto et al, 2013b, pages 93 and 94.
[113] Barto et al, 2013b, Table 3, page 26.
[114] Lindgren and Durbin, 2013.
[115] Barto et al, 2013b, Table 3 (page 26).
[116] Windberg and Hozer, 2007.

combustion. This accident did not lead to a substantial release of radioactive material to the atmosphere, because it occurred inside a closed tank submerged in a pool. Nevertheless, this accident provides real-world evidence of the significance of phenomena such as cladding ballooning and burst. Regrettably, NRC's consequence study has not accounted for all relevant phenomena.

(X-28) Paragraphs X-7 through X-27, above, address various aspects of phenomena relevant to a pool fire. The Thompson draft consequence declaration contains a further critique of NRC's consideration of such phenomena.[117] Taken together, those sources support the following findings:

- NRC failed to understand a comparatively simple technical issue for more than two decades, because its staff were shielded from public challenge and did not engage in the open discourse that is essential to scientific inquiry.
- With limited exceptions, NRC staff remain shielded from public challenge and scientific discourse.
- NRC's latest analysis of pool fires (i.e., NRC's consequence study) ignores a number of technical issues that are significant to a determination of pool-fire risk.
- The NRC staff proposes to close off further inquiry into pool-fire risk.
- Apparently, the NRC staff believes that the acquisition of a thorough understanding of pool-fire phenomena is unnecessary because the probability of unmitigated partial or total loss of water from a pool is, in their view, negligible.

(X-29) NRC's deficient understanding of pool-fire phenomena is significant for the draft GEIS's determination of the environmental impact of pool fires, because that determination relies heavily on the judgment of NRC staff, especially in the context of malevolent acts. In many instances that reliance is undocumented or poorly documented.

Probability of a pool fire

(X-30) I now turn to discussing the probability of a pool fire. In this discussion I generally use the term "frequency" instead of "probability", because in some situations this indicator could have a value exceeding 1. A pool fire could be caused by an accident or a malevolent act. In the context of accidents, I have always been concerned about potential situations in which a radioactive release occurs at a reactor near to a pool. Given such a situation, the radiation field created by the reactor release, and other influences, could preclude mitigating actions needed to keep the pool in a safe state. In the context of malevolent acts, an analogous situation could arise. Additionally, a malevolent actor could preclude pool-related mitigating actions in ways that did not rely on obtaining a radioactive release from a nearby reactor.

(X-31) The draft GEIS relies upon the findings of PRA-type studies for its estimation of the frequency of accident-induced pool fires. Drawing upon such studies, the draft GEIS asserts that the frequency of a pool fire, caused by an accident, is in the range 5.8×10^{-7} to

[117] Thompson, 2013a.

2.4×10^{-6} per year.[118] Although not explicitly stated as such, this assertion refers to a frequency per pool-year. A pool-year is analogous to the concept of a reactor-year, which is introduced in paragraph V-5, above. Note that a frequency of 2.4×10^{-6} per pool-year, which is low, would become a much higher value if accumulated across many pools over many years. I address that matter below.

(X-32) The discussion in Section V, above, regarding the limitations of PRA, suggests that the actual frequency of a pool fire may be substantially higher than is asserted in the draft GEIS. Here, I focus on an issue that reinforces that suggestion. That issue is the linkage of pool risk and reactor risk. As discussed in Section VIII, above, NRC has never done a credible analysis of this linkage. Moreover, there is persuasive evidence, including the Fukushima accident, that a reactor accident could be part of a cascading sequence of incidents that preclude mitigating actions needed to maintain nearby pools in a safe state. Finally, as discussed in Section VIII, pool storage of spent fuel, as considered in the draft GEIS, will probably occur at locations near operational reactors.

(X-33) As discussed in paragraph V-21, above, direct experience of reactor accidents suggests that the frequency of accident-induced severe core damage may be in the vicinity of 3.2×10^{-4} per reactor-year. Let us now consider the conditional probability of a pool fire, given severe core damage at a nearby reactor. Experience suggests that this conditional probability is less than 1, because there have been 5 core melts and 0 pool fires at commercial facilities. Given the present state of knowledge, selecting a value of 0.1 for this conditional probability is prudent. Thus, a reasonable estimate for the frequency of an accident-induced pool fire, associated with an accident at a nearby reactor, is $0.1 \times 3.2 \times 10^{-4} = 3.2 \times 10^{-5}$ per pool-year.[119] That value is 13 times higher than the pool-fire frequency (i.e., 2.4×10^{-6} per pool-year) at the upper end of the range asserted by the draft GEIS, and 55 times higher than the frequency (i.e., 5.8×10^{-7} per pool-year) at the lower end of the range.

(X-34) The discussion in the three preceding paragraphs can be structured in terms of the equation that is set forth in paragraph V-31, above. In that context, "PRA finding" is the pool-fire frequency asserted by the draft GEIS. The present state of knowledge suggests that "Reality factor #1" has a value of about one order of magnitude (i.e., factor of 10) at the upper end of the draft GEIS's frequency range. That value reflects the fact that the PRA-type analyses cited in the draft GEIS did not account for linkage of pool risk and reactor risk.

(X-35) As discussed in paragraph VI-11, above, the draft GEIS asserts that the probability of an attack-induced pool fire is "very low". In Section VI, however, I present evidence to the contrary. In my judgment, a prudent decision maker would

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[118] NRC, 2013b, Appendix F, Table F-1 (page F-4). Also see: Collins and Hubbard, 2001, Table 3.1 (page 3-9).

[119] Here, I make the simplifying assumption that each reactor has a risk linkage with one nearby pool other than its own pool, and vice versa.

conclude from this evidence that a successful attack on a reactor or spent-fuel-storage facility in the United States over the coming decades is as likely to occur as are major national challenges that are planned for, such as severe natural disasters or engagement in wars.

(X-36) Here, I expand slightly upon the discussion in Section VI, while being careful to not disclose information that would assist a potential attacker. First, consider a potential situation in which a malevolent actor creates a cascading sequence of incidents that includes a radioactive release from a reactor. Given such a situation, the radiation field created by the reactor release, and other influences, could preclude mitigating actions needed to keep nearby pools in a safe state.

(X-37) In paragraphs VIII-19 through VIII-22, above, I draw from analysis by Morris et al to discuss a potential situation in which a large aircraft strikes a reactor. That event could be a malevolent act. I show that the aircraft impact could be part of a cascading sequence of incidents that includes a pool fire. Since the attacks of 11 September 2001 in New York and Washington, acquisition of a large aircraft by a malevolent actor has become more difficult. Also, precise aiming of a large aircraft at low altitude is difficult. However, a malevolent actor has other options. That actor might, for example, employ a comparatively small aircraft equipped with explosive devices.

(X-38) Now, consider a situation in which a malevolent actor has direct access to a pool. NUREG-0575 postulated such a situation, as discussed in paragraphs VI-2 through VI-6, above. The malevolent acts postulated in NUREG-0575 are summarized in Table VI-1. In the Mode 4 case, adversaries are assumed to temporarily take command of a spent-fuel pool while deploying an explosive device that could breach the floor of the pool. In that situation, as a slight adjustment of the Mode 4 case, the adversaries could use the explosive device to breach a wall of the pool, causing rapid drainage of water. The adversaries could ensure that some residual water is present. The exposed portion of the fuel would begin to heat up. Without prompt implementation of mitigating actions, a pool fire could follow. The adversaries could, in various ways, hinder or preclude mitigating actions.

(X-39) NRC proffers two, mutually inconsistent narratives about the threat of an attack on a spent-fuel pool. In one narrative, the pools are safe and secure, and no further action is needed to reduce the risk of a pool fire. In the other narrative, information about the potential for a pool fire must remain secret, because that information could be useful to an adversary.[120] Both narratives cannot be true. Apparently, NRC recognizes that the pools are vulnerable to attack, but believes that hiding that vulnerability under a veil of secrecy will eliminate the potential for attack. That belief is imprudent. Non-State

[120] NRC's consequence study mentions "security assessments" that were completed in 2006-2008, and further states that the results of these studies are not publicly available because they contain "sensitive information that could be useful to an adversary". (See: Barto et al, 2013b, page 14.)

adversaries of the United States have repeatedly demonstrated a level of technical knowledge such that they could readily understand the mechanisms underlying a pool fire, without recourse to NRC's secret studies. Thus, NRC's secrecy does not provide protection. Instead, it denies US citizens a full accounting of the risk of a pool fire.

Consequences of a pool fire

(X-40) I now turn to discussing the consequences of a pool fire. The draft GEIS provides two types of quantitative estimate of the consequences of a pool fire. One type is the value of an outcome per event (i.e., per pool fire). The second type is the frequency-weighted value of the outcome, which is calculated by multiplying the value per event by the supposed frequency of the event. The supposed frequency is expressed on a per-pool-year basis. The draft GEIS takes the position that the frequency-weighted value is the appropriate indicator of an environmental impact. I reject that position, as discussed below. Here, I discuss consequences on a per-event basis.

(X-41) The draft GEIS sets forth the following estimates of quantitative outcomes of a pool fire, on a per-event basis, in its Table F-1:[121]

- Collective radiation dose ranging from 47,000 person-Sv to 260,000 person-Sv across the population living within 50 miles, with no accounting of collective dose at greater distances.
- Latent fatalities (i.e., deaths occurring months or years after the event) ranging from 20,000 to 27,000, across the population residing at distances up to 500 miles.
- Onsite and offsite economic damage ranging from \$56 billion to \$58 billion (in 2010 dollars).

(X-42) NRC's consequence study, which is not cited in the draft GEIS, provides some quantitative estimates of pool-fire consequences.[122] These estimates do not appear in the draft GEIS. I discuss these estimates because they help to show that the draft GEIS substantially under-estimates the potential consequences of a pool fire. These estimates are specific to a potential fire at the Peach Bottom site in Pennsylvania. The particular estimates shown below are for an atmospheric release containing 330 PBq (i.e., 8.8 MCi) of the radioactive isotope Cs-137. That is a minor fraction of the inventory available for release. There are two operational reactors at the Peach Bottom site. Each reactor has its own spent-fuel pool, and each pool now contains about 2,180 PBq (i.e., 59 MCi) of Cs-137.[123] The quantity (i.e., mass) of fuel in each pool is equivalent to 5 reactor cores. For

[121] NRC, 2013b, Table F-1 (page F-4).
[122] The pool fire considered in NRC's consequence study would begin in recently-discharged fuel. In this declaration, I consider older spent fuel that falls under the ambit of the draft GEIS. However, the consequences that I discuss would be determined primarily by the magnitude of release of comparatively long-lived radio-isotopes, principally Cs-137. Thus, the consequences predicted by NRC's consequence study are applicable to the situation that I consider.
[123] Satorius, 2013b, Enclosure 1, Table 72 (page 133).

a postulated release of 330 PBq of Cs-137, NRC's consequence study predicts the following average outcomes of a pool fire, on a per-event basis:[124]

- Collective radiation dose of 350,000 person-Sv across a population living within an unspecified distance.
- Land area interdicted (i.e., rendered unfit for habitation) of 24,300 square km (i.e., 9,400 square miles).[125]
- Long-term displacement of 4.1 million people.[126]

(X-43) The numbers shown in paragraphs X-41 and X-42 begin to show the scale of the national disaster that could arise from a pool fire. Long-term displacement of 4.1 million people, which is an average case and not a worst case, would be a disaster of historic magnitude.[127] As discussed in paragraph IV-16, above, this event would cause substantial political stress and other adverse consequences. The social, political, and economic consequences would be diverse and difficult to predict, but would undoubtedly be severe. Moreover, the estimates described in paragraph X-42 assume a release of only 7% of the inventory of Cs-137 in the two pools at the Peach Bottom site. A larger release could occur.

(X-44) The estimate of economic damage that is set forth in the draft GEIS, and is shown in paragraph X-41, above, is much lower than other, more credible, estimates. Here, I discuss two estimates of this kind. One estimate is set forth in a 2004 journal article by Beyea et al.[128] That article accompanies this declaration as Exhibit #46. The second estimate is set forth in a 2007 report by the French government agency IRSN.[129] That report accompanies this declaration as Exhibit #47. A related paper by IRSN analysts is discussed in paragraphs IV-11 through IV-13, above.

(X-45) Beyea et al considered two potential, atmospheric releases. One release would consist of 130 PBq (i.e., 3.5 MCi) of Cs-137, and the other release would consist of 1,300 PBq (i.e., 35 MCi) of Cs-137. These releases represent two possible outcomes of a pool fire. The larger release would represent 60% of the Cs-137 inventory now in each of the two pools at the Peach Bottom site. Beyea et al estimated offsite economic damage for the two releases, at each of five nuclear-power-plant sites. For the 130 PBq release, the estimated offsite economic damage, averaged across the five sites, was $91 billion. For

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124 Barto et al, 2013b, Table 33 (page 162).
125 The relationship between the estimated average area of interdicted land and distance is as follows: 1,200 square miles within a 50-mile distance; 3,100 square miles within a 100-mile distance; and 9,400 square miles within a 500-mile distance. (See: Barto et al, 2013b, Table 35.)
126 The relationship between the estimated average number of displaced people and distance is as follows: 780,000 people within a 50-mile distance; 2.0 million people within a 100-mile distance; and 4.1 million people within a 500-mile distance. (See: Barto et al, 2013b, Table 36.)
127 For a given atmospheric release, the estimated number of displaced people varies with wind direction, atmospheric stability, precipitation, and other factors. NRC's consequence study presents an average case.
128 Beyea et al, 2004.
129 IRSN, 2007.

the 1,300 PBq release, the estimated offsite economic damage, averaged across the five sites, was $385 billion.[130] Both values are substantially higher than the economic-damage estimate of $56 billion to $58 billion, covering both onsite and offsite damage, that is set forth in the draft GEIS. Yet, Beyea et al did not consider a full range of contributors to offsite economic damage. Nor did they consider onsite economic damage.

(X-46) A more comprehensive set of contributors to economic damage was considered by IRSN. Their findings are set forth in Table X-1, drawing from IRSN's 2007 report. That report was secret when first prepared, but was leaked to the press in early 2013 and, soon thereafter, was published by IRSN. The report considered an atmospheric release from a reactor at the Dampierre site in France. Economic damage was attributed primarily to the presence of 100 PBq of Cs-137 in the release. Thus, IRSN's findings are applicable to a pool fire. This pool fire would not be a worst-case event. A release of 100 PBq of Cs-137 would represent only 5% of the Cs-137 inventory now in each of the two pools at the Peach Bottom site.

(X-47) The cost (i.e., economic damage) estimates shown in Table X-1 are in Euro. Here, I use a currency conversion of US$1.40 per Euro. With that conversion, Table X-1 shows that IRSN's base-case estimate of economic damage from a release of 100 PBq of Cs-137 in France is $1,060 billion (760 billion Euro). The low-case estimate is $410 billion (290 billion Euro), and the high-case estimate is $8,060 billion (5,760 billion Euro). For comparison, the GDP of the United States in 2012 was $15,700 billion.[131]

(X-48) A cost study of the type done by IRSN would yield different results if done for a US nuclear site. There is no reason to expect, however, that the estimated economic damage would be substantially lower in the US case. The damage could be higher. Thus, IRSN's 2007 analysis provides, until a better estimate becomes available, a reasonable default estimate of economic damage from a pool fire in the United States that would release 100 PBq (2.7 MCi) of Cs-137. I am not aware of any other analysis that considers all of the cost contributors that are considered in the IRSN analysis. The draft GEIS's estimation of economic damage, as shown in paragraph X-41, is derived from analysis that is substantially inferior to the IRSN analysis.

(X-49) The economic damage estimated by IRSN would be only part of the consequences of a pool fire. The accompanying social and political consequences would be diverse and difficult to predict, but would undoubtedly be severe. Thus, a pool fire could be a national disaster of historic dimensions. That is why IRSN analysts, whose work is described in paragraphs IV-11 through IV-13, above, said in their 2012 paper that a massive release of radioactive material would be "an unmanageable European catastrophe".[132] In their 2012 paper, these analysts did not disclose the magnitude of a

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[130] Beyea et al, 2004, Table 3 (page 131).
[131] World Bank website, "GDP (current US$)", accessed on 13 December 2013 at: http://data.worldbank.org/indicator/NY.GDP.MKTP.CD
[132] Pascucci-Cahen and Patrick, 2012.

"massive" release. I assume that this release would contain no more than 100 PBq of Cs-137, the amount considered in IRSN's 2007 report. That report was secret when the IRSN analysts presented their 2012 paper.

(X-50) Japan's experience with fallout from the 2011 Fukushima accident is instructive. The pattern of radioactive fallout across Japan is complex, as shown in Figure V-4. That fallout contained about 6 PBq of Cs-137, as shown in Table V-1. This amount of Cs-137 is comparatively small in the context of a potential release from a pool fire. Yet, the impacts of the Fukushima fallout on Japan are diverse and significant. For example, it is reported that 160,000 people were displaced from land contaminated by the Fukushima accident, and about one-third of this population remains in temporary housing. There is considerable uncertainty about the number of people who may be able to return to their homes.[133] Also, all of Japan's nuclear power plants remain shut down, due to public concern about their operation.

Determination of radiological risk and environmental impact

(X-51) I now turn to the final subject I address in Section X, namely the determination of radiological risk and environmental impact. As discussed in Section IV, above, NRC employs what I describe as an "arithmetic" definition of risk. That definition is fundamentally flawed for the reasons I set forth in Section IV.

(X-52) The flawed nature of the arithmetic definition of risk is clearly evident in the draft GEIS, NRC's consequence study, and the NRC staff's Tier 3 analysis. Each of those documents uses frequency-weighted consequences, as discussed in paragraph X-40, above, as a measure of environmental impact. In that manner, disastrous consequences of a potential pool fire, such as the long-term displacement of 4.1 million people, are made to appear small by multiplying the consequences by a supposedly low frequency.

(X-53) Also, NRC focuses on each facility in isolation. That focus is evident in NRC's discussion of frequency in terms of occurrence per reactor-year or per pool-year. For some, limited, technical purposes, this single-facility focus is appropriate. It is, however, inappropriate when considering the risk experienced by a citizen. The United States currently has 100 operational, commercial reactors, roughly the same number of spent-fuel pools, and various other nuclear facilities.[134] A citizen is exposed to the radiological risk associated with a number of facilities. This point is illustrated by NRC's finding, as discussed in paragraph X-42, above, that a pool fire at the Peach Bottom site could lead to the long-term displacement of 4.1 million people. About 800,000 of those people would have resided within 50 miles of the site, while about 1.2 million would have resided between 50 and 100 miles from the site, and about 2.1 million would have resided

[133] Knight and Slodkowski, 2013.
[134] An operational reactor is a reactor that is normally in operation except when shut down for refueling, maintenance, or repair.

between 100 and 500 miles from the site.[135] Clearly, this event would have long-range consequences, extending far beyond the vicinity of the afflicted site. A citizen at a given location could be vulnerable to impacts of this nature originating at any of a number of sites.[136]

(X-54) Moreover, if such an event occurred, citizens would experience significant consequences even if they did not suffer from substantial, immediate injury such as displacement from their homes. The economic, social, and political consequences of this event would be felt by everyone residing in the United States, and by many people outside its borders. This pool fire would be a national disaster with international implications.

(X-55) Thus, in considering the probability of a pool fire, an appropriate indicator would be the frequency of the event occurring anywhere in the United States during a specified time period. Given the existence of operational reactors in Canada and Mexico, the geographic perimeter might logically be extended to North America. For the purposes of this declaration, however, I set that option aside because it would be legally and politically difficult to implement.

(X-56) What would be the appropriate time period for a determination of frequency? Given that a pool fire could be a national disaster of historic dimensions, a reasonable time period would be a century. If that time period were employed in the context of the United States as a geographic unit, then the frequency of a pool fire would be expressed in terms of the number of occurrences per century, where the occurrence could be at any location within the United States. This concept of frequency would be compatible with the particular characteristics of pool-fire risk. Hereafter, I refer to this concept as "cumulative frequency". Note, as discussed previously, that this indicator could have a value greater than 1.

(X-57) There are now 100 operational reactors in the United States. As discussed in Section IX, above, the draft GEIS allows for the continuation of this situation indefinitely. Thus, for the purpose of illustrating pool-fire risk, it is reasonable to consider a scenario in which 100 reactors are operational throughout a period of 100 years. In this scenario, each reactor has a risk linkage with one nearby pool other than its own pool, and vice versa. Each of these nearby pools is assumed to fall under the ambit of the draft GEIS because the reactor that it served is no longer licensed for operation. I assume that each nearby pool is equipped with high-density racks, and that the risk posed by each reactor-pool linkage is uniform across the fleet and constant over time. This "status quo" scenario is entirely compatible with the draft GEIS.

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[135] Barto et al, 2013b, Table 36 (page 169).

[136] The flexRISK project in Austria developed a computer-model capability to assess the radiological risk, at any location in Europe, that arises from operation of all nuclear facilities across Europe. That capability could be applied to the United States. An overview of the flexRISK project was accessed on 14 December 2013 from: http://flexrisk.boku.ac.at/en/index.html

(X-58) For this illustrative scenario, the cumulative frequency of a pool fire can be determined by simple extrapolation of current estimates of pool-fire frequency, which are expressed on a per-pool-year basis. Consider first the frequency estimate of $2.4x10^{-6}$ per pool-year that is set forth in the draft GEIS in the context of an accident-induced pool fire, as discussed in paragraph X-31, above. In that case, the cumulative frequency would be $100x100x2.4x10^{-6} = 0.024$ events per century. Now, consider the revised frequency estimate of $3.2x10^{-5}$ per pool-year that is set forth in paragraph X-33. This revised estimate accounts for linkage of pool risk and reactor risk, still in the context of an accident-induced pool fire. In this case, the cumulative frequency would be $100x100x3.2x10^{-5} = 0.32$ events per century.

(X-59) At this point in Section X, I am ready to evaluate the draft GEIS's assessment of the environmental impact of pool fires. I provide this evaluation in paragraph X-60, addressing accident-induced pool fires, and in paragraph X-61, addressing attack-induced pool fires. In both cases, I find that the draft GEIS's assessment of environmental impact is incorrect. Paragraphs X-60 and X-61 provide my evaluation and its underlying rationale.

(X-60) The draft GEIS asserts that the environmental impact of accident-induced pool fires is SMALL.[137] However, as shown above, the draft GEIS indicates that the cumulative frequency of such fires could be 0.024 events per century. Also, NRC's consequence study shows that the consequences of a pool fire could be severe, with outcomes such as the long-term displacement of 4.1 million people. IRSN's analysis shows that outcomes could include economic damage measured in trillions of dollars. Therefore, the environmental impact of accident-induced pool fires is not SMALL. Instead, it is LARGE. This finding does not account for linkage of pool risk and reactor risk. If that linkage is accounted for, as is appropriate, the cumulative frequency of accident-induced pool fires could be 0.32 events per century. In that case, it is even more evident that the environmental impact of accident-induced pool fires is not SMALL. Instead, it is LARGE. Thus, the draft GEIS substantially under-estimates the environmental impact of accident-induced pool fires. Also, the draft GEIS ignores the possibility that the risk environment will become more adverse in the future. In addition, the draft GEIS uses a flawed definition of risk – the arithmetic definition.

(X-61) The draft GEIS further asserts that the environmental impact of attack-induced pool fires is SMALL.[138] However, from the discussions in Section VI and paragraphs X-35 through X-39, above, it is clear that the cumulative frequency of attack-induced pool fires could be substantial. Also, NRC's consequence study shows that the consequences of a pool fire could be severe, with outcomes such as the long-term displacement of 4.1 million people. IRSN's analysis shows that outcomes could include economic damage measured in trillions of dollars. Therefore, the environmental impact of attack-induced

[137] NRC, 2013b, Table 4-2 (page 4-91).
[138] NRC, 2013b, Table 4-2 (page 4-91).

pool fires is not SMALL. Instead, it is LARGE. Thus, the draft GEIS substantially under-estimates the environmental impact of attack-induced pool fires. Also, the draft GEIS ignores the possibility that the risk environment will become more adverse in the future. In addition, the draft GEIS uses a flawed definition of risk – the arithmetic definition. Moreover, application of the arithmetic definition is additionally flawed in this instance because the indicators that are multiplied together are nebulous.

XI. Cask Fire: Probability and Consequences

(XI-1) The draft GEIS assumes that spent fuel will be stored initially in pools and subsequently in dry casks. A group of dry casks will constitute an ISFSI. During cask storage there is a potential for a "cask fire". That event could occur if a malevolent actor gains access to a dry cask containing spent fuel and attacks the cask in a manner that produces a self-propagating reaction between air and zircaloy fuel cladding, leading to a substantial atmospheric release of radio-isotopes including Cs-137. An accident could conceivably cause a cask fire at a storage facility, but I do not consider that possibility here. The draft GEIS does not consider the occurrence of a cask fire caused by either accident or attack.

(XI-2) In the Thompson scoping declaration, I outlined the potential for an attack-induced cask fire.[139] I first discussed a potential precursor to a cask fire – a reasonably foreseeable attack that would penetrate a cask, damage fuel inside the cask, and cause a release of radioactive material to the atmosphere. The feasibility of such an attack has been demonstrated in tests whose findings have been openly published. In my judgment, an attacker could, with a few additional steps, readily initiate a cask fire. NRC has not conceded that an attacker could take these additional steps and initiate a cask fire.

(XI-3) The difference between my position and that of NRC could be resolved by commissioning an independent "Red Team" of persons who have relevant experience in practice and research. That team could conduct tests at a national laboratory or military base, to determine how readily a cask fire could be initiated. The tests could involve the use of tracer materials, thereby contributing to estimation of the radioactive release that could result from a cask fire. The general findings of the tests should be published, but some details of the tests may not be appropriate for publication. Until such tests are done, NRC will not be able to complete an adequate GEIS on the environmental impacts of storing spent fuel.

(XI-4) The probability and impacts of an attack-induced cask fire are interrelated. Also, the relationship between probability and impacts is influenced by the extent to which casks are protected from attack. Moreover, the difference between the risk of attack-induced pool fires and the risk of attack-induced cask fires is a significant issue in the context of national security. The concept of protective deterrence provides a useful perspective on that difference. These matters are discussed below.

[139] Thompson, 2013b, paragraphs VII-15 through VII-16 and VIII-14 through VIII-18.

(XI-5) The effort needed to successfully attack an ISFSI and produce a cask fire could be roughly the same as the effort needed to successfully attack a spent-fuel pool and produce a pool fire. Let us examine the implications of that finding during a future period when pools and ISFSIs coexist. As discussed in paragraph VI-10 and elsewhere in this declaration, there is persuasive evidence that an attack-induced pool fire is as likely to occur as are major national challenges that are planned for, such as severe natural disasters or engagement in wars. An identical statement could be made about a cask fire, if two provisos were satisfied. The first proviso is that attackers would be able to achieve roughly the same outcomes by attacking a pool or an ISFSI. If that proviso were not satisfied, and the attack on the ISFSI would achieve a lower outcome, the attackers would have a reduced incentive to attack the ISFSI. The second proviso is that the casks sit on concrete pads in the open air without additional protection, which is current practice. If that proviso were not satisfied, and additional protection was provided, the attackers would have to expend greater effort to achieve the same outcome, which would reduce their incentive to attack.

(XI-6) These provisos show how probability and impacts are interrelated. If the expected outcome of an attack on an ISFSI would be smaller than the outcome of an attack on a pool, other factors being equal, then a malevolent actor would be less likely to attack the ISFSI. The probability of the attack would decrease even further if the casks in the ISFSI were provided with additional protection against attack. Thus, either decreasing the expected outcome of an attack, or increasing the effort required to achieve a given outcome, would decrease the probability of attack. In the context of national security, that effect is encompassed within the concept of protective deterrence. Implementation of that concept could benefit the nation. Accordingly, the Thompson scoping declaration made the following recommendation:[140]

> "**Recommendation #22:** In assessing the overall impacts of storing SNF or HLW, the proposed EIS [i.e., the draft GEIS] should consider the implications of alternative storage options for a national strategy of protective deterrence."

(XI-7) Table XI-1 shows how the United States could benefit from policies that ensured that critical infrastructure is designed to be robust and inherently safer. The benefits could include, for example, a reduction in the federal government's perceived need to conduct surveillance of the domestic population. That matter is a subject of current debate. Designing critical infrastructure to be robust and inherently safer would be part of a national strategy of protective deterrence.

(XI-8) Nuclear facilities – including reactors, pools, and ISFSIs using dry casks – are components of critical infrastructure. In the context of storing spent fuel, a dry cask is more robust and inherently safer than is a pool equipped with high-density racks. A dry cask in an ISFSI with enhanced protection would be even more robust and inherently

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[140] Thompson, 2013b, Section IX and Section X.

safer. Thus, the aspects of radiological risk that I discuss in this declaration are significant for national security, and could be productively addressed within the context of protective deterrence. The draft GEIS is oblivious to this matter, and does not respond to my recommendation as quoted in paragraph XI-6, above. More generally, NRC appears oblivious to its potential ability to benefit the nation by implementing principles of protective deterrence.

(XI-9) The first step in assessing potential consequences of an attack-induced cask fire is to determine the inventory of radioactive material that is in the cask and available for release. Here, I focus on the radio-isotope Cs-137. I consider, as an illustrative example, a cask holding 32 PWR fuel assemblies. With reasonable assumptions, one can readily calculate that the cask contains 67 PBq (i.e., 1.8 MCi) of Cs-137.[141]

(XI-10) A successful attack on an ISFSI, in which attackers expended an effort roughly the same as the effort needed to successfully attack a spent-fuel pool and cause a pool fire, could cause a cask fire in one or perhaps two casks. For illustration, let us assume that two casks would experience a fire and the fractional release of Cs-137 to the atmosphere would be 50%. In that case, the total atmospheric release from two typical casks holding 32 PWR fuel assemblies per cask would contain 67 PBq of Cs-137. That would be a substantial release, with a magnitude between the Fukushima release (36 PBq) and the Chernobyl release (85 PBq), as shown in Table V-1.

(XI-11) Section X, above, discusses the consequences of atmospheric releases of various amounts of Cs-137. For example, as discussed in paragraph X-42, release of 330 PBq of Cs-137 could lead to severe consequences including long-term displacement of 4.1 million people. Also, as discussed in paragraphs X-46 through X-48, release of 100 PBq of Cs-137 could create economic damage of about $1 trillion in the "base" case and $8 trillion in the "high" case. In addition, there would be severe consequences of a social and political nature.

(XI-12) Thus, it is clear that a release of 67 PBq of Cs-137 during a cask-fire incident could lead to severe consequences. Yet, a pool fire could lead to a much larger release, with correspondingly greater consequences. For example, as noted in paragraph X-42, each of the two pools at the Peach Bottom site now contains about 2,180 PBq of Cs-137. The fractional release of Cs-137 during a pool fire could be substantial, potentially exceeding 50%. At Peach Bottom, where two pools are in close proximity, an attack on one pool could ultimately lead to fires in both pools. Thus, a pool-fire release exceeding 2,000 PBq of Cs-137 is entirely credible.

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[141] Assumptions in the calculation are: (i) there are 32 PWR spent fuel assemblies in the cask; (ii) each fuel assembly has a mass of 0.45 Mg HM; (iii) the fuel has a burnup of 50 GWt-days per Mg HM; (iv) the fuel is aged 10 years after discharge from a reactor; and (v) 1 GWt-day of fission energy yields 1.17×10^{14} Bq of Cs-137.

(XI-13) The effort needed to successfully attack an ISFSI and produce an atmospheric release of 67 PBq of Cs-137 could be roughly the same as the effort needed to successfully attack a spent-fuel pool and produce a pool fire. However, the pool-fire release could be much larger than 67 PBq of Cs-137. As discussed above, at Peach Bottom a pool-fire release could exceed 2,000 PBq of Cs-137. Informed attackers would be aware of this discrepancy in potential outcomes. Accordingly, they would tend to target a pool rather than an ISFSI, other factors being equal. If the ISFSI were provided with enhanced protection, the comparative attractiveness of the ISFSI as a target would be even lower. Section XII, below, discusses some options for providing ISFSIs with enhanced protection.

(XI-14) At present, pools and ISFSIs coexist in the United States. Thus, given the comparative attractiveness of pools and ISFSIs as targets, a successful attack on a pool is currently more likely than a successful attack on an ISFSI. However, the draft GEIS contemplates a future in which there would be ISFSIs and no pools. That situation could continue into the indefinite future. Diminution of radioactive decay heat in spent fuel over time would be irrelevant to the creation of a cask fire. The risk environment could become more adverse over time. For example, security measures at ISFSIs could degrade over time. Also, an increased propensity for violent conflict could find expression through attacks on ISFSIs. Thus, the frequency of successful attacks on ISFSIs could be much greater in the future than it is today.

(XI-15) The findings set forth in Section XI, up to this point, support three conclusions about the environmental impact of attacks on ISFSIs. Here, I use the creation of one or more cask fires as an indicator of the success of an attack on an ISFSI.

(XI-16) The first conclusion is as follows. As discussed in paragraph VI-11, above, the draft GEIS asserts that the environmental impact of attacks on ISFSIs is SMALL. However, the cumulative frequency of successful attacks on ISFSIs could be substantial. Also, the consequences of a successful attack could be severe. Therefore, the environmental impact of attacks on ISFSIs is not SMALL. Instead, it is LARGE. Thus, the draft GEIS substantially under-estimates the environmental impact of attacks on ISFSIs. Also, the draft GEIS ignores the possibility that the risk environment will become more adverse in the future. In addition, the draft GEIS uses a flawed definition of risk – the arithmetic definition. Moreover, application of the arithmetic definition is additionally flawed in this instance because the indicators that are multiplied together are nebulous.

(XI-17) The second conclusion is as follows. While pools and ISFSIs coexist, as is true today, the cumulative frequency of successful attacks on pools is likely to exceed the cumulative frequency of successful attacks on ISFSIs. However, the draft GEIS contemplates a future in which there would be ISFSIs and no pools. In that case, the cumulative frequency of successful attacks on ISFSIs could be comparable to the currently-applicable cumulative frequency of successful attacks on pools, if there were no change in the risk environment. Whether or not pools coexist with ISFSIs in the future, the risk environment could become more adverse, leading to an increase in the cumulative frequency of successful attacks on ISFSIs.

(XI-18) The third conclusion is as follows. The cumulative frequency of successful attacks on ISFSIs, now and in the future, could be decreased by providing ISFSIs with enhanced protection against attack.

XII. Risk-Reducing Options

(XII-1) There are numerous options for reducing the radiological risk arising from management of spent fuel and other radioactive waste produced by the nuclear fuel cycle. The draft GEIS does not discuss any options of this type. Here, I provide a brief discussion of a few options. This discussion does not purport to be comprehensive.

(XII-2) Table XII-1 outlines some options for reducing the risk of a pool fire at a nuclear power plant. This table was prepared in the context of a spent-fuel pool that serves an operational reactor. A similar table could be prepared for a pool that no longer serves an operational reactor.

(XII-3) The most effective option in Table XII-1 is to re-equip the pool with low-density, open-frame racks. In the case of BWR fuel, a corollary action could be the removal of channel boxes from the fuel. When nuclear power plants in the present US fleet first entered service, their spent-fuel pools were equipped with low-density, open-frame racks. The margin of safety provided by this configuration was lost when the nuclear industry adopted high-density racks as a way to minimize short-term costs.

(XII-4) Over a period of decades, pursuit of short-term cost minimization has increased the radiological risk of nuclear power production in various respects. This pursuit influenced the design of the nuclear power plants that participated in the Fukushima accident of 2011. Other manifestations of this pursuit include reactor power uprates, use of higher-burnup fuel, shorter refueling periods, and use of high-density racks in spent-fuel pools.

(XII-5) Section XI, above, discusses some of the implications of providing enhanced protection of ISFSIs. In the United States, a typical ISFSI consists of dry casks sitting on a concrete pad in the open air. Other countries provide greater protection.

(XII-6) Sweden has taken an interesting approach to ISFSI design. The Swedes have built the Clab facility, in which spent-fuel pools are located in underground caverns excavated in rock. The Clab facility has been described in a brochure published by SKB, the company that manages Sweden's radioactive waste.[142] That brochure accompanies this declaration as Exhibit #48. One sees from the brochure that the ceiling of each cavern is 32 m below the surface. The intervening rock is granite.

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[142] SKB, 2006.

(XII-7) The Clab facility will probably not be replicated in the United States. It represents a comparatively expensive approach to managing spent fuel. Also, although Clab is not designed as a repository, there might be political pressure to employ such a facility as a repository if repeated efforts to build a repository were to fail. For that reason, I recommend that interim storage of spent fuel be done at the surface, to reduce the likelihood that an interim storage facility could become a repository by default.

(XII-8) The German approach to ISFSI design is to store spent fuel in dry casks that are, with one exception, located within buildings at the surface.[143] The design of these buildings is described in a conference paper by Thomauske.[144] That paper accompanies this declaration as Exhibit #49. Two basic designs are used. One design is by STEAG, and the other by WTI. Cross-sectional drawings in Thomauske's paper suggest that the STEAG design would be more robust against attack. That observation is confirmed by analyses showing that the STEAG design would be more robust against impact by a large aircraft.

(XII-9) Holtec is a US-based vendor of dry casks used for storing spent fuel at ISFSIs. The Holtec design approach is modular. Fuel is sealed inside a multi-purpose canister (MPC) that is designed to be placed inside overpacks of various types. Holtec has developed an overpack, known as the HI-STORM 100U, that would be more robust against attack than present overpacks. A standard MPC would be placed, in a vertical-axis position, inside the 100U overpack. The 100U overpack would be sunk below ground except for its lid. Holtec has described the robustness of the 100U system as follows:[145]

> "Release of radioactivity from the HI-STORM 100U by any mechanical means (crashing aircraft, missile, etc.) is virtually impossible. The only access path into the cavity for a missile is vertically downward, which is guarded by an arched, concrete-fortified steel lid weighing in excess of 10 tons. The lid design, at present configured to easily thwart a crashing aircraft, can be further buttressed to withstand more severe battlefield weapons, if required in the future for homeland security considerations. The lid is engineered to be conveniently replaceable by a later model, if the potency of threat is deemed to escalate to levels that are considered non-credible today."

(XII-10) Paragraphs XII-6 through XII-9 show that options are available for providing enhanced protection of ISFSIs. Use of such options at ISFSIs across the United States would support a national strategy of protective deterrence.

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[143] The exception is the Neckarwestheim ISFSI, which consists of two concrete-lined tunnels in the wall of a quarry.
[144] Thomauske, 2003.
[145] Holtec, 2007. A current description of the 100U system was accessed on 15 December 2013 from: http://www.holtecinternational.com/productsandservices/wasteandfuelmanagement/hi-storm/

XIII. Conclusions

(XIII-1) I provide conclusions in two categories. The first category is "reference conclusions". These are set forth at some length, linked consecutively to the portions of this declaration from which they were derived. The second category is "summary conclusions". These are expressed concisely, and are arranged to support a coherent argument.

(XIII-2) The reference conclusions, and the body of this declaration, represent my definitive findings. The summary conclusions may be less exact.

(XIII-3) My reference conclusions are set forth below. The heading for each conclusion shows the portion of this declaration from which the conclusion was principally derived. These conclusions are:

<u>Reference Conclusion #1 (derived from Section IV)</u>

The draft GEIS defines radiological risk as the numerical product of the probability and the consequences of an event, and further argues that a high-consequence, low-probability event, such as a severe accident, could be determined to have a small environmental impact if the risk is sufficiently low. In the context of the draft GEIS, that definition of radiological risk, and the associated determination of environmental impact, are fundamentally flawed from at least four overlapping perspectives:

- First, numerical estimates of consequences and probability are typically incomplete and highly uncertain.
- Second, significant aspects of consequences and probability are not susceptible to numerical estimation.
- Third, larger consequences can be qualitatively different than smaller consequences.
- Fourth, devotees of this definition of risk typically argue, as does the draft GEIS, that equal levels of "risk", as they define it, should be equally acceptable to citizens. That argument may be given a scientific gloss, but is actually a statement laden with subjective values and interests. An informed citizen could reject the argument on reasonable grounds.

<u>Reference Conclusion #2 (derived from Section V)</u>

The draft GEIS relies on PRA-type studies for its estimation of radiological risk. Studies of this type can provide useful information about radiological risk, for certain purposes. However, these studies cannot provide a credible estimate of the probability of a radiological event such as a pool fire. The relationship between a PRA finding and reality can be represented as follows:

Actual probability of event = (PRA finding)x(Reality factor #1) + (Reality factor #2)

Where the variables in this equation are as follows:

- "Actual probability of event" refers to the real-world numerical probability of an outcome such as: fuel damage; release of a specified amount of radioactive material; contamination of a specified area of land above a specified dose threshold; or accrual of a specified collective dose to people offsite.
- "PRA finding" refers to a PRA estimate of the probability of the outcome in question – this could be a mean, median, or other representation of a probability distribution.
- "Reality factor #1" is a number, typically greater than 1, that represents influences that are within the paradigm of PRA but are not properly accounted for in contemporary PRAs – these influences include: complexity; inadequate data; and deficiencies in institutional culture and practice.
- "Reality factor #2" is a number that represents influences outside the paradigm of PRA – these influences include: gross errors in design, construction, or operation; and malevolent acts.

And the following observations apply:

- Experience suggests that Reality factor #1 for severe accidents may have a value that exceeds 1 by several orders of magnitude (i.e., factors of 10).
- Reality factor #2 has two numerical components: (i) a retrospective component that can be determined empirically based on the occurrence of events; and (ii) a prospective component that will remain unknown for the foreseeable future.
- Both Reality factors may vary significantly in response to variations in the future risk environment.
- This version of the equation is applicable when the values of "PRA finding" and "Actual probability of event" are both less than 1. At higher values, the term "probability" would be replaced by the term "frequency".

<u>Reference Conclusion #3 (derived from Section VI)</u>

In light of human history, observation of the contemporary world, and consideration of possible societal trends, a prudent decision maker would conclude that a successful attack on a reactor or spent-fuel-storage facility in the United States over the coming decades is as likely to occur as are major national challenges that are planned for, such as severe natural disasters or engagement in wars.

<u>Reference Conclusion #4 (derived from Section VII)</u>

The draft GEIS sets forth a highly optimistic view of the future conditions that will affect stored spent fuel. It assumes that institutional controls will remain operative into the indefinite future, arguing that this assumption "avoids unreasonable speculation regarding what might happen in the future". This assumption, like other optimistic assumptions in the draft GEIS, is neither reasonable nor prudent. Moreover, assuming static conditions is speculative in the extreme, and shows a profound ignorance of human history. Given the long timeframes envisioned in the draft GEIS, the only reasonable approach is to consider a broad range of scenarios. Those scenarios would encompass substantial changes in the risk environment over time. The changes could be non-uniform across the United States.

<u>Reference Conclusion #5 (derived from Section VIII)</u>

Pool storage of spent fuel, as considered in the draft GEIS, could occur, and probably will occur, at locations near operational reactors. Accordingly, the draft GEIS should have carefully considered the potential linkage of radiological risk among pools and operational reactors at each site. The draft GEIS has not considered this matter.

<u>Reference Conclusion #6 (derived from Section VIII)</u>

Risk linkages among spent-fuel pools and operational reactors at a site could be manifested in a cascading sequence of incidents that preclude mitigating actions needed to maintain pools in a safe state. Mitigating actions could be precluded by, for example, a radiation field arising from the release of radioactive material. NRC has never, to my knowledge, published a credible technical analysis of a cascading sequence of incidents of this type, or publicly stated that it has performed such analysis in secret. Until such analysis is done properly, NRC will not be able to complete an adequate GEIS on the environmental impacts of storing spent fuel.

<u>Reference Conclusion #7 (derived from Section IX)</u>

The draft GEIS does not set forth any scenario for the future use of nuclear power or, more specifically, for the future creation of spent fuel. Thus, in the draft GEIS, the timeframe for creation of spent fuel spans an unknown but potentially vast range, as does the quantity of spent fuel created in that timeframe. Accordingly, the radiological risk posed by storing spent fuel is unbounded. In this manner, the draft GEIS has denied itself the ability to assess the long-term radiological risk of storing spent fuel. One cannot assess a quantity that is unbounded. This grave deficiency could have been avoided by judicious use of scenarios. A scenario-based approach could, in principle, have allowed the draft GEIS to bound the radiological risk of storing spent fuel. Moreover, such an approach could have allowed the draft GEIS to compare the risk posed by different scenarios and different options for managing spent fuel.

<u>Reference Conclusion #8 (derived from Section X)</u>

The draft GEIS fails to cite a number of documents that are relevant to its findings about the risk of pool fires. Moreover, some recently published documents in this category had a substantial but undocumented influence on the draft GEIS. The lack of documentation of this influence handicaps those who seek to comment on the draft GEIS. Documents not cited in the draft GEIS that are particularly significant include:

- Appendix J of NUREG-0575.[146]
- NRC's consequence study. [147]
- The NRC staff's Tier 3 analysis.[148]

Reference Conclusion #9 (derived from Section X)

The draft GEIS reflects NRC's present understanding of phenomena relevant to a pool fire. That understanding is deficient from the following perspectives:

- NRC failed to understand a comparatively simple technical issue for more than two decades, because its staff were shielded from public challenge and did not engage in the open discourse that is essential to scientific inquiry.
- With limited exceptions, NRC staff remain shielded from public challenge and scientific discourse.
- NRC's latest analysis of pool fires (i.e., NRC's consequence study) ignores a number of technical issues that are significant to a determination of pool-fire risk.
- The NRC staff proposes to close off further inquiry into pool-fire risk.
- Apparently, the NRC staff believes that the acquisition of a thorough understanding of pool-fire phenomena is unnecessary because the probability of unmitigated partial or total loss of water from a pool is negligible.

Reference Conclusion #10 (derived from Section X)

The draft GEIS significantly under-estimates the probability of an accident-induced pool fire, in part because it does not consider the linkage of pool risk and reactor risk. The present state of knowledge suggests that the under-estimate is by at least one order of magnitude (i.e., factor of 10).

Reference Conclusion #11 (derived from Section X)

The draft GEIS significantly under-estimates the probability of an attack-induced pool fire. That probability cannot be determined quantitatively. My qualitative assessment is provided in Conclusion #3, above.

Reference Conclusion #12 (derived from Section X)

The draft GEIS substantially under-estimates the consequences of a pool fire. Those consequences could include the long-term displacement of millions of people, economic damage measured in trillions of dollars, and adverse social and political outcomes. A pool fire yielding these consequences would be a national disaster of historic dimensions.

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[146] NRC, 1979.
[147] Barto et al, 2013b.
[148] Satorius, 2013b.

<u>Reference Conclusion #13 (derived from Section X)</u>

The draft GEIS considers the risk of a pool fire in terms of the probability of its occurrence at a particular pool within a 1-year timeframe. That approach to risk assessment does not account for the potential magnitude and scope of the consequences of a pool fire. Instead, the radiological risk of a pool fire should be considered in terms of the cumulative frequency of its occurrence, over a period of a century, at any location within the United States.

<u>Reference Conclusion #14 (derived from Section X)</u>

The draft GEIS asserts that the environmental impact of accident-induced pool fires is SMALL. However, the cumulative frequency of such fires is substantial, and the consequences of a pool fire could be severe. Therefore, the environmental impact of accident-induced pool fires is not SMALL. Instead, it is LARGE. Thus, the draft GEIS substantially under-estimates the environmental impact of accident-induced pool fires. Also, the draft GEIS ignores the possibility that the risk environment will become more adverse in the future. In addition, the draft GEIS uses a flawed definition of risk – the arithmetic definition.

<u>Reference Conclusion #15 (derived from Section X)</u>

The draft GEIS asserts that the environmental impact of attack-induced pool fires is SMALL. However, the cumulative frequency of such fires is substantial, and the consequences of a pool fire could be severe. Therefore, the environmental impact of accident-induced pool fires is not SMALL. Instead, it is LARGE. Thus, the draft GEIS substantially under-estimates the environmental impact of attack-induced pool fires. Also, the draft GEIS ignores the possibility that the risk environment will become more adverse in the future. In addition, the draft GEIS uses a flawed definition of risk – the arithmetic definition. Moreover, application of the arithmetic definition is additionally flawed in this instance because the indicators that are multiplied together are nebulous.

<u>Reference Conclusion #16 (derived from Section XI)</u>

The draft GEIS asserts that the environmental impact of attacks on ISFSIs is SMALL. However, the cumulative frequency of successful attacks on ISFSIs could be substantial. Also, the consequences of a successful attack could be severe. Therefore, the environmental impact of attacks on ISFSIs is not SMALL. Instead, it is LARGE. Thus, the draft GEIS substantially under-estimates the environmental impact of attacks on ISFSIs. Also, the draft GEIS ignores the possibility that the risk environment will become more adverse in the future. In addition, the draft GEIS uses a flawed definition of risk – the arithmetic definition. Moreover, application of the arithmetic definition is additionally flawed in this instance because the indicators that are multiplied together are nebulous.

<u>Reference Conclusion #17 (derived from Section XI)</u>

While pools and ISFSIs coexist, as is true today, the cumulative frequency of successful attacks on pools is likely to exceed the cumulative frequency of successful attacks on ISFSIs. However, the draft GEIS contemplates a future in which there would be ISFSIs and no pools. In that case, the cumulative frequency of successful attacks on ISFSIs could be comparable to the currently-applicable cumulative frequency of successful attacks on pools, if there were no change in the risk environment. Whether or not pools coexist with ISFSIs in the future, the risk environment could become more adverse, leading to an increase in the cumulative frequency of successful attacks on ISFSIs.

<u>Reference Conclusion #18 (derived from Section XI)</u>

The cumulative frequency of successful attacks on ISFSIs, now and in the future, could be decreased by providing ISFSIs with enhanced protection against attack.

<u>Reference Conclusion #19 (derived from Section XII)</u>

The draft GEIS does not consider options for reducing the radiological risk arising from management of spent fuel. However, numerous options of this kind are available. For example, options are available for providing enhanced protection of ISFSIs. Use of such options at ISFSIs across the United States would support a national strategy of protective deterrence.

(XIII-4) My summary conclusions are set forth below. They are:

<u>Summary Conclusions</u>

1. The draft GEIS asserts that the environmental impact of accident-induced or attack-induced pool fires is SMALL in both cases. That assertion is incorrect. The environmental impact is LARGE in both cases.
2. The draft GEIS asserts that the environmental impact of attacks on ISFSIs is SMALL. That assertion is incorrect. The environmental impact is LARGE.
3. The draft GEIS's assertions regarding the environmental impacts of pool fires and attacks on ISFSIs are incorrect because the draft GEIS: (i) employs an inappropriate definition of radiological risk; (ii) inappropriately assesses radiological risk on a single-facility basis over a one-year period; and (iii) under-estimates the probability and consequences of radiological incidents at pools and ISFSIs.
4. An appropriate definition of radiological risk would: (i) account for qualitative factors affecting probability and consequences; (ii) recognize qualitative differences between small and large consequences; and (iii) repudiate the idea that large consequences are tolerable if their supposed probability is low.

5. An appropriate assessment of radiological risk at pools and ISFSIs would examine cumulative risk across all US facilities over a period of a century, and would account for potential changes in the risk environment.
6. The draft GEIS under-estimates the probability and consequences of radiological incidents at pools and ISFSIs because: (i) NRC has not conducted the comprehensive empirical and analytic inquiry needed to thoroughly understand probability and consequences in this context; (ii) NRC staff are shielded from public challenge and scientific discourse; and (iii) NRC inappropriately assumes that the risk environment will remain static.
7. The NRC staff proposes to close off further inquiry into the probability and consequences of radiological incidents at pools.
8. NRC has ignored my recommendation to conduct further inquiry into the probability and consequences of cask fires.
9. Options are available to reduce the probability and consequences of radiological incidents at pools and ISFSIs, with collateral benefits to the nation via enhancement of protective deterrence, but these options are ignored in the draft GEIS.

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I declare, under penalty of perjury, that the facts set forth in the foregoing narrative, and in the four appendices below, are true and correct to the best of my knowledge and belief, and that the opinions expressed therein are based on my best professional judgment.

Executed on 19 December 2013.

G.R. Thompson

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Gordon R. Thompson

APPENDIX A: Tables and Figures

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Table IV-1
Some Categories of Risk Posed by a Commercial Nuclear Facility: Author's Definitions

Category	Definition	Mechanisms
Radiological risk	Potential for harm to humans as a result of unplanned exposure to ionizing radiation	Exposure arising from: • Release of radioactive material via air or water pathways, or • Line-of-sight exposure to unshielded radioactive material or a criticality event
Proliferation risk	Potential for diversion of fissile material or radioactive material to weapons use	Diversion by: • Non-State actors who defeat safeguards procedures and devices, or • The host State
Program risk	Potential for facility function to diverge substantially from original design objectives	Functional divergence due to: • Failure of facility to enter service or operate as specified, or • Policy or regulatory shift that alters design objectives or facility operation, or • Changed economic and societal conditions, or • Conventional accident or attack affecting the facility

Notes:
(a) In this declaration, the general term "risk" is defined as the potential for an unplanned, undesired outcome. There are various categories of risk, including the three categories in this table.
(b) In the case of radiological risk, the events leading to unplanned exposure to radiation could be accidents or attacks.
(c) The term "proliferation risk" is often used to refer to the potential for diversion of fissile material, for use in nuclear weapons. Here, the term also covers the potential for diversion of radioactive material, for use in radiological weapons.

Table V-1
Amounts of Cesium-137 Related to the Chernobyl and Fukushima #1 Accidents

Category	Amount of Cesium-137 (PBq)
Chernobyl release to atmosphere (1986)	85
Fukushima #1 release to atmosphere (2011)	36
Deposition on Japan due to the Fukushima #1 atmospheric release	6.4
Pre-release inventory in reactor cores of Fukushima #1, Units 1-3 (total for 3 cores)	940
Pre-release inventory in spent-fuel pools of Fukushima #1, Units 1-4 (total for 4 pools)	2,200

Notes:
(a) This table shows estimated amounts of Cesium-137 from: Stohl et al, 2011. The estimates for release from Fukushima #1 and deposition on Japan may change as new information becomes available.
(b) Stohl et al, 2011, provide the following data and estimates for Fukushima #1, Units 1-4, just prior to the March 2011 accident:

Indicator	Unit 1	Unit 2	Unit 3	Unit 4
Number of fuel assemblies in reactor core	400	548	548	0
Number of fuel assemblies in reactor spent-fuel pool	392	615	566	1,535
Cesium-137 inventory in reactor core (Bq)	2.40E+17	3.49E+17	3.49E+17	0
Cesium-137 inventory in reactor pool (Bq)	2.21E+17	4.49E+17	3.96E+17	1.11E+18

(The core capacity of Unit 4 was 548 assemblies. The core of Unit 3 contained some MOX fuel assemblies at the time of the accident.)
(c) Assuming a total Cesium-137 release to atmosphere of 36 PBq, originating entirely from the reactor cores of Units 1, 2, and 3, which contained 940 PBq, the overall release fraction to atmosphere for Cesium-137 was 36/940 = 0.038 = 3.8 percent.

Table V-2
Estimated Human Dose Commitment from the Chernobyl Release of Radioactive Material to Atmosphere in 1986

Region	50-Year Collective Dose Commitment (person-Gy)	50-Year Average Individual Dose Commitment (mGy)
USSR (European)	4.7E+05	6.1E+00
USSR (Asian)	1.1E+05	Not available
Europe (non-USSR)	5.8E+05	1.2E+00
Asia (non-USSR)	2.7E+04	1.4E-02
USA	1.1E+03	4.6E-03
Northern Hemisphere Total	1.2E+06	Not available

Notes:
(a) These estimated doses are whole-body doses, from: DOE, 1987, Table 5.16, "preferred estimate".
(b) Most of the dose is attributable to Cesium-137 (see: DOE, 1987, page x).
(c) Estimates for non-USSR countries show that, on average, about 50% of the collective dose is attributable to external exposure, and about 50% is attributable to ingestion (see: DOE, 1987, Table 5.14). Uncertainty in these estimates is greater for ingestion than for external exposure.
(d) In this instance, 1 Gy is equivalent to 1 Sv.

Table V-3
Insurance Premiums Paid by Ontario Power Generation (OPG) for Nuclear Liability and Terrorism Coverage of the Darlington Station, 2005-2012

Period	Premium for Period ($)
2012	753,680
2011	749,654
2010	734,585
2009	728,262
2008	715,920
2007	708,934
2006	717,413
2005	714,373
Total, 2005-2012	5,822,821
Average Year, 2005-2012	727,853

Notes:
(a) Premium data were obtained from copies of annual invoices from Marsh Canada Limited to OPG. These copies were provided by OPG to Shawn-Patrick Stensil of Greenpeace Canada in February 2013, pursuant to a request by Stensil under the Freedom of Information and Protection of Privacy Act.
(b) Marsh Canada received the premium payments on behalf of the Nuclear Insurance Association of Canada (NIAC) and other insurance pools, which may have included British Nuclear Insurers and American Nuclear Insurers.
(c) In addition to paying the amounts shown to Marsh Canada, OPG also paid an 8% sales tax on each amount to the province of Ontario.
(d) The components of the total premium (i.e., nuclear liability, and terrorism) are available, for the years shown, only for 2005. In that year, the terrorism premium was $88,086 (12.3% of the total premium) and the nuclear liability premium was $626,287 (87.7% of the total premium).
(e) Prior to 2005, a combined premium payment was made for the Darlington and Pickering stations and, in earlier years, for the Bruce station as well.

Table V-4
Accident-Probability Implications of Insurance Premiums Paid by OPG for Coverage Associated with Operation of the Darlington Station

Liability Limit: Coverage A, Accidents	Net Premium to Cover Stated Liability (per RY)	Implied Probability of Event (per RY)
$75 million	$127,000	1.69E-03
$650 million	$508,000 to $762,000	7.82E-04 to 1.17E-03
$1,000 million	$635,000 to $1,016,000	6.35E-04 to 1.02E-03

Notes:
(a) Table V-3 shows gross, pre-tax insurance premiums paid by OPG for nuclear liability and terrorism coverage of the 4-unit Darlington station, over the period 2005-2012. The annual average gross premium for the station during that period was $727,853. In 2005, the terrorism premium accounted for 12.3% of the gross premium. Here, it is assumed that 30% of the gross premium is allocated to: (i) terrorism premium; (ii) administration; (iii) contingency; (iv) reinsurance premium paid to the Canadian government; and (v) profit. Thus, 70% of the gross premium is assumed here to be the net premium that supports offsite Coverage A (i.e., legal liability for bodily injury or property damage) through the private insurers in the NIAC pool, for an accident not involving a malevolent act. Throughout the period 2005-2012 and currently, the limit on that liability is $75 million. Thus, the net premium per RY for a $75 million maximum liability = $727,853 x 0.7 x 0.25 = $127,000 per RY.
(b) Dermot Murphy of NIAC has said that increasing the liability limit from $75 million to $650 million would require a premium increase by a factor of approximately 4 to 6, while a limit of $1,000 million would require a premium increase by a factor of approximately 5 to 8. (See: Murphy, 2009.) These factors are applied in the second column of the table.
(c) The "implied probability of event", in the third column, is calculated by dividing the amount in the second column by the amount in the first column, for each row. This implied probability represents NIAC's assessment of the probability of a claim up to the liability limit.
(d) As indicated in note (a), above, the "implied probability of event" that is calculated here applies to an accident in which offsite damage (i.e., bodily injury or property damage) arises from a release of radioactive material at Darlington. The calculation shown here does not apply to a release caused by a malevolent act.

Table VI-1
Potential Sabotage Events at a Spent-Fuel Storage Pool, as Postulated in NRC's August 1979 GEIS on Handling and Storage of Spent LWR Fuel

Event Designator	General Description of Event	Additional Details
Mode 1	• Between 1 and 1,000 fuel assemblies undergo extensive damage by high-explosive charges detonated under water • Adversaries commandeer the central control room and hold it for approx. 0.5 hr to prevent the ventilation fans from being turned off	• One adversary can carry 3 charges, each of which can damage 4 fuel assemblies • Damage to 1,000 assemblies (i.e., by 83 adversaries) is a "worst-case bounding estimate"
Mode 2	• Identical to Mode 1 except that, in addition, an adversary enters the ventilation building and removes or ruptures the HEPA filters	
Mode 3	• Identical to Mode 1 within the pool building except that, in addition, adversaries breach two opposite walls of the building by explosives or other means	• Adversaries enter the central control room or ventilation building and turn off or disable the ventilation fans
Mode 4	• Identical to Mode 1 except that, in addition, adversaries use an additional explosive charge or other means to breach the pool liner and 1.5 m-thick concrete floor of the pool	

Notes:
(a) Information in this table is from Appendix J of: NRC, 1979.
(b) The postulated fuel damage ruptures the cladding of each rod in an affected fuel assembly, releasing "contained gases" (gap activity) to the pool water, whereupon the released gases bubble to the water surface and enter the air volume above that surface.

Table VI-2
Potential Types of Attack on a Reactor or Spent-Fuel Storage Facility, Leading to Atmospheric Release of Radioactive Material

Type of Event	Facility Behavior	Some Relevant Instruments and Modes of Attack	Characteristics of Atmospheric Release
Type 1: Vaporization or Pulverization	• All or part of facility is vaporized or pulverized	• Facility is within the fireball of a nuclear-weapon explosion	• Radioactive material in facility is lofted into the atmosphere and amplifies fallout from nuc. explosion
Type 2: Rupture and Dispersal (Large)	• Facility structures are broken open • Fuel is dislodged from facility and broken apart • Some ignition of zircaloy fuel cladding may occur, typically without sustained combustion	• Aerial bombing • Artillery, rockets, etc. • Effects of blast etc. outside the fireball of a nuclear-weapon explosion	• Solid pieces of various sizes are scattered in vicinity • Gases and small particles form an aerial plume that travels downwind • Some release of volatile species (esp. Cesium-137) if zirc. combustion occurs
Type 3: Rupture and Dispersal (Small)	• Facility structures are penetrated but retain basic shape • Fuel may be damaged but most rods retain basic shape • Damage to cooling systems could lead to zirc. combustion	• Vehicle bomb • Impact by commercial aircraft • Perforation by shaped charge	• Scattering and plume formation as in Type 2 event, but involving smaller amounts of material • Substantial release of volatile species if zirc. combustion occurs
Type 4: Precise, Informed Targeting	• Facility structures are penetrated, creating a release pathway • Zirc. combustion is initiated indirectly by damage to cooling systems, or by direct ignition	• Missiles (military or improvised) with tandem warheads • Close-up use of attack instruments (e.g., shaped charge, incendiary, thermic lance)	• Scattering and plume formation as in Type 3 event • Substantial release of volatile species, potentially exceeding amount in Type 3 release

Table VI-3
Some Potential Modes and Instruments of Attack on a Nuclear Power Plant

Attack Mode/Instrument	Characteristics	Present Defenses at US Plants
Commando-style attack	• Could involve heavy weapons and sophisticated tactics • Successful attack would require substantial planning and resources	Alarms, fences, and armed guards, with offsite backup
Land-vehicle bomb	• Readily obtainable • Highly destructive if detonated at target	Vehicle barriers at entry points to Protected Area
Small guided missile (anti-tank, etc.)	• Readily obtainable • Highly destructive at point of impact	None if missile launched from offsite
Commercial aircraft	• More difficult to obtain than pre-9/11 • Can destroy larger, softer targets	None
Explosive-laden smaller aircraft	• Readily obtainable • Can destroy smaller, harder targets	None
10-kilotonne nuclear weapon	• Difficult to obtain • Assured destruction if detonated at target	None

Notes:
(a) This table is adapted from: Thompson, 2007, Table 7-4. Further citations are provided in that table and its supporting narrative. For additional, supporting information of more recent vintage, see: Ahearne et al, 2012, Chapter 5.
(b) Defenses at nuclear power plants around the world are typically no more robust than at US plants.

Table VI-4
The Shaped Charge as a Potential Instrument of Attack

Category of Information	Selected Information in Category
General information	• Shaped charges have many civilian and military applications, and have been used for decades • Applications include human-carried demolition charges or warheads for anti-tank missiles • Construction and use does not require assistance from a government or access to classified information
Use in World War II	• The German MISTEL, designed to be carried in the nose of an un-manned bomber aircraft, is the largest known shaped charge • Japan used a smaller version of this device, the SAKURA bomb, for kamikaze attacks against US warships
A large, contemporary device	• Developed by a US government laboratory for mounting in the nose of a cruise missile • Described in detail in an unclassified, published report (citation is voluntarily withheld here) • Purpose is to penetrate large thicknesses of rock or concrete as the first stage of a "tandem" warhead • Configuration is a cylinder with a diameter of 71 cm and a length of 72 cm • When tested in November 2002, created a hole of 25 cm diameter in tuff rock to a depth of 5.9 m • Device has a mass of 410 kg; would be within the payload capacity of many general-aviation aircraft
A potential delivery vehicle	• A Beechcraft King Air 90 general-aviation aircraft can carry a payload of up to 990 kg at a speed of up to 460 km/hr • The price of a used, operational King Air 90 in the USA can be as low as $0.4 million

Source:
This table is adapted from Table 7-6 of: Thompson, 2009.

Table VI-5
Performance of US Army Shaped Charges, M3 and M2A3

Target Material	Indicator	Value for Stated Type of Shaped Charge	
		Type: M3	**Type: M2A3**
Reinforced concrete	Maximum wall thickness that can be perforated	150 cm	90 cm
	Depth of penetration in thick walls	150 cm	75 cm
	Diameter of hole	• 13 cm at entrance • 5 cm minimum	• 9 cm at entrance • 5 cm minimum
	Depth of hole with second charge placed over first hole	210 cm	110 cm
Armor plate	Perforation	At least 50 cm	30 cm
	Average diameter of hole	6 cm	4 cm

Notes:
(a) Data are from US Army Field Manual FM 5-25: Army, 1967, pp 13-15 and page 100.
(b) The M2A3 charge has a mass of 5 kg, a maximum diameter of 18 cm, and a total length of 38 cm including the standoff ring.
(c) The M3 charge has a mass of 14 kg, a maximum diameter of 23 cm, a charge length of 39 cm, and a standoff pedestal 38 cm long.

Table X-1
IRSN Estimates of Costs Arising from a "Massive" Atmospheric Release of Radioactive Material from a French 900 MWe PWR

Cost Category	Estimated Cost (billion Euro)		
	Base Case	**Low Case**	**High Case**
On-site costs	10	5	15
Off-site radiological costs	106	38	281
Contaminated territories	393	130	4,875
Image costs	130	75	176
Costs related to power production	90	30	360
Indirect effects	31	9	50
Total (rounded)	760	290	5,760

Notes:
(a) Data are from: IRSN, 2007, Tables A4.4.4 and A4.4.5.
(b) The assumed release would be from the Dampierre nuclear generating station, which has four 900 MWe PWR units and is located on the Loire River south of Paris. The release is described (IRSN, 2007, page 37) as follows: "Par simplification, le scenario considere la dispersion en deux heures d'un tiers de l'inventaire du coeur, ce qui est le bon ordre de grandeur pour le cesium, contributeur preponderant des couts." Thus, the release apparently includes one-third of one reactor's core inventory of Cesium isotopes, which are said to be the major contributors to the estimated costs. The many radio-isotopes in a reactor core have widely varying volatilities and chemical properties. Thus, their release fractions will vary. The IRSN text, quoted above, does not address this matter.
(c) An estimate of the core inventory of Cs-137 in a 900 MWe PWR can be made by assuming: (i) total fuel mass = 75 Mg HM; (ii) average fuel burnup at discharge = 50 GWt-days per Mg HM; (iii) Cs-137 yield = 1.17E+14 Bq per GWt-day of fission; and (iv) one-third of the core is discharged at each refueling, and a refueling outage is imminent, so that average fuel burnup in the core = (2/3) x discharge burnup. With those assumptions, the core inventory of Cs-137 = 1.17E+14 x 75 x (2/3) x 50 = 2.9E+17 Bq. One-third of that inventory = 9.7E+16 Bq = 97 PBq.
(d) IRSN used the COSYMA code to estimate plume behavior and radiological impacts for 144 weather conditions. The "base case" estimates shown in the table are said to reflect median results. The "low case" (scenario favorable) and "high case" (scenario defavorable) estimates reflect non-median results and, apparently, changes in analytic assumptions.

Table XI-1
Selected Approaches to Protecting Critical Infrastructure in the USA From Attack by Non-State Actors, and Some Strengths and Weaknesses of these Approaches

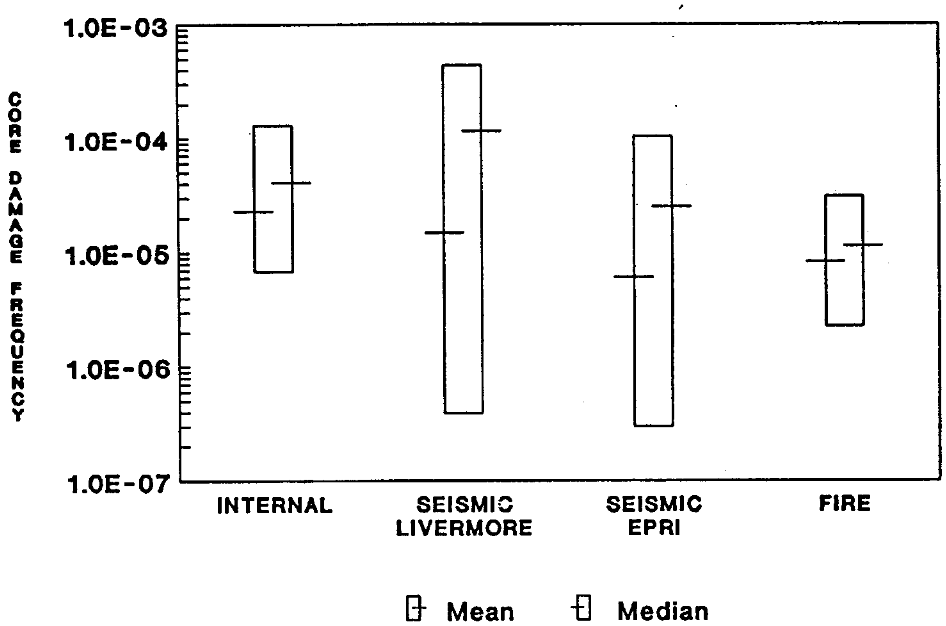
Approach	Strengths	Weaknesses
Approach #1: Offensive military operations internationally	• Could deter or prevent governments from supporting non-State actors hostile to the USA	• Could promote growth of non-State groups hostile to the USA, and build sympathy for these groups in foreign populations • Could be costly in terms of lives, money, etc.
Approach #2: International police cooperation within a legal framework	• Could identify and intercept potential attackers	• Implementation could be slow and/or incomplete • Requires ongoing international cooperation
Approach #3: Surveillance and control of the domestic population	• Could identify and intercept potential attackers	• Could destroy civil liberties, leading to political, social, and economic decline of the USA
Approach #4: Secrecy about design and operation of infrastructure facilities	• Could prevent attackers from identifying points of vulnerability	• Could suppress a true understanding of risk • Could contribute to political, social, and economic decline
Approach #5: Active defense of infrastructure facilities (by use of guards, guns, gates, etc.)	• Could stop attackers before they reach the target	• Requires ongoing expenditure & vigilance • May require military involvement
Approach #6: Robust and inherently-safer design of infrastructure facilities (**Note:** This approach could be part of a "protective deterrence" strategy for the USA.)	• Could allow target to survive attack without damage, thus contributing to protective deterrence • Could substitute for other protective approaches, avoiding their costs and adverse impacts • Could reduce risks from accidents & natural hazards	• Could involve higher capital costs

Notes:
(a) These approaches could be used in parallel, with differing weightings.
(b) Approach #6 would contribute to "protective deterrence", which is distinct from "counter-attack deterrence".

Table XII-1
Selected Options to Reduce the Risk of a Pool Fire at a PWR or BWR Plant

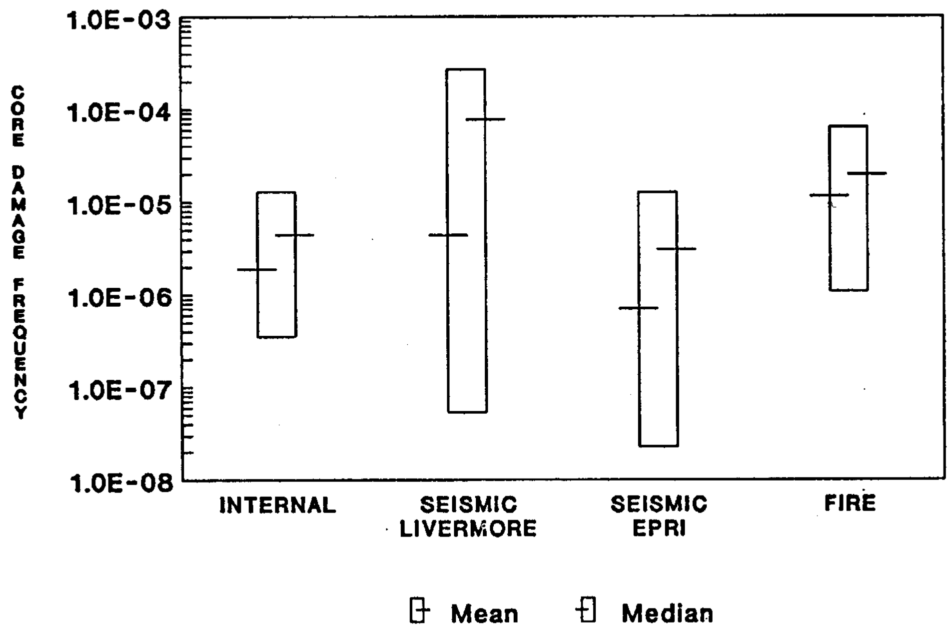
Option	Passive or Active?	Does Option Address Fire Scenarios Arising From: Attack?	Does Option Address Fire Scenarios Arising From: Other Events?	Comments
Re-equip pool with low-density, open-frame racks	Passive	Yes	Yes	• Would substantially reduce pool inventory of radioactive material • Would prevent auto-ignition of fuel in almost all cases
Install emergency water sprays above pool	Active	Yes	Yes	• Spray system must be highly robust • Spraying water on overheated fuel could feed Zr-steam reaction • Pool overflow could disable reactor safety systems (especially at BWRs with Mark I and II containments)
Mix hotter (younger) and colder (older) fuel in pool	Passive	Yes	Yes	• Could delay or prevent auto-ignition in some cases • Would be ineffective if debris or residual water blocks air flow • Could promote fire propagation to older fuel
Minimize movement of spent-fuel cask over pool	Active	No (Most cases)	Yes	• Could conflict with adoption of low-density, open-frame racks
Deploy air-defense system (e.g., Sentinel and Phalanx) at site	Active	Yes	No	• Implementation would require presence of military personnel at site
Develop enhanced onsite capability for damage control	Active	Yes	Yes	• Would require new equipment, staff and training • Personnel must function in extreme environments

Figure V-1
Core Damage Frequency for Accidents at a Surry PWR Nuclear Power Plant, as Estimated in the NRC Study NUREG-1150



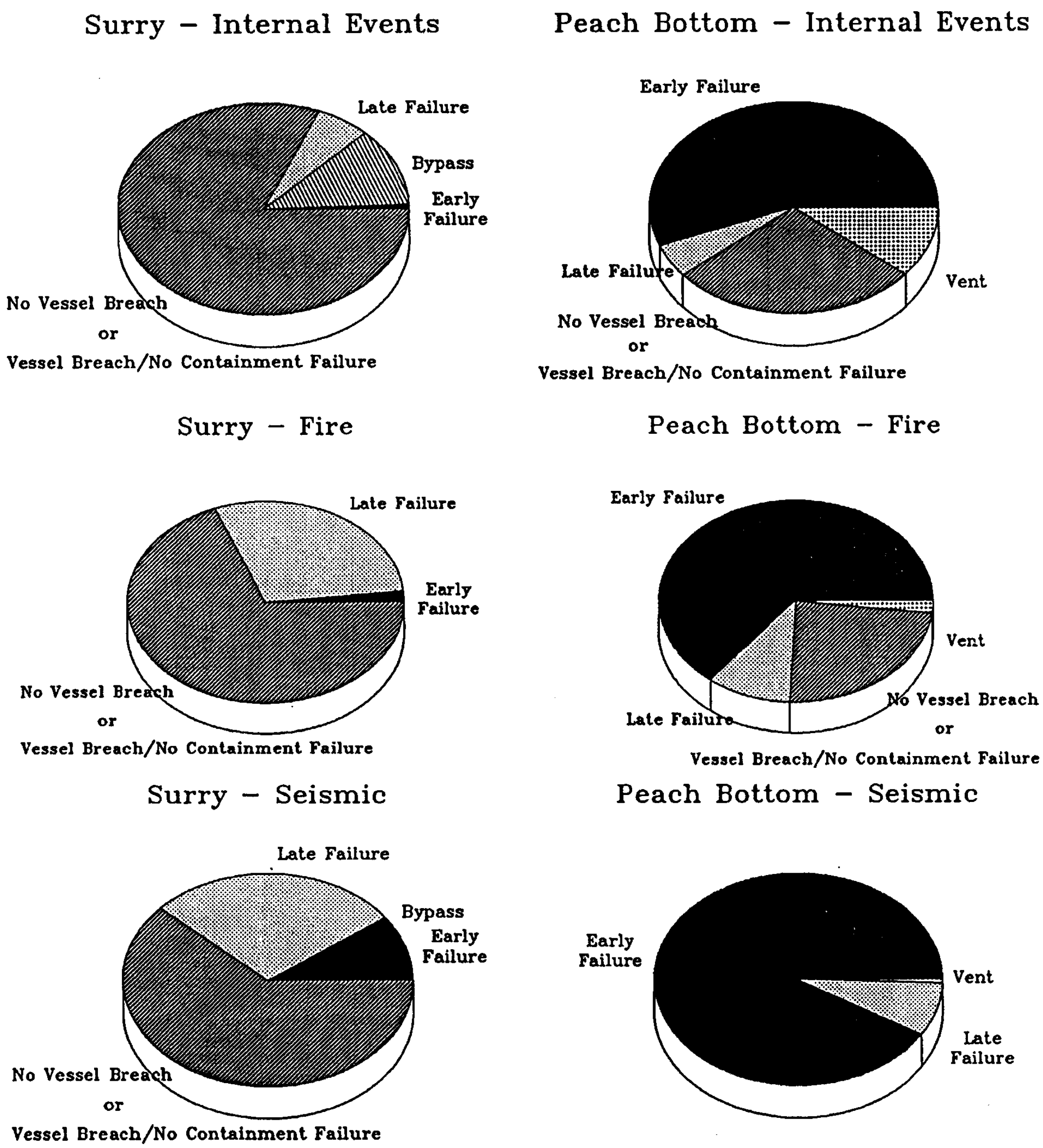
Notes:
(a) This figure is adapted from Figure 8.7 of: NRC, 1990.
(b) The bars range from the 5th percentile (lower bound) to the 95th percentile (upper bound) of the estimated core damage frequency (CDF). CDF values shown are per reactor-year (RY).
(c) "Internal" initiating events encompass equipment failure, human error, etc. "External" initiating events encompass earthquake, flood, strong wind, fire, etc.
(d) Two estimates are shown for the CDF from earthquakes (seismic effects). One estimate derives from seismic predictions done at Lawrence Livermore National Laboratory (Livermore), the other from predictions done at the Electric Power Research Institute (EPRI).
(e) CDFs were not estimated for external initiating events other than earthquake and fire.
(f) Malevolent acts were not considered.

Figure V-2
Core Damage Frequency for Accidents at a Peach Bottom BWR Nuclear Power Plant, as Estimated in the NRC Study NUREG-1150



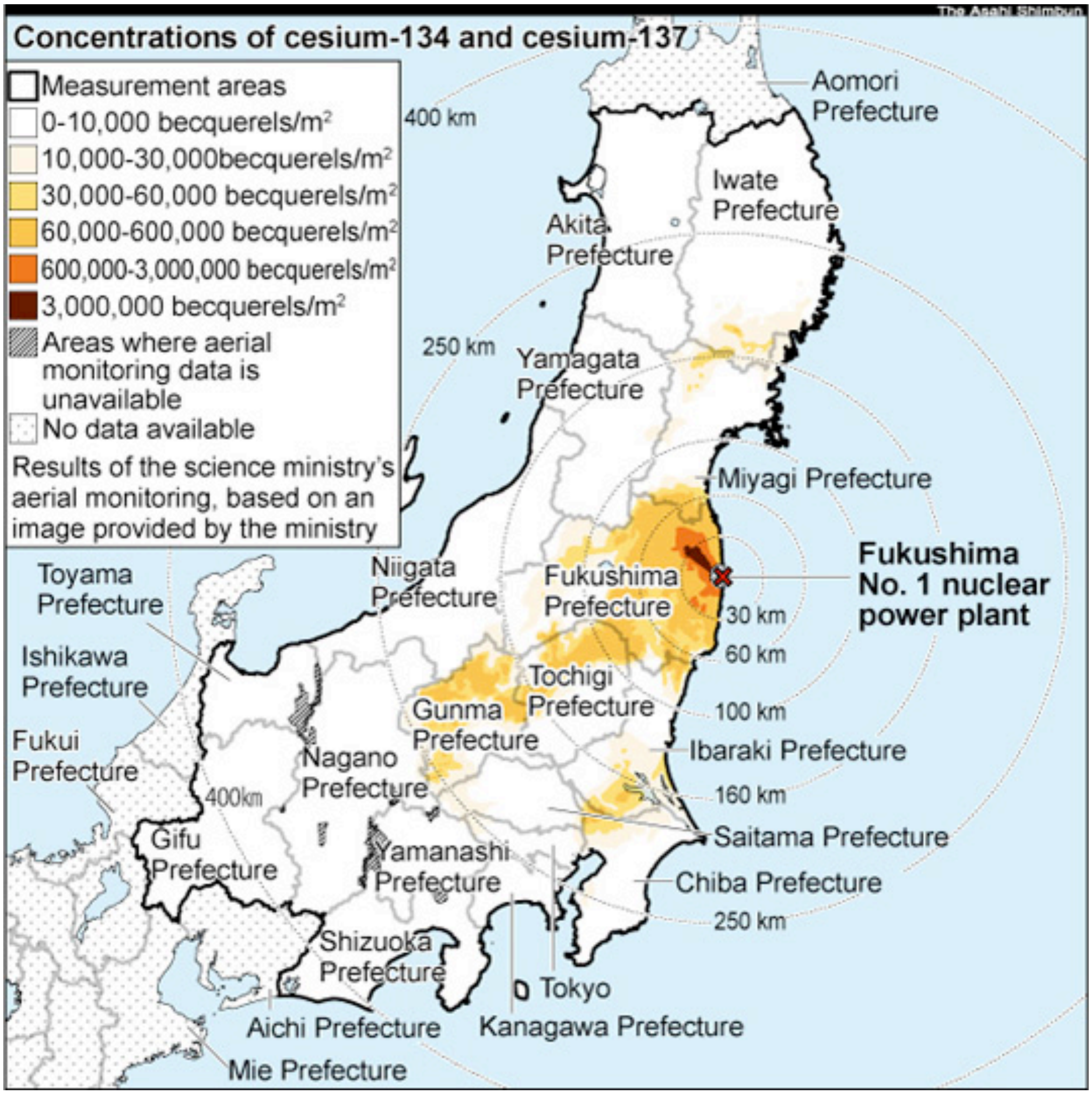
Notes:
(a) This figure is adapted from Figure 8.8 of: NRC, 1990.
(b) Notes (b) through (f) of Figure V-1 also apply here.

Figure V-3
Conditional Probability of Containment Failure Following a Core-Damage Accident at a Surry PWR or Peach Bottom BWR Nuclear Power Plant, as Estimated in the NRC Study NUREG-1150



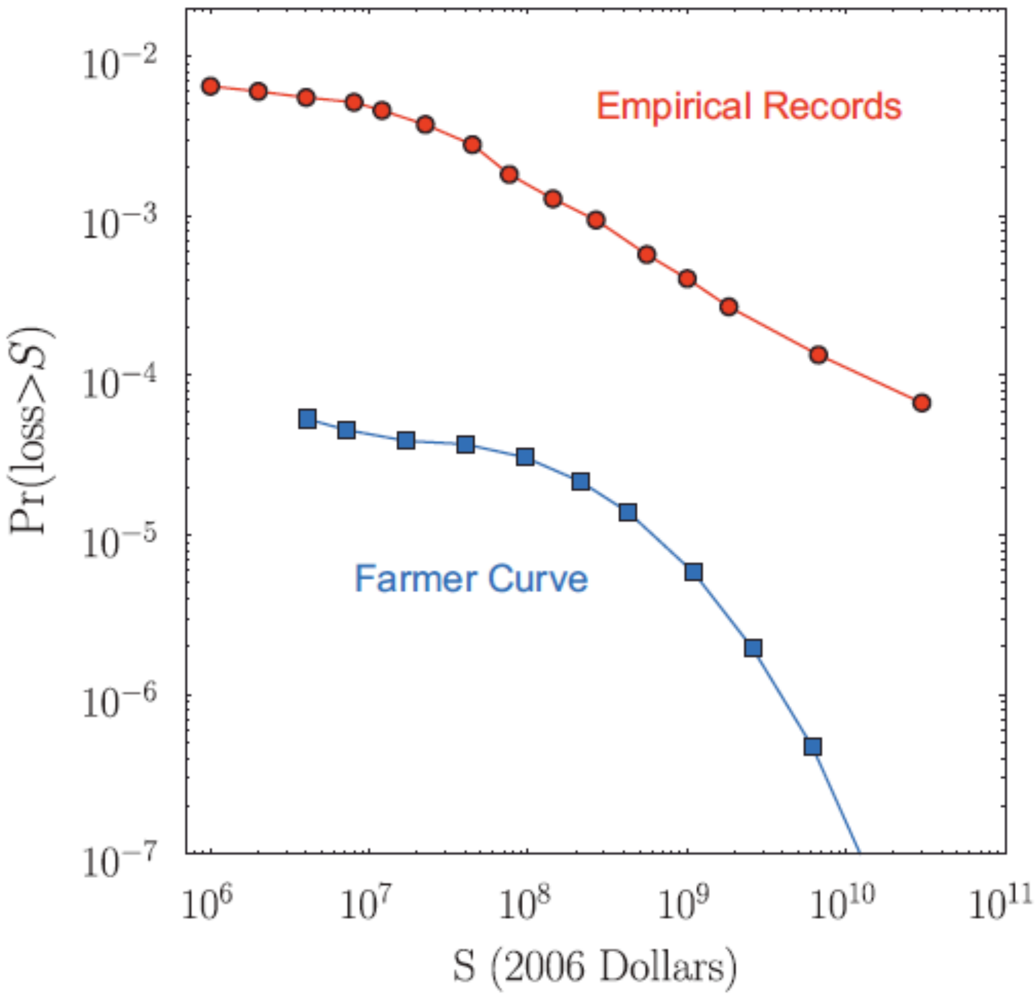
Note:
This figure is adapted from Figure 9.5 of: NRC, 1990.

Figure V-4
Contamination of Land in Japan by Radioactive Cesium Released to Atmosphere During the Fukushima #1 Accident of 2011



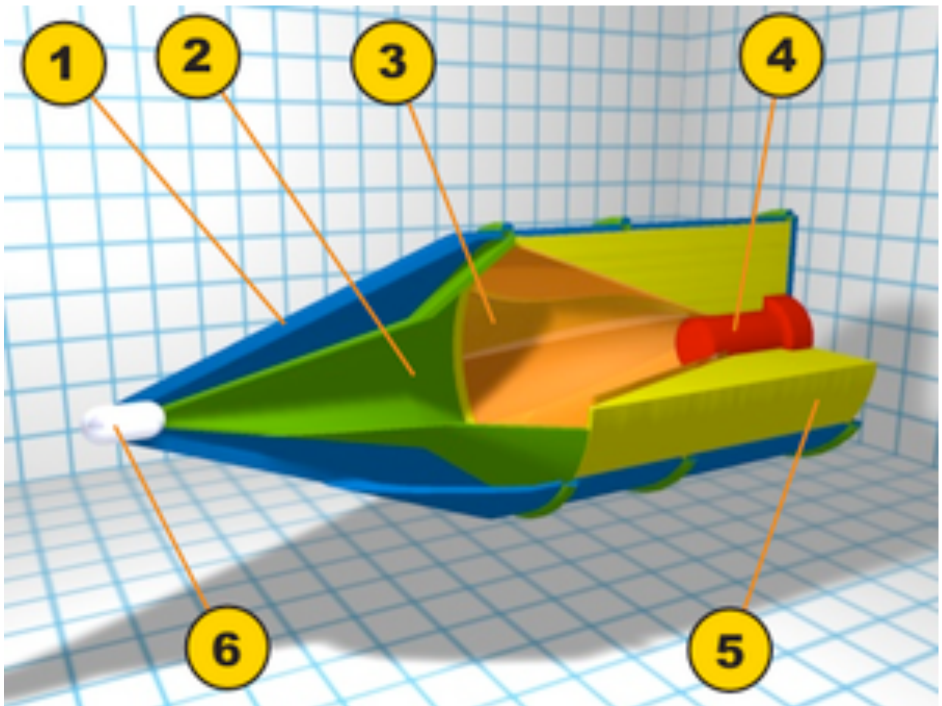
Source:
Asahi Shimbun, 2011.

Figure V-5
Probability Distribution of Monetized Losses from Nuclear-Facility Incidents: Sornette et al's Comparison of Empirical Data with PRA Estimates



Notes:
(a) This figure is a reproduction of Figure 1 from: Sornette et al, 2013.
(b) The curves shown are complementary cumulative distribution functions.
(c) The vertical axis is probability per reactor-year (or facility-year).
(d) The "Farmer Curve" is based on findings from NRC's Reactor Safety Study, which was the first reactor PRA. In this curve, monetized losses are associated with radiological impacts.
(e) The "Empirical Records" curve is based on Sovacool's compilation of data on 99 incidents at nuclear facilities. In this curve, monetized losses may, or may not, be associated with radiological impacts.

Figure VI-1
Schematic View of a Generic Shaped-Charge Warhead



Notes:
(a) Figure accessed on 4 March 2012 from: http://en.wikipedia.org/wiki/Shaped_charge
(b) Key:

Item 1: Aerodynamic cover
Item 2: Empty cavity
Item 3: Conical liner (typically made of ductile metal)
Item 4: Detonator
Item 5: Explosive
Item 6: Piezo-electric trigger

(c) Upon detonation, a portion of the conical liner would be formed into a high-velocity jet directed toward the target. The remainder of the liner would form a slower-moving slug of material.

Figure VI-2
MISTEL System for Aircraft Delivery of a Shaped Charge, World War II

Notes:
(a) Photograph accessed on 5 March 2012 from:
http://www.historyofwar.org/Pictures/pictures_Ju_88_mistel.html
(b) A shaped-charge warhead can be seen at the nose of the lower (converted bomber) aircraft, replacing the cockpit. The aerodynamic cover in front of the warhead would have a contact fuse at its tip, to detonate the shaped charge at the appropriate standoff distance.
(c) A human pilot in the upper (fighter) aircraft would control the entire rig, and would point it toward the target. Then, the upper aircraft would separate and move away, and the lower aircraft would be guided to the target by an autopilot.

Figure VI-3
January 2008 Test of a Raytheon Shaped Charge, Intended as the Penetration (Precursor) Stage of a Tandem Warhead System

Before Test

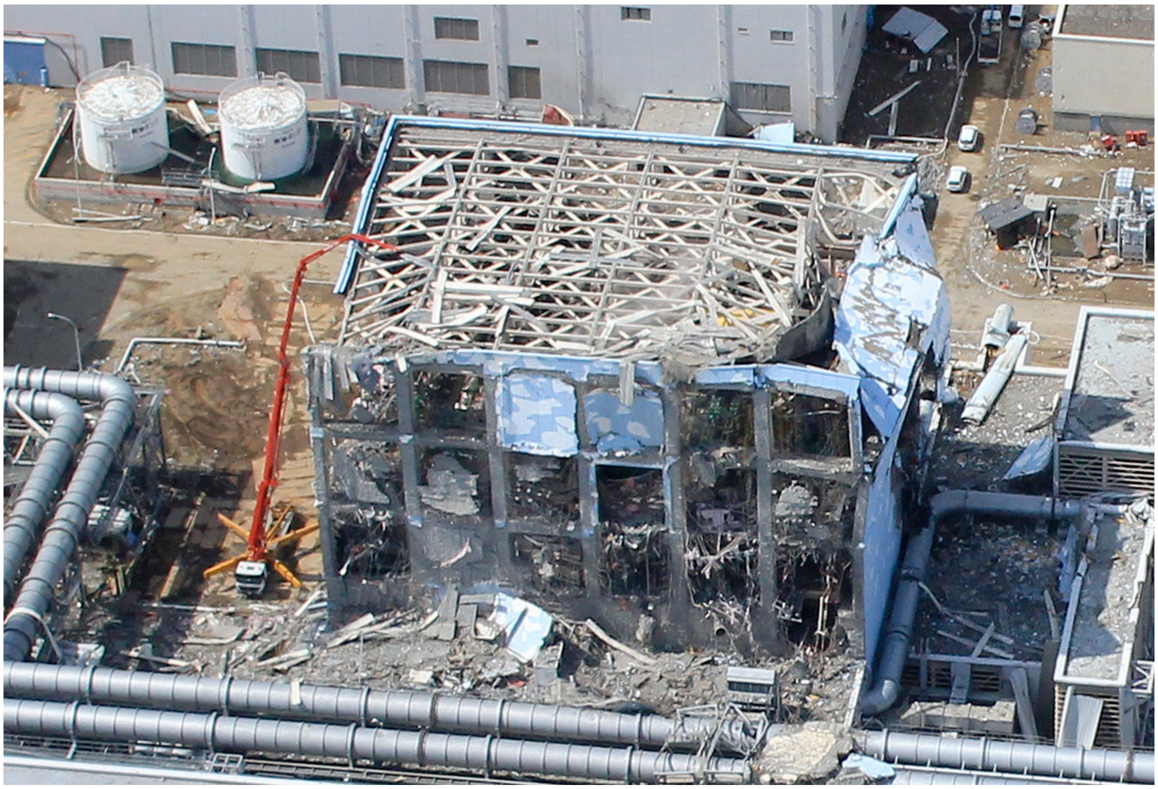
After Test (viewed from the attacked face)

Notes:
(a) These photographs are from: Raytheon, 2008. For additional, supporting information, see: Warwick, 2008.
(b) The shaped-charge jet penetrated about 5.9 m into a steel-reinforced concrete block with a thickness of 6.1 m. Although penetration was incomplete, the block was largely destroyed, as shown. Compressive strength of the concrete was 870 bar.
(c) The shaped charge had a diameter of 61 cm and contained 230 kg of high explosive. It was sized to fit inside the US Air Force's AGM-129 Advanced Cruise Missile.

Figure VI-4
Aftermath of a Small-Aircraft Suicide Attack on an Office Building in Austin, Texas, February 2010

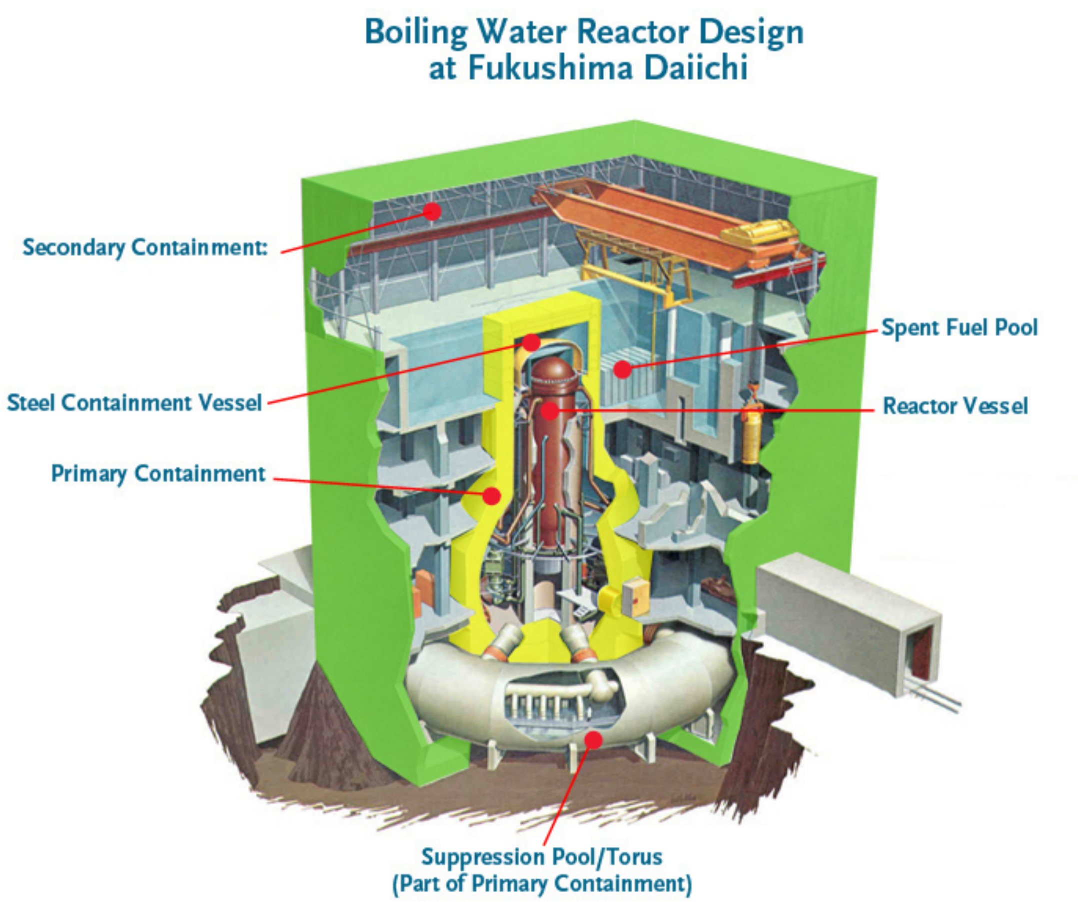
Notes:
(a) Photograph and information in these notes are from: Brick, 2010.
(b) A major tenant of the building was the Internal Revenue Service (IRS).
(c) The aircraft was a single-engine, fixed-wing Piper flown by its owner, Andrew Joseph Stack III, an Austin resident who worked as a computer engineer.
(d) A statement left by Mr Stack indicated that a dispute with the IRS had brought him to a point of suicidal rage.

Figure VIII-1
Unit 4 at the Fukushima #1 Site During the 2011 Accident



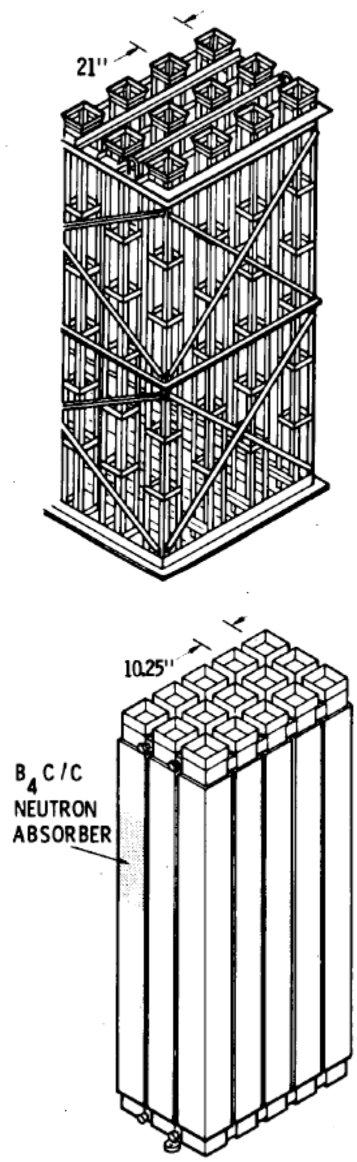
Source:
Accessed on 20 February 2012 from Ria Novosti at:
http://en.rian.ru/analysis/20110426/163701909.html; image by Reuters Air Photo Service.

Figure VIII-2
Schematic View of a BWR Reactor with a Mark I Containment, as Used at the Fukushima #1 Site and Elsewhere



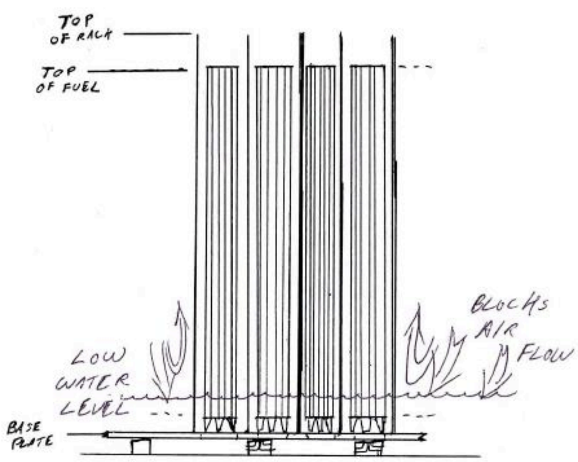
Notes:
(a) This figure accessed on 24 February 2012 from:
http://safetyfirst.nei.org/japan/background-on-fukushima-situation/
(b) All BWR reactors with Mark I containments have the same basic configuration. Details vary for specific reactors.

Figure X-1
PWR Spent Fuel Storage Racks: Low-Density and High-Density Designs



Notes:
(a) These drawings are from: Benjamin et al, 1979, page 18.
(b) The upper drawing shows a low-density, open-frame rack, and the lower drawing shows a high-density, closed-frame rack.

Figure X-2
An Argonne Analyst's Illustration of the Effect of Residual Water on Heat Transfer from Spent Fuel in a Partially Drained Pool Equipped with High-Density Racks



Water addition: adding water to the bottom of an empty spent fuel pool can damage an assembly with a heat rate of 7kw or less that has reached equilibrium in air! -- *The water can block the circulation of air and cause the fuel assembly to overheat. The heat removed by the low level of water is insufficient to cool the assembly.*

Notes:
(a) Figure and accompanying text are from: Braun, 2010.
(b) Braun considers, as a typical example, a fuel assembly that would generate 10 MWt in a reactor at full power. According to Braun, at a time point after reactor shutdown of $1.0\text{x}10^7$ sec (116 days), the assembly would produce 7.8 kW of decay heat.
(c) Braun goes on to discuss a related situation in which water level descends slowly from the top of the rack by boiling off due to decay heat. He says:

- "As the levels drop, steam from the boil-off will cool the uncovered parts of the fuel.
- At some point, the rising steam will be insufficient to cool the uncovered fuel and clad temperatures will rise until they reach the "ignition" point.
- Where is this level? Detailed calculations are needed. Experts suggest that it is somewhere between 20 and 80% of assembly height, possibly around the mid-point.
- When the water is at the bottom of the fuel, say about the 20% level, the steaming rate is probably insufficient to cool the rest of the assembly, and air circulation is not possible. So fuel assemblies that may be safe in air are likely to melt with a low water level.
- Detailed calculations are needed to address specific issues of geometry and heat transfer."

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Gordon R. Thompson, "The US Effort to Dispose of High-Level Radioactive Waste", *Energy and Environment*, Volume 19, Nos. 3+4, 2008, pp 391-412.

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Gordon R. Thompson, *Risk-Related Impacts from Continued Operation of the Indian Point Nuclear Power Plants* (Cambridge, Massachusetts: Institute for Resource and Security Studies, 28 November 2007).

(Thompson, 2005)
Gordon R. Thompson, *Reasonably Foreseeable Security Events: Potential threats to options for long-term management of UK radioactive waste* (Cambridge, Massachusetts: Institute for Resource and Security Studies, 2 November 2005).

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Gordon Thompson, *Robust Storage of Spent Nuclear Fuel: A Neglected Issue of Homeland Security* (Cambridge, Massachusetts: Institute for Resource and Security Studies, January 2003).

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APPENDIX C: List of Exhibits

Exhibit #1
Gordon R. Thompson, Declaration, "Recommendations for the US Nuclear Regulatory Commission's Consideration of Environmental Impacts of Long-Term, Temporary Storage of Spent Nuclear Fuel or Related High-Level Waste", 2 January 2013.

Exhibit #2
Andrew Barto and nine other authors, *Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a US Mark I Boiling Water Reactor, Draft Report* (Washington, DC: US Nuclear Regulatory Commission, June 2013).

Exhibit #3
Gordon R. Thompson, Declaration, "Comments on the US Nuclear Regulatory Commission's Draft Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a US Mark I Boiling Water Reactor", 1 August 2013.

Exhibit #4
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Exhibit #5
Gordon R. Thompson, *Environmental Impacts of Storing Spent Nuclear Fuel and High-Level Waste from Commercial Nuclear Reactors: A Critique of NRC's Waste Confidence Decision and Environmental Impact Determination* (Cambridge, Massachusetts: Institute for Resource and Security Studies, 6 February 2009).

Exhibit #6
Robert Alvarez, Jan Beyea, Klaus Janberg, Jungmin Kang, Ed Lyman, Allison Macfarlane, Gordon Thompson, and Frank von Hippel, "Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States", *Science and Global Security,* Volume 11, 2003, pp 1-51.

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Exhibit #8
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Exhibit #9
Gordon R. Thompson, *Reasonably Foreseeable Security Events: Potential threats to options for long-term management of UK radioactive waste* (Cambridge, Massachusetts: Institute for Resource and Security Studies, 2 November 2005).

Exhibit #10
Gordon R. Thompson, *Handbook to Support Assessment of Radiological Risk Arising from Management of Spent Nuclear Fuel* (Cambridge, Massachusetts: Institute for Resource and Security Studies, 31 January 2013).

Exhibit #11
Ludivine Pascucci-Cahen and Momal Patrick (IRSN), "Massive radiological releases profoundly differ from controlled releases", paper for presentation at the Eurosafe conference, Brussels, 5-6 November 2012.

Exhibit #12
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Exhibit #13
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Exhibit #14
Kristin Shrader-Frechette, "Technological Risk and Small Probabilities", *Journal of Business Ethics*, Volume 4, 1985, pp 431-445.

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Exhibit #16
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Exhibit #17
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Exhibit #19
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Exhibit #20
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Exhibit #21
Raymond Gallucci, ""What – Me Worry?" "Why So Serious?": A Personal View on the Fukushima Nuclear Reactor Accidents", *Risk Analysis*, Volume 32, Number 9, 2012, pp 1444-1450.

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Exhibit #26
Gordon R. Thompson, *Risk-Related Impacts from Continued Operation of the Indian Point Nuclear Power Plants* (Cambridge, Massachusetts: Institute for Resource and Security Studies, 28 November 2007).

Exhibit #27
Gordon Thompson, *Robust Storage of Spent Nuclear Fuel: A Neglected Issue of Homeland Security* (Cambridge, Massachusetts: Institute for Resource and Security Studies, January 2003).

Exhibit #28
Mark Holt and Anthony Andrews, *Nuclear Power Plant Security and Vulnerabilities* (Washington, DC: Congressional Research Service, 28 August 2012).

Exhibit #29
John F. Ahearne and eight other authors, with editing by Charles D. Ferguson and Frank A. Settle, *The Future of Nuclear Power in the United States* (Washington, DC: Federation of American Scientists, and Washington and Lee University, February 2012).

Exhibit #30
Anthony L. Honnellio and Stan Rydell, "Sabotage vulnerability of nuclear power plants", *International Journal of Nuclear Governance, Economy and Ecology*, Volume 1, Number 3, 2007, pp 312-321.

Exhibit #31
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Exhibit #32
Lenka Kollar and three other authors, *Safeguards Approaches for Very Long-Term Storage of Spent Nuclear Fuel* (Argonne, Illinois: Argonne National Laboratory, July 2013).

Exhibit #33
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Exhibit #34
Suzanne Schroer and Mohammad Modarres, "An event classification schema for evaluating site risk in a multi-unit nuclear power plant probabilistic risk assessment", *Reliability Engineering and System Safety*, Volume 117, 2003, pp 40-51.

Exhibit #35
Andrew Barto and nine other authors, *Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a US Mark I Boiling Water Reactor* (Washington, DC: US Nuclear Regulatory Commission, October 2013). This document is provided here with its cover memo: Mark A. Satorius, memo to NRC Commissioners, "SECY-13-0112: Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a US Mark I Boiling Water Reactor", 9 October 2013.

Exhibit #36
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E. D. Throm, *Regulatory Analysis for the Resolution of Generic Issue 82, "Beyond Design Basis Accidents in Spent Fuel Pools", NUREG-1353* (Washington, DC: US Nuclear Regulatory Commission, April 1989).

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US Nuclear Regulatory Commission Staff, "NRC Staff Response to Intervenor's Request for Admission of Late-Filed Environmental Contentions", Docket No. 50-400-LA, ASLBP No. 99-762-02-LA, 3 March 2000.

Exhibit #40
J. Sam Armijo (Chairman, NRC Advisory Committee on Reactor Safeguards), letter and enclosures to Ms. Diane Curran, Esq., 20 November 2013.

Exhibit #41
Dana A. Powers (Chairman, NRC Advisory Committee on Reactor Safeguards), letter to Richard A. Meserve (Chairman, NRC), "Subject: Draft Final Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants", 13 April 2000.

Exhibit #42
Farouk Eltawila (Office of Nuclear Regulatory Research, NRC), memorandum to Gary Holahan (Office of Nuclear Reactor Regulation, NRC), "RES Review of and Response to ACRS Comments on Spent Fuel Cladding Behavior Following a Loss-of-Water Accident During Pool Storage", 15 May 2001. Attached to this memorandum is an undated draft report: H. M. Chung (Argonne) and S. Basu (NRC), "Spent Fuel Cladding Behavior Following Loss-of-Water Accident During Pool Storage".

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K. Natesan and W.K. Soppet, *Air Oxidation Kinetics for Zr-Based Alloys, NUREG/CR-6846* (Washington, DC: NRC, June 2004).

Exhibit #44
E.R. Lindgren and S.G. Durbin, *Characterization of Thermal-Hydraulic and Ignition Phenomena in Prototypic, Full-Length Boiling Water Reactor Spent Fuel Assemblies After a Postulated Complete Loss-of-Coolant Accident, NUREG/CR-7143* (Washington, DC: NRC, March 2013).

Exhibit #45
Peter Windberg and Zoltan Hozer, "CODEX-CT-1 and CT-2 Integral Tests: Two Possible Scenarios of the Paks-2 Incident", paper presented at the international conference: Nuclear Energy for New Europe 2007, Slovenia, 10-13 September 2007.

Exhibit #46
Jan Beyea, Ed Lyman, and Frank von Hippel, "Damages from a Major Release of Cs-137 into the Atmosphere of the United States", *Science and Global Security*, Volume 12, 2004, pp 125-136.

Exhibit #47
Institut de Radioprotection et de Surete Nucleaire, *Examen de la methode d'analyse cout-benefice pour la surete, Rapport DSR No. 157, Annex du Chapitre 4, Evaluation Economique des Consequences d'Accidents Graves et Enseignements* (France: IRSN, 5 July 2007).

Exhibit #48
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Exhibit #49
Bruno Thomauske, "Realization of the German Concept for Interim Storage of Spent Nuclear Fuel – Current Situation and Prospects", paper presented at the WM'03 Conference, Tucson, Arizona, 23-27 February 2003.

APPENDIX D: Curriculum Vitae

Curriculum Vitae for Gordon R. Thompson
June 2011

Professional expertise

• Technical and policy analysis in the fields of energy, environment, sustainable development, human security, and international security.

Current appointments

• Executive director, Institute for Resource & Security Studies (IRSS), Cambridge, Massachusetts (since 1984).
• Senior research scientist, George Perkins Marsh Institute, Clark University, Worcester, Massachusetts (since 2002).

Education

• D.Phil., applied mathematics, Oxford University (Balliol College), 1973.
• B.E., mechanical engineering, Univ. of New South Wales, Sydney, Australia, 1967.
• B.Sc., mathematics & physics, Univ. of New South Wales, 1966.

Project sponsors and tasks (selected)

• Nautilus Institute and RMIT University, 2009-2011: conduct policy and technical analysis on transfer of nuclear power plant technology to consumer countries.
• Attorney General of Massachusetts, 2006-2008 and 2011: analyze risk issues and prepare expert testimony associated with the Pilgrim and Vermont Yankee nuclear power plants; current analysis addresses lessons learned from the Fukushima accident of 2011.
• CharityHelp International and other sponsors, 2009-2011: co-convene the Connectivity to Enhance Global Human Security initiative.
• US Institute of Peace and other sponsors, 2005-2011: co-convene the Working Group on US-Iran Health Science Cooperation.
• Texans for a Sound Energy Policy, 2009: review of the US Nuclear Regulatory Commission's Draft Waste Confidence Decision.
• Green Energy Coalition, Pembina Institute, and Ontario Sustainable Energy Association, 2008: prepared testimony for submission to the Ontario Energy Board.
• Greenpeace Canada, 2007-2011: conduct technical and policy analysis on risk and sustainability issues related to the use of nuclear energy.
• World Health Organization, 2006-2007: conducted policy analysis on the potential for "health-bridge" programs to improve cooperation within and between nations.

• Sierra Club of Canada, 2006-2007: prepared a strategy for development of planning and public-engagement tools to facilitate action on climate change.
• Mothers for Peace, California, 2002-2009: analyzed risk issues and prepared expert testimony associated with the Diablo Canyon nuclear power plants.
• Riverkeeper, New York, 2007-2008: analyzed risk issues and prepared expert testimony associated with the Indian Point nuclear power plants.
• Minnesota Center for Environmental Advocacy, and Minnesotans for an Energy Efficient Economy, 2005-2006: conducted technical analysis and provided expert testimony regarding the Monticello nuclear power plant.
• California Energy Commission, 2005: conducted technical analysis and participated in an expert workshop regarding safety and security of commercial nuclear facilities.
• Committee on Radioactive Waste Management (a committee appointed by the UK government), 2005: provided expert advice and technical analysis on long-term safety and security of radioactive waste management.
• Legal Resources Centre, Cape Town, South Africa, 2004-2007: conducted technical analysis regarding the proposed South African pebble bed modular nuclear reactor.
• STAR Foundation, New York, 2002-2004: reviewed planning and actions for decommissioning of research reactors at Brookhaven National Laboratory.
• Attorney General of Utah, 2003: conducted technical analysis and provided expert testimony regarding a proposed national storage facility for spent nuclear fuel.
• Citizens Awareness Network, Massachusetts, 2002-2003: conducted analysis on robust storage of spent nuclear fuel.
• Tides Center, California, 2002-2004: conducted analysis for the Santa Susana Field Laboratory (SSFL) Advisory Panel regarding the history of releases of hazardous material from the SSFL.
• Orange County, North Carolina, 1999-2002: assessed risk issues associated with the Harris nuclear power plant, identified risk-reduction options, and prepared expert testimony.
• William and Flora Hewlett Foundation and other sponsors, 1999-2009: performed research and project development for conflict-management projects, through IRSS's International Conflict Management Program.
• STAR Foundation, New York, 2000-2001: assessed risk issues associated with the Millstone nuclear power plant, identified risk-reduction options, and prepared expert testimony.
• Massachusetts Water Resources Authority, 2000: evaluated risks associated with water supply and wastewater systems that serve greater Boston.
• Canadian Senate, Energy & Environment Committee, 2000: reviewed risk issues associated with the Pickering Nuclear Generating Station.
• Greenpeace International, Amsterdam, 2000: reviewed impacts associated with the La Hague nuclear complex in France.
• Government of Ireland, 1998-2001: developed framework for assessment of impacts and alternative options associated with the Sellafield nuclear complex in the UK.
• Clark University, Worcester, Massachusetts, 1998-1999: participated in confidential review of outcomes of a major foundation's grants related to climate change.

• UN High Commissioner for Refugees, 1998: co-developed a strategy for conflict management in the CIS region.
• General Council of County Councils (Ireland), W. Alton Jones Foundation (USA), and Nuclear Free Local Authorities (UK), 1996-2000: assessed environmental and economic issues of nuclear fuel reprocessing in the UK; assessed alternative options.
• Environmental School, Clark University, Worcester, Massachusetts, 1996: session leader at the Summer Institute, "Local Perspectives on a Global Environment".
• Greenpeace Germany, Hamburg, 1995-1996: performed a study on war, terrorism and nuclear power plants.
• HKH Foundation, New York, and Winston Foundation for World Peace, Washington, DC, 1994-1996: studies and workshops on preventive action and its role in US national security planning.
• Carnegie Corporation of New York, Winston Foundation for World Peace, Washington, DC, and others, 1995: collaboration with the Organization for Security and Cooperation in Europe to facilitate improved coordination of activities and exchange of knowledge in the field of conflict management.
• World Bank, 1993-1994: a study on management of data describing the performance of projects funded by the Global Environment Facility (joint project of IRSS and Clark University).
• International Physicians for the Prevention of Nuclear War, 1993-1994: a study on the international control of weapons-usable fissile material.
• Government of Lower Saxony, Hannover, Germany, 1993: analysis of standards for radioactive waste disposal.
• University of Vienna (using funds supplied by the Austrian government), 1992: review of radioactive waste management at the Dukovany nuclear power plant, Czech Republic.
• Sandia National Laboratories, 1992-1993: advice to the US Department of Energy's Office of Foreign Intelligence.
• US Department of Energy and Battelle Pacific Northwest Laboratories, 1991-1992: advice for the Intergovernmental Panel on Climate Change regarding the design of an information system on technologies that can limit greenhouse gas emissions (joint project of IRSS, Clark University and the Center for Strategic and International Studies).
• Winston Foundation for World Peace, Boston, Massachusetts, and other funding sources, 1992-1993: development and publication of recommendations for strengthening the International Atomic Energy Agency.
• MacArthur Foundation, Chicago, Illinois, W. Alton Jones Foundation, Charlottesville, Virginia, and other funding sources, 1984-1993: policy analysis and public education on a "global approach" to arms control and disarmament.
• Energy Research Foundation, Columbia, South Carolina, and Peace Development Fund, Amherst, Massachusetts, 1988-1992: review of the US government's tritium production (for nuclear weapons) and its implications.
• Coalition of Environmental Groups, Toronto, Ontario (using funds supplied by Ontario Hydro under the direction of the Ontario government), 1990-1993: coordination and conduct of analysis and preparation of testimony on accident risk of nuclear power plants.
• Greenpeace International, Amsterdam, Netherlands, 1988-1990: review of probabilistic risk assessment for nuclear power plants.

• Bellerive Foundation, Geneva, Switzerland, 1989-1990: planning for a June 1990 colloquium on disarmament, and editing of proceedings.
• Iler Research Institute, Harrow, Ontario, 1989-1990: analysis of regulatory response to boiling-water reactor accident potential.
• Winston Foundation for World Peace, Boston, Massachusetts, and other funding sources, 1988-1989: analysis of future options for NATO (joint project of IRSS and the Institute for Peace and International Security).
• Nevada Nuclear Waste Project Office, Carson City, Nevada (via Clark University), 1989-1990: analyses of risk aspects of radioactive waste management and disposal.
• Ontario Nuclear Safety Review (conducted by the Ontario government), Toronto, Ontario, 1987: review of safety aspects of CANDU reactors.
• Washington Department of Ecology, Olympia, Washington, 1987: analyses of risk aspects of a proposed radioactive waste repository at Hanford.
• Natural Resources Defense Council, Washington, DC, 1986-1987: preparation of expert testimony on hazards of the Savannah River Plant, South Carolina.
• Lakes Environmental Association, Bridgton, Maine, 1986: analysis of federal regulations for disposal of radioactive waste.
• Greenpeace Germany, Hamburg, 1986: participation in an international study on the hazards of nuclear power plants.
• Three Mile Island Public Health Fund, Philadelphia, Pennsylvania, 1983-1989: studies related to the Three Mile Island nuclear power plant and emergency response planning.
• Attorney General, Commonwealth of Massachusetts, 1984-1989: analyses of the safety of the Seabrook nuclear power plant, and preparation of expert testimony.
• Union of Concerned Scientists, Cambridge, Massachusetts, 1980-1985: studies on energy demand and supply, nuclear arms control, and the safety of nuclear installations.
• Conservation Law Foundation of New England, Boston, Massachusetts, 1985: preparation of expert testimony on cogeneration potential at a Maine paper mill.
• Town & Country Planning Association, London, UK, 1982-1984: coordination and conduct of a study on safety and radioactive waste implications of the proposed Sizewell nuclear power plant, and testimony to the Sizewell Public Inquiry.
• US Environmental Protection Agency, Washington, DC, 1980-1981: assessment of the cleanup of Three Mile Island Unit 2 nuclear power plant.
• Center for Energy & Environmental Studies, Princeton University, Princeton, New Jersey, and Solar Energy Research Institute, Golden, Colorado, 1979-1980: studies on the potentials of renewable energy sources.
• Government of Lower Saxony, Hannover, Federal Republic of Germany, 1978-1979: coordination and conduct of studies on safety and security aspects of the proposed Gorleben nuclear fuel cycle center.

<u>Other experience (selected)</u>

• Principal investigator, project on "Exploring the Role of 'Sustainable Cities' in Preventing Climate Disruption", involving IRSS and three other organizations, 1990-1991.
• Visiting fellow, Peace Research Centre, Australian National University, 1989.

• Principal investigator, Three Mile Island emergency planning study, involving IRSS, Clark University and other partners, 1987-1989.
• Co-leadership (with Paul Walker) of a study group on nuclear weapons proliferation, Institute of Politics, Harvard University, 1981.
• Foundation (with others) of an ecological political movement in Oxford, UK, which contested the 1979 Parliamentary election.
• Conduct of cross-examination and presentation of expert testimony, on behalf of the Political Ecology Research Group, at the 1977 Public Inquiry into proposed expansion of reprocessing capacity at Windscale, UK.
• Conduct of research on plasma theory (while a D.Phil candidate), as an associate staff member, Culham Laboratory, UK Atomic Energy Authority, 1969-1973.
• Service as a design engineer on coal-fired power plants, New South Wales Electricity Commission, Sydney, Australia, 1968.

Publications (selected)

• *New and Significant Information from the Fukushima Daiichi Accident in the Context of Future Operation of the Pilgrim Nuclear Power Plant*, a report for the Attorney General, Commonwealth of Massachusetts, June 2011.
• *Outline of a Code of Conduct for Transfer of Nuclear Power Plant Technology to Consumer Countries*, a report for Nautilus Institute and RMIT University, April 2011.
• *Environmental Impacts of Storing Spent Nuclear Fuel and High-Level Waste from Commercial Nuclear Reactors: A Critique of NRC's Waste Confidence Decision and Environmental Impact Determination*, a report for Texans for a Sound Energy Policy, Victoria, Texas, February 2009.
• *Scope of the EIS for New Nuclear Power Plants at the Darlington Site in Ontario: Accidents, Malfunctions and the Precautionary Approach*, a report for Greenpeace Canada, November 2008.
• *Cost Implications of the Residual Radiological Risk of Nuclear Generation of Electricity in Ontario*, a report for the Green Energy Coalition et al, July 2008.
• "The US Effort to Dispose of High-Level Radioactive Waste", *Energy and Environment*, Volume 19, Numbers 3 and 4 (joint issue), 2008, pp 391-412.
• *Design and Siting Criteria for Nuclear Power Plants in the 21st Century*, a report for Greenpeace Canada, January 2008.
• *Risk-Related Impacts from Continued Operation of the Indian Point Nuclear Power Plants*, a report for Riverkeeper, Tarrytown, New York, November 2007.
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• *Health as a Bridge for Peace: Achievements, Challenges, and Opportunities for Action by WHO* (with Paula Gutlove), a report for the Department for Health Action in Crises, World Health Organization, Geneva, December 2006.
• "Using Psychosocial Healing in Postconflict Reconstruction" (with Paula Gutlove), in Mari Fitzduff and Chris E. Stout (eds), *The Psychology of Resolving Global Conflicts: From War to Peace*, Praeger Security International, 2006.

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• *Radiological Risk of Homeport Basing of a Nuclear-Propelled Aircraft Carrier in Yokosuka, Japan*, a report for the Citizens Coalition Concerning the Homeporting of a CVN in Yokosuka, June 2006.
• *Risks and Risk-Reducing Options Associated with Pool Storage of Spent Nuclear Fuel at the Pilgrim and Vermont Yankee Nuclear Power Plants*, a report for the Attorney General, Commonwealth of Massachusetts, May 2006.
• *Reasonably Foreseeable Security Events: Potential threats to options for long-term management of UK radioactive waste*, a report for the UK Committee on Radioactive Waste Management, November 2005.
• "Plasma, policy and progress", *The Australian Mathematical Society Gazette*, Volume 32, Number 3, 2005, pp 162-168.
• "A Psychosocial-Healing Approach to Post-Conflict Reconstruction" (with Paula Gutlove), *Mind & Human Interaction*, Volume 14, Number 1, 2005, pp 35-63.
• "Designing Infrastructure for New Goals and Constraints", Proceedings of the conference, *Working Together: R&D Partnerships in Homeland Security*, Boston, Massachusetts, 27-28 April 2005, sponsored by the US Department of Homeland Security. (A version of this paper has also been published as CRS Discussion Paper 2005-02, Center for Risk and Security, George Perkins Marsh Institute, Clark University, Worcester, Massachusetts.)
• "Potential Radioactive Releases from Commercial Reactors and Spent Fuel", Proceedings of the conference, *Working Together: R&D Partnerships in Homeland Security*, Boston, Massachusetts, 27-28 April 2005, sponsored by the US Department of Homeland Security. (A version of this paper has also been published as CRS Discussion Paper 2005-03, Center for Risk and Security, George Perkins Marsh Institute, Clark University, Worcester, Massachusetts.)
• *Safety of the Proposed South African Pebble Bed Modular Reactor*, a report for the Legal Resources Centre, Cape Town, South Africa, 12 January 2005.
• *Releases of Hazardous Material from the Santa Susana Field Laboratory: A Retrospective Review*, a report for the SSFL Advisory Panel, June 2004.
• *Decommissioning of Research Reactors at Brookhaven National Laboratory: Status, Future Options and Hazards*, a report for STAR Foundation, East Hampton, New York, April 2004.
• "Psychosocial Healing and Post-Conflict Social reconstruction in the Former Yugoslavia" (with Paula Gutlove), *Medicine, Conflict and Survival*, Volume 20, Number 2, April-June 2004, pp 136-150.
• "Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States" (with Robert Alvarez, Jan Beyea, Klaus Janberg, Jungmin Kang, Ed Lyman, Allison Macfarlane and Frank N. von Hippel), *Science and Global Security*, Volume 11, 2003, pp 1-51.
• "Health, Human Security, and Social Reconstruction in Afghanistan" (with Paula Gutlove and Jacob Hale Russell), in John D. Montgomery and Dennis A. Rondinelli (eds), *Beyond Reconstruction in Afghanistan*, Palgrave Macmillan, 2004.

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• "Human Security: Expanding the Scope of Public Health" (with Paula Gutlove), *Medicine, Conflict and Survival*, Volume 19, 2003, pp 17-34.
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• *Robust Storage of Spent Nuclear Fuel: A Neglected Issue of Homeland Security*, a report for Citizens Awareness Network, Shelburne Falls, Massachusetts, January 2003.
• *Medical Network for Social Reconstruction in the Former Yugoslavia: A Survey of Participants' Views on the Network's Goals and Achievements*, IRSS, Cambridge, Massachusetts, September 2001.
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• *A Review of the Accident Risk Posed by the Pickering 'A' Nuclear Generating Station,* a report for the Standing Committee on Energy, Environment and Natural Resources, Canadian Senate, August 2000.
• *High-Level Radioactive Liquid Waste at Sellafield: An Updated Review*, a report for the UK Nuclear Free Local Authorities, June 2000.
• *Hazard Potential of the La Hague Site: An Initial Review*, a report for Greenpeace International, May 2000.
• *A Strategy for Conflict Management: Integrated Action in Theory and Practice* (with Paula Gutlove), IRSS, Cambridge, Massachusetts, March 1999.
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• *Safety of the Storage of Liquid High-Level Waste at Sellafield* (with Peter Taylor), Nuclear Free Local Authorities, UK, November 1996.
• *Assembling Evidence on the Effectiveness of Preventive Actions, their Benefits, and their Costs: A Guide for Preparation of Evidence*, IRSS, Cambridge, Massachusetts, August 1996.
• *War, Terrorism and Nuclear Power Plants,* Peace Research Centre, Australian National University, Canberra, October 1996.

• "The Potential for Cooperation by the OSCE and Non-Governmental Actors on Conflict Management" (with Paula Gutlove), *Helsinki Monitor*, Volume 6 (1995), Number 3.
• "Potential Characteristics of Severe Reactor Accidents at Nuclear Plants", "Monitoring and Modelling Atmospheric Dispersion of Radioactivity Following a Reactor Accident" (with Richard Sclove, Ulrike Fink and Peter Taylor), "Safety Status of Nuclear Reactors and Classification of Emergency Action Levels", and "The Use of Probabilistic Risk Assessment in Emergency Response Planning for Nuclear Power Plant Accidents" (with Robert Goble), in D. Golding, J. X. Kasperson and R. E. Kasperson (eds), *Preparing for Nuclear Power Plant Accidents*, Westview Press, Boulder, Colorado, 1995.
• *A Data Manager for the Global Environment Facility* (with Robert Goble), Environment Department, The World Bank, June 1994.
• *Preventive Diplomacy and National Security* (with Paula Gutlove), Winston Foundation for World Peace, Washington, DC, May 1994.
• *Opportunities for International Control of Weapons-Usable Fissile Material*, International Physicians for the Prevention of Nuclear War, Cambridge, Massachusetts, January 1994.
• "Article III and IAEA Safeguards", in F. Barnaby and P. Ingram (eds), *Strengthening the Non-Proliferation Regime*, Oxford Research Group, Oxford, UK, December 1993.
• *Risk Implications of Potential New Nuclear Plants in Ontario* (prepared with the help of eight consultants), a report for the Coalition of Environmental Groups, Toronto, submitted to the Ontario Environmental Assessment Board, November 1992 (3 volumes).
• *Strengthening the International Atomic Energy Agency*, IRSS, Cambridge, Massachusetts, September 1992.
• *Design of an Information System on Technologies that can Limit Greenhouse Gas Emissions* (with Robert Goble and F. Scott Bush), Center for Strategic and International Studies, Washington, DC, May 1992.
• *Managing Nuclear Accidents: A Model Emergency Response Plan for Power Plants and Communities* (with six other authors), Westview Press, Boulder, CO, 1992.
• "Let's X-out the K" (with Steven C. Sholly), *Bulletin of the Atomic Scientists*, March 1992, pp 14-15.
• "A Worldwide Programme for Controlling Fissile Material", and "A Global Strategy for Nuclear Arms Control", in F. Barnaby (ed), *Plutonium and Security*, Macmillan Press, UK, 1992.
• *No Restart for K Reactor* (with Steven C. Sholly), IRSS, Cambridge, Massachusetts, October 1991.
• *Regulatory Response to the Potential for Reactor Accidents: The Example of Boiling-Water Reactors,* IRSS, Cambridge, Massachusetts, February 1991.
• *Peace by Piece: New Options for International Arms Control and Disarmament*, IRSS, Cambridge, Massachusetts, January 1991.
• *Developing Practical Measures to Prevent Climate Disruption* (with Robert Goble), CENTED Research Report No. 6, Clark University, Worcester, Massachusetts, August 1990.
• "Treaty a Useful Relic", *Bulletin of the Atomic Scientists*, July/August 1990, pp 32-33.

• "Practical Steps for the 1990s", in Sadruddin Aga Khan (ed), *Non-Proliferation in a Disarming World*, Proceedings of the Groupe de Bellerive's 6th International Colloquium, Bellerive Foundation, Geneva, Switzerland, 1990.
• *A Global Approach to Controlling Nuclear Weapons*, IRSS, Cambridge, Massachusetts, October 1989.
• *IAEA Safety Targets and Probabilistic Risk Assessment* (with three other authors), Greenpeace International, Amsterdam, August 1989.
• *New Directions for NATO* (with Paul Walker and Pam Solo), published jointly by IRSS and the Institute for Peace and International Security (both of Cambridge, Massachusetts), December 1988.
• "Verifying a Halt to the Nuclear Arms Race", in F. Barnaby (ed), *A Handbook of Verification Procedures*, Macmillan Press, UK, 1990.
• "Verification of a Cutoff in the Production of Fissile Material", in F.Barnaby (ed), *A Handbook of Verification Procedures*, Macmillan Press, UK, 1990.
• "Severe Accident Potential of CANDU Reactors," Consultant's Report in *The Safety of Ontario's Nuclear Power Reactors*, Ontario Nuclear Safety Review, Toronto, February 1988.
• *Nuclear-Free Zones* (edited with David Pitt), Croom Helm Ltd, Beckenham, UK, 1987.
• *Risk Assessment Review For the Socioeconomic Impact Assessment of the Proposed High-Level Nuclear Waste Repository at Hanford Site, Washington* (edited; written with five other authors), prepared for the Washington Department of Ecology, December 1987.
• *The Nuclear Freeze Revisited* (with Andrew Haines), Nuclear Freeze and Arms Control Research Project, Bristol, UK, November 1986. Variants of the same paper have appeared as Working Paper No. 18, Peace Research Centre, Australian National University, Canberra, February 1987, and in *ADIU Report*, University of Sussex, Brighton, UK, Jan/Feb 1987, pp 6-9.
• *International Nuclear Reactor Hazard Study* (with fifteen other authors), Greenpeace, Hamburg, Federal Republic of Germany (2 volumes), September 1986.
• "What happened at Reactor Four" (the Chernobyl reactor accident), *Bulletin of the Atomic Scientists*, August/September 1986, pp 26-31.
• *The Source Term Debate: A Report by the Union of Concerned Scientists* (with Steven C. Sholly), Union of Concerned Scientists, Cambridge, Massachusetts, January 1986.
• "Checks on the spread" (a review of three books on nuclear proliferation), *Nature*, 14 November 1985, pp 127-128.
• Editing of *Perspectives on Proliferation*, August 1985, published by the Proliferation Reform Project, IRSS.
• "A Turning Point for the NPT ?", *ADIU Report*, University of Sussex, Brighton, UK, Nov/Dec 1984, pp 1-4.
• "Energy Economics", in J. Dennis (ed), *The Nuclear Almanac*, Addison-Wesley, Reading, Massachusetts, 1984.
• "The Genesis of Nuclear Power", in J. Tirman (ed), *The Militarization of High Technology*, Ballinger, Cambridge, Massachusetts, 1984.
• *A Second Chance: New Hampshire's Electricity Future as a Model for the Nation* (with Linzee Weld), Union of Concerned Scientists, Cambridge, Massachusetts, 1983.

• *Safety and Waste Management Implications of the Sizewell PWR* (prepared with the help of six consultants), a report to the Town & Country Planning Association, London, UK, 1983.
• *Utility-Scale Electrical Storage in the USA: The Prospects of Pumped Hydro, Compressed Air, and Batteries*, Princeton University report PU/CEES #120, 1981.
• *The Prospects for Wind and Wave Power in North America*, Princeton University report PU/CEES # 117, 1981.
• *Hydroelectric Power in the USA: Evolving to Meet New Needs*, Princeton University report PU/CEES # 115, 1981.
• Editing and part authorship of "Potential Accidents & Their Effects", Chapter III of *Report of the Gorleben International Review*, published in German by the Government of Lower Saxony, FRG, 1979; Chapter III published in English by the Political Ecology Research Group, Oxford, UK.
• *A Study of the Consequences to the Public of a Severe Accident at a Commercial FBR located at Kalkar, West Germany*, Political Ecology Research Group, 1978.

<u>Expert presentations and testimony (selected)</u>

• Egyptian Council for Foreign Affairs, Cairo, May 2011: presentation, "Nuclear Technology and Global Child Health: Threats and Opportunities".
• Bibliotecha Alexandrina, Egypt, April 2011: presentation, "Accelerating a Green-Technology Transition: A Leading Role for the BA".
• Conference, *Prospects for Nuclear Non-Proliferation and Disarmament*, Cairo, October 2010: presentation (with Paula Gutlove), "The Potential for Near-Term Confidence-Building Measures and Cooperative Actions for an Eventual Middle East NWFZ, Promoting the 2012 Conference".
• Blue Ribbon Commission on America's Nuclear Future, Washington, DC, September 2010: presentation to the Subcommittee on transportation & storage of radioactive waste.
• Green Cross Strategy Workshop, Geneva, May 2010: presentation, "Nuclear Weapons and Power: Issues and Opportunities".
• Munk Centre for International Studies, University of Toronto, March 2010: presentation (with Paula Gutlove), "Demonstrating a New Approach to Stability in Afghanistan: Remote Engagement for Community Empowerment and Rural Development".
• Maxwell School, Syracuse University, February 2009: presentation, "A Second Track for Climate Negotiations: The Biosphere as Common Property".
• Marsh Institute, Clark University, February 2009: presentation, "Green Energy, Economic Renewal and Societal Learning: Research/Action Opportunities for Academia".
• Society for Risk Analysis annual meeting, Boston, Massachusetts, December 2008: presentation, "Multi-Criteria Frameworks for Considering Diverse Risks in Infrastructure Design".
• Institute of Environmental Studies, University of New South Wales, Sydney, Australia, April 2008: presentation, "Citizen Engagement for Sustainable Society".
• Department of Urban and Regional Planning, Shaheed Beheshti University, Tehran, April 2008: presentation, "Sustainable Cities: Challenges and Opportunities".

• National Academy of Sciences, Washington, DC, January 2008: presentation, "What do interested parties think about the expansion of nuclear energy?"
• Abt Associates, Cambridge, Massachusetts, March 2007: presentation, "Creating Informed Action on Climate Change".
• Universities of Medical Science in Tabriz and Isfahan, Iran, April 2007: presentation, "Healthy Design of the Built Environment".
• Minnesota Public Utilities Commission, 2006: testimony regarding trends, risks and costs associated with management of spent fuel from the Monticello nuclear power plant.
• Presentation, "Are Nuclear Installations Terrorist Targets?", at the conference, *Nuclear Energy: Does it Have a Future?*, Drogheda, County Louth, Ireland, 10-11 March 2005.
• Presentation at the session, "UN Security Council Resolution 1244 and Final Status for Kosovo", at the conference, *Lessons Learned from the Balkan Conflicts*, Boston College, Chestnut Hill, Massachusetts, 16-17 October 2004.
• California Public Utilities Commission, 2004: testimony regarding the nature and cost of potential measures for enhanced defense of the Diablo Canyon nuclear power plant.
• European Parliament, 2003: invited presentation to EP members regarding safety and security issues at the Sellafield nuclear site in the UK, and broader implications.
• US Congress, 2002 and 2003: invited presentations at member-sponsored staff briefings on vulnerabilities of nuclear-power facilities to attack and options for improved defenses.
• Numerous public forums in the USA, 2001-2006: invited presentations to public officials and general audiences regarding vulnerabilities of nuclear-power facilities to attack and options for improved defenses.
• UK Consensus Conference on Radioactive Waste Management, 1999: invited testimony on information and decision-making.
• Joint Committee on Public Enterprise and Transport, Irish Parliament, 1999: invited testimony on nuclear fuel reprocessing and international security.
• UK and Irish Parliaments, 1998: invited presentations to members on risks and alternative options associated with nuclear fuel reprocessing in the UK.
• Center for Russian Environmental Policy, Moscow, 1996: invited presentation at a forum in parallel with the G-7 Nuclear Safety Summit.
• Lacey Township Zoning Board, New Jersey, 1995: testimony regarding radioactive waste management.
• Ontario Court of Justice, Toronto, Ontario, 1993: testimony regarding Canada's Nuclear Liability Act.
• Oxford Research Group, seminar on "The Plutonium Legacy", Rhodes House, Oxford, UK, 1993: invited presentation on nuclear safeguards.
• Defense Nuclear Facilities Safety Board, Washington, DC, 1991: testimony regarding the proposed restart of K-reactor, Savannah River Site.
• Conference to consider amending the Partial Test Ban Treaty, United Nations, New York, 1991: presentation on a global approach to arms control and disarmament.
• US Department of Energy, hearing on draft EIS for new production reactor capacity, Columbia, South Carolina, 1991: testimony on tritium need and implications of tritium production options.

• Society for Risk Analysis, 1990 annual meeting, New Orleans, special session on nuclear emergency planning: presentation on real-time techniques for anticipating emergencies.
• Parliamentarians' Global Action, 11th Annual Parliamentary Forum, United Nations, Geneva, 1990: invited presentation on the potential for multilateral nuclear arms control.
• Advisory Committee on Nuclear Facility Safety, Washington, DC, 1989: testimony on public access to information and on government accountability.
• Peace Research Centre, Australian National University, seminar on "Australia and the Fourth NPT Review Conference", Canberra, 1989: invited presentation regarding a universal nuclear weapons non-proliferation regime.
• Carnegie Endowment for International Peace, Conference on "Nuclear Non-Proliferation and the Role of Private Organizations", Washington, DC, 1989: invited presentation on options for reform of the non-proliferation regime.
• US Department of Energy, EIS scoping hearing, Columbia, South Carolina, 1988: testimony on appropriate scope of an EIS for new production reactor capacity.
• International Physicians for the Prevention of Nuclear War, 6th and 7th Annual Congresses, Koln, FRG, 1986 and Moscow, USSR, 1987: invited presentations on relationships between nuclear power and the threat of nuclear war.
• County Council, Richland County, South Carolina, 1987: testimony on implications of severe reactor accidents at the Savannah River Plant.
• Maine Land Use Regulation Commission, 1985: testimony on cogeneration potential at facilities of Great Northern Paper Company.
• Interfaith Hearings on Nuclear Issues, Toronto, Ontario, 1984: invited presentations on options for Canada's nuclear trade and Canada's involvement in nuclear arms control.
• Sizewell Public Inquiry, UK, 1984: testimony on safety and radioactive waste implications of the proposed Sizewell nuclear power plant.
• New Hampshire Public Utilities Commission, 1983: testimony on electricity demand and supply options for New Hampshire.
• Atomic Safety & Licensing Board, US Nuclear Regulatory Commission, 1983: testimony on use of filtered venting at the Indian Point nuclear power plant.
• US National Advisory Committee on Oceans and Atmosphere, 1982: testimony on implications of ocean disposal of radioactive waste.
• Environmental & Energy Study Conference, US Congress, 1982: invited presentation on implications of radioactive waste management.

December 16, 2013

UNITED STATES OF AMERICA
BEFORE THE NUCLEAR REGULATORY COMMISSION

In the Matter of Proposed Rule: Waste Confidence – Continued Storage of Spent Nuclear Fuel 10 C.F.R. Part 51 Draft Waste Confidence Generic Environmental Impact Statement	)	Docket No. 2012-0246

DECLARATION OF MARK COOPER

I. INTRODUCTION AND STATEMENT OF QUALIFICATIONS

Under penalty of perjury, I, Mark Cooper, declare as follows:

My name is Mark Cooper. I am a Senior Fellow for Economic Analysis at the Institute for Energy and the Environment at Vermont Law School. A copy of my curriculum vitae is attached. I am an expert in the field of economic and policy analysis with a focus on energy, technology, and communications issues.

For over thirty years I have analyzed the economics of energy production and consumption on behalf of consumer organizations and public interests groups, focusing in the past four years on cost of the alternative resources available to meet electricity needs for the next several decades. My analyses are presented in a series of articles,[1] reports,[2] and testimonies before state regulatory

[1] Cooper, Mark. "The Only Thing that is Unavoidable About Nuclear Power is its High Cost," *Corporate Knights,* forthcoming; "Nuclear Safety and Affordable Reactors: Can We Have Both?," *Bulletin of the Atomic Scientists,* 2012; "Nuclear Safety and Nuclear Economics, Fukushima Reignites the Never-Ending Debate: Is Nuclear Power Not Worth the Risk at Any Price?," *Symposium on the Future of Nuclear Power,* University of Pittsburgh, March 27-28, 2012; "Post-Fukushima Case for Ending Price Anderson," *Bulletin of the Atomic Scientists,* October 2011; "The Implications of Fukushima: The US Perspective," *Bulletin of the Atomic Scientists,* July/August 2011 67: 8-13.

[2] Renaissance in Reverse: Competition Pushes Aging U.S. Nuclear Reactors to the Brink of

agencies[3] and state and federal legislatures.[4] I have served as an expert witness in several regulatory proceedings involving electricity and nuclear reactors, starting with proceedings before the Mississippi Public Service Commission almost thirty years ago regarding the proposed Grand Gulf II nuclear reactor and including proceedings before the Florida and South Carolina Commissions regarding the proposed reactors in those states.[5]

In the course of my economic analyses of electricity alternatives, I have developed a general framework that I refer to as a "multi-criteria portfolio analysis" for evaluating and choosing between the available alternatives in the increasingly complex and ambiguous conditions of the electricity market.[6] My analysis has focused on comparative economic analysis of the nuclear-gas comparison

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Economic Abandonment, July 2013; *Public Risk, Private Profit, Ratepayer Cost, Utility Imprudence: Advanced Cost Recovery for Reactor Construction Creates Another Nuclear Fiasco, Not a Renaissance,* March 2013; *Fundamental Flaws In SCE&G's Comparative Economic Analysis,* October 1, 2012; *Policy Challenges of Nuclear Reactor Construction: Cost Escalation and Crowding Out Alternatives*, September, 2010; *All Risk, No Reward,* December 2009; *The Economics of Nuclear Reactors: Renaissance of Relapse*, June 2009; *Climate Change and the Electricity Consumer: Background Analysis to Support a Policy Dialogue*, June 2008.

[3] "Testimony on Behalf of Utah Heal," *Carbon County Court;* "Testimony and Surrebuttal Testimony on Behalf Of The Sierra Club," Before the *South Carolina Public Service Commission*, Docket No. 2012-203-E; "Direct Testimony of Dr. Mark N Cooper in Re: Nuclear Plant Cost Recovery for the Southern Alliance for Clear Energy," Before the *Florida Public Service Commission*, FPSC Docket No. 100009-EI, August 2010; "'Direct Testimony of Dr. Mark N Cooper in Re: Nuclear Plant Cost Recovery for the Southern Alliance for Clear Energy," Before the *Florida Public Service Commission*, FPSC Docket No. 090009-EI, July 15, 2009.

[4] *Nuclear Economics after Fukushima,* Before the *Standing Committee on Natural Resources House of Commons*, Ottawa Canada, March 24, 2011; "Testimony of Dr. Mark Cooper on House File 9," Before the *Minnesota House of Representatives Committee on Commerce and Regulatory Reform*, February 9, 2011; 'Economic Advisability of Increasing Loan Guarantees for the Construction of Nuclear Power Plants," Before the *Domestic Policy Subcommittee, Committee on Oversight and Government Reform, U.S. House of Representatives,* April 20, 2010.

[5] *See* citations to written testimony in Note 3 above. I also provided oral testimony on the witness stand. "On Behalf of Mississippi Legal Services Coalition in the Matter of the Citation to Show Cause Why the Mississippi Power and Light Company and Middle South Energy Should Not Adhere to the Representation Relied Upon by the Mississippi Public Service Commission in Determining the Need and Economic Justification for Additional Generating Capacity in the Form of A Rehearing on Certification of the Grand Gulf Nuclear Project," Before the *Mississippi Public Service Commission*, Docket No. U-4387, August 13, 1984.

[6] "Least Cost Planning for 21st Century Electricity Supply: Meeting the Challenges of Complexity and Ambiguity in Decision Making," *MACRUC Annual Conference*, June 5, 2011; "Risk, Uncertainty and Ignorance: Analytic Tools for Least-Cost Strategies to Meet Electricity Needs in a Complex

driven by utility concentration on these two technologies, but also including efficiency[7] and wind.[8] The analysis has covered regional, national, and international levels, as well as on the impact of specific institutional arrangements on ratepayers.[9]

PURPOSE AND FINDINGS

The purpose of my declaration is to evaluate whether the costs of nuclear waste management, including onsite spent nuclear reactor fuel storage and permanent disposal, are high enough to significantly affect the outcome of an analysis that compares the costs and benefits of nuclear reactors with other electricity sources. I understand that this type of analysis is generally conducted by the NRC in the course of its environmental review for new reactor license applications and applications for renewal of existing reactor licenses. In the discussion below, I analyze two of the most important costs of nuclear waste management – the cost of "temporary" storage of spent fuel at reactors and the cost of building, filling, and operating a permanent repository for that fuel. The cost of decommissioning the reactors and closing the permanent repository are also costs of nuclear waste management, but I do not include them in this analysis.

Age," *Variable Renewable Energy and Natural Gas: Two Great Things that Go Together, or Best Not to Mix Them*. NARUC Winter Committee Meetings, Energy Resources, Environment and Gas Committee, February 15, 2011.

[7] "Prudent Resource Acquisition in a Complex Decision Making Environment: Multidimensional Analysis Highlights the Superiority of Efficiency," *Current Approaches to Integrated Resource Planning, 2011 ACEEE National Conference on Energy Efficiency as a Resource*, Denver, September 26, 2011; *Building on the Success of Energy Efficiency Programs to Ensure an Affordable Energy Future,* February 2010; *A Consumer Analysis of Energy Efficiency and Renewable Energy Standards: The Cornerstone of Consumer-Friendly Energy/Environmental Policy,* May 2009; *The Impact of Maximizing Energy Efficiency on Residential Electricity and Natural Gas Utility Bills in a Carbon-Constrained Environment: Estimates of National and State-By-State Consumer Savings*, 2009.

[8] *Capturing the Value Of Offshore Wind To Promote a Secure, Affordable, Low-Carbon Electricity Future: A Multi-Criteria, Portfolio Approach to Electricity Generation Resource Acquisition in the United Kingdom,* October 2012.

[9] *Public Risk, Private Profit: Ratepayer Cost, Utility Imprudence: Advanced Cost Recovery for Reactor Construction Creates Another Nuclear Fiasco, Not a Renaissance,* March 2013; *Advanced Cost Recovery for Nuclear Reactors,* March, 2011*; Economic Advisability of Increasing Loan Guarantees for the Construction of Nuclear Power Plants,* Domestic Policy Subcommittee, Committee on Oversight and Government Reform, U.S. House of Representatives, April 20, 2010; "Further Nuclear Power Subsidies are Wrongheaded," *Bulletin of the Atomic Scientists,* December 2009.

At present, the public is paying for the management of nuclear waste in three ways. Utilities pay a fee to the U.S. Department of Energy (DOE) for a Nuclear Waste Fund that is intended to pay for the repository. This fee is collected from ratepayers. The cost of temporary at-reactor storage is also being recovered by utilities from taxpayers in the form of penalties imposed on the federal government for the failure to execute its contractual commitment to take the spent fuel off reactor sites.[10] This penalty is paid out of the U.S. Treasury and has not decreased the Nuclear Waste Fund. Finally, utilities collect funds from ratepayers for the decommissioning of reactors. Questions about the use of the funds and whether they are adequate are not the subject of my declaration, which focuses only on the question of the magnitude of the costs relative to the cost of power from nuclear reactors and the other potential resources that could be used to meet the need for electricity. Nevertheless, as discussed below, these advance payments have a bearing on the applicability of a discount rate to nuclear waste disposal cost estimates.

My analysis shows that the costs of managing spent nuclear fuel are likely to be quite large in absolute value, running to hundreds of billions of dollars (in constant 2012 dollars). They are in the range of $10 to $20 per MWH ($0.01 to $0.02 per kWh), which is certainly large enough in relative value to affect the outcome of analyses that compare the cost of nuclear power to the alternatives available in the United States. Therefore, the cost of nuclear waste management is a significant cost that should be included in the NRC's economic comparisons of nuclear power with energy efficiency and other alternative energy sources.

II. ESTIMATING THE COST OF SPENT FUEL MANAGEMENT

For the purposes of this analysis, I start with the most recent U.S. government estimates of costs of electricity generation and costs of spent fuel disposal: "Levelized Cost of New Generation Resources in the Annual Energy Outlook," prepared by the U.S. Energy Information

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[10] See, e.g., *Ntl. Assoc. of Regulatory Util. Comm'rs v. United States DOE*, 680 F.3d 819 (D.C. Cir. 2013).

Administration (EIA) in 2013[11] and the "Nuclear Waste Fund Fee Adequacy Assessment Report" prepared by the U.S. Department of Energy (DOE) in 2013.[12] Each of these studies has some limitations.

I believe that the EIA has been wildly optimistic about the cost of nuclear power over the past decade, but I suspect that the NRC would be inclined to rely heavily on its estimates, and therefore I use it as my base case. I also show that the same conclusion would be reached if I were to rely on recent estimates from utility industry sources and Wall Street analysts.

The DOE's recent analysis of the cost of a permanent nuclear waste repository is the most recent in a series of government analyses of those costs.[13] Because it was prepared as part of DOE's legal obligation to assess whether current fees are adequate to fund a permanent repository, it takes a very narrow view of the costs considered. It does not consider at-reactor storage costs, and it assumes that the repository opens very quickly.[14] Neither of these assumptions appears consistent with the current reality of nuclear waste management or sound economic analysis of waste management costs. As I show below, this view ignores at least half of the cost associated with nuclear waste management. Nevertheless, the DOE's analysis provides a useful starting point for estimating the cost of one component of nuclear waste management.

REPOSITORY COSTS

The narrow costs of constructing and filling a permanent waste repository considered by the DOE can be a starting point for the analysis of the total cost of nuclear waste management. Exhibit MNC-1 shows a number of estimates, prepared by government agencies over the past thirty years,

[11] Energy Information Administration, "Levelized Cost of New Generation Resources in the Annual Energy Outlook," *Annual Energy Outlook*, 2013 (hereinafter EIA 2013).
[12] U.S. Department of Energy Nuclear Waste Fund Fee Adequacy Assessment Report, January 2013 (hereafter DOE, 2013).
[13] DOE, 2013.
[14] *Id.* p. 9, DOE 2013 assumes one pilot consolidated storage facility and one full-scale consolidated storage facility. It also assumes a time period of 34 years between the siting and opening of a repository.

of the cost of this subset of waste management activities. I have endeavored to ensure that the comparisons involve only the specific set of costs associated with the repository. While at-reactor storage costs are included in some of the later estimates, I exclude these costs in order to maintain consistency with the DOE's analysis. I exclude historic costs that are sunk and not considered in each forward looking estimate. I convert all costs to real 2012 dollars using the Producer Price Index for intermediate goods (rather than the PPI for finished goods or the Consumer Price Index, which would include many types of distribution costs not included in an activity like the construction and operation of a repository).[15] The cost per metric ton of uranium (used interchangeably with the term "heavy metal") is calculated based on the number of tons assumed in each of the individual studies.[16] The most recent DOE estimate used just over 141,000 metric tons of heavy metal (MTHM) as the total amount of spent fuel that has been produced and will be produced given present reactor licenses and reactors under construction. Studies by the Government Accountability Office (GAO) and the Blue Ribbon Commission, in comparison, used just over 153,000 MTHM, but they counted civilian and defense material not associated with civilian nuclear reactors.

The early estimates and the most recent estimate are for generic waste repositories. The others were for Yucca Mountain, which is generally assumed to be a bit more costly than a generic site. The DOE analysis of repository costs takes this into account.[17]

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[15] GAO, "Nuclear Waste Management; Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives," Government Accountability Office, GAO-10-48, November 2010 (hereafter GAO 2009) presents analyses in discounted 2009 dollars where the discount rate reflects complex Monte Carlo simulations. Cliff W. Hamal, Julie M. Carey and Christopher L. Ring, Navigant, *Spent Nuclear Fuel Management: How Centralized Interim Storage Can Expand Options and Reduce Costs,* for the Blue Ribbon Commission on America's Nuclear Future, May 16, 2011. (Hereafter Hamal, 2011), have estimated the "best estimate," which is 1.34 times the mean from GAO. Stating that in 2012 dollars yields an adjustment factor of 1.47. I use this to restate all GAO estimates in real, 2012, undiscounted dollars.

[16] This is the convention adopted by Hamal, 2011.

[17] DOE 2013, p. 12: "To derive a cost estimate for a generic repository, rather than one located at

Exhibit MNC-1 shows the mid-point, or "best estimate" from each of the studies. Two things are clear from this history of cost estimation:

First, the estimated cost of spent fuel disposal in a repository has been escalating dramatically, which is typical of cost estimates involving nuclear power. The trend is slightly stronger for the cost estimates since the 1990s.

Second, the repository costs are very large in absolute value, reaching a hundred billion dollars. They are certainly large enough to be included in any economic analysis comparing the costs and benefits of nuclear reactor operation. As discussed below, the costs are also large enough to affect the economics of nuclear power compared to alternatives.

While using the "best estimates" is useful to demonstrate a strong and consistent pattern of rising estimated costs, it hides a great deal of uncertainty about the cost. Exhibit MNC-2 shows the range of costs in the two most recent estimates. There is a great deal of uncertainty about cost in the most recent DOE study, which is typical of estimates involving nuclear power.[18] I will discuss my method for addressing this uncertainty below.

AT-REACTOR STORAGE

The recent GAO analysis[19] and the Blue Ribbon Commission study[20] have recognized the increasing importance that onsite storage of nuclear waste plays in the overall cost of nuclear waste management. Onsite spent fuel storage is becoming the central cost driver of nuclear waste management because very long periods of onsite storage – up to 300 years – are being considered.[21]

Yucca Mountain, the TSLCC [Total System Life Cycle Cost] cost estimate was reviewed and costs that were deemed specific to the Yucca Mountain site were removed from the estimate."

[18] The standard deviation of the estimate of the repository costs is large compared to the "best estimate." The coefficient of variation (the standard deviation divided by the mean) is 0.75.

[19] GAO, 2009.

[20] Hamal, 2011.

[21] Dennis Vinson, Ron Kesterson, and Adrian Mendez-Torres, "Inventory and Description of Commercial Reactor Fuels within the United States," Prepared for U.S. Department of Energy Campaign Program Savannah River National Laboratory, March 31, 2011. Which is also noted in

These costs are reflected in Exhibit MNC-3, which includes the GAO scenario in which waste remains on site for a long period of time (100 to 500 years). The GAO estimates in Exhibit MNC-3 suggest that the longer waste remains in storage on site, the higher the cost is likely to be. The Blue Ribbon Commission "best estimate" for 100 year at-reactor storage restated in 2012 dollars is just over $100 billion.[22]

Given that much longer periods of time for at-reactor storage are being contemplated, even this figure is too low for three reasons:

First, when a nuclear reactor shuts down permanently, the waste at the reactor site becomes "stranded." That is, the site must be operated solely for the purpose of attending to the waste. This means that the costs of many activities that were once attributed to operating the reactor must now be allocated to managing the waste. The Blue Ribbon Commission study suggests that the cost of managing stranded waste is five times as high as the cost of managing waste at an operating site.[23]

Second, over hundreds of years, storage casks will deteriorate and have to be replaced. I have assumed that cask replacement will be necessary every 100 years at a cost of $1.6 million per cask, assuming no escalation in real costs.[24] Given this cost and the amount of material that will

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Eric M. Davied, *Long-Term Interim Storage for Used Nuclear Fuel: Dry Cask Storage in Centralized Storage Facilities,* Texas A& M University, 2011, identifying cask capacity at 10 to 15 MTU. (Hereafter, Davied 2011).

[22] Hamal, 2011, estimates just under $72 billion for the large repository (including transportation) compared to the GAO estimate of $53 billion. I use the difference (71.46/53= 1.348) to scale up to undiscounted dollars. Bringing the figure to 2012 dollars involves inflating by a factor of 1.096. The adjustment factor is 1.477. Hamal's "best estimate" cost for the repository would $78.3 billion in 2012 dollars compared to the DOE midpoint cost of $88.9 billion.

[23] This cost difference is derived from Hamal, 2011, p. 27. GAO, 2009 shows no difference between the average at-reactor storage costs for 100 years, which would include a substantial period in which spent fuel is not stranded, and the cost of 500-years of at-reactor storage. This suggests that stranding has not been taken into account, which was the central thrust of Hamal, 2011.

[24] My assumption of cask replacement every 100 years is consistent with the NRC's Draft Waste Confidence Environmental Impacts Statement, p. xxviii, 2013. Davied, 2011, identifies cask capacity at 10 to 15 MTU.

have to be stored, the GAO estimates of storage are low. Repackaging costs could be on the order to $75 billion.[25]

Third, as with all nuclear costs, repackaging cost appear to be increasing dramatically.[26]

This analysis also excludes potentially significant costs associated with the repackaging and transportation of high burnup spent nuclear fuel over the next 30-50 years. For instance, in 2012 an expert with the National Academy of Engineering reported that "the technical basis for the spent fuel currently being discharged (high utilization, burnup fuels) is not well established… the NRC has not yet granted a license for the transport of the higher burnup fuels that are now commonly discharged from reactors. In addition, spent fuel that may have degraded after extended storage may present new obstacles to safe transport."[27] Even the Nuclear Regulatory Commission (NRC) admits "there is limited data to show that the cladding of spent fuel with burnups greater than 45,000 MWd/MTU will remain undamaged during the licensing period" for dry spent fuel storage facilities.[28]

COMBINING AT-REACTOR STORAGE AND PERMANENT REPOSITORY COSTS

Exhibit MNC-4 adds at-reactor storage costs to the most recent DOE estimates for the cost of the repository. The stranded waste costs are based on the difference in cost estimated in the Blue Ribbon Commission report between very rapid transfer of stranded waste to central storage and no

[25] GAO, 2009 uses the figure of $1.6 million per cask. With 153,000 metric tons of waste and 10 tons per cask, the cost of repackaging all spent fuel is $24.480 billion. Three repackaging operations would be just under $75 billion.

[26] Michiel P.H. Brongers, *Appendix CC, Nuclear Waste Storage*, CC Technologies Solutions, Inc., N.D., p. cc-2, gives a figure of $1.2 million; GAO, 2009, p. 56, puts the cost at $1.6 million per cask, which is shown as a modification of the earlier assumption of $1.2 million. GAO, 2009, reflects similar trends.

[27] National Academy of Engineering, "Managing Nuclear Waste", Summer 2012, pp 21, 31, http://www.nae.edu/File.aspx?id=60739.

[28] U.S. Nuclear Regulatory Commission, "Standard Review Plan for Spent Fuel Dry Storage Facilities, Final Report" NUREG-1567, March 2000. p. 6-15,http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1567/sr1567.pdf.

transfer until 70 years later.[29] That difference is slightly more than $24 billion over the first 70 years. Extrapolating to 300 years, the difference in the stranded waste cost would be $105 billion.

Repackaging of waste is necessary as long as it is not deposited in a permanent repository.[30] Therefore, repackaging costs must be added. Assuming three rounds of repackaging in 300 years, repackaging adds another $75 billion to the cost of managing spent fuel.

Combining these cost estimates for storage and disposal of spent fuel yields a cost range of approximately $210 to $350 billion.

OTHER POTENTIAL COSTS

The estimated cost range of $210 to $350 billion for spent fuel management leaves out significant costs. First, it does not include an escalation in the real cost of at-reactor storage and the escalation in the real cost of construction and operation of a permanent repository. Both of these have exhibited significant historical trends of increasing real cost. Second, the estimate in Exhibit MNC-4 does not include the cost or risk of accidents that may be significant with onsite storage of waste, especially during the very long period of onsite storage that is being contemplated. Large quantities of dangerous materials stored at sites close to population centers create a risk of accidents that can impose severe economic disruption and social dislocation. While much of the discussion of nuclear accidents focuses on public health issues, the economic and social impacts are substantial. The estimated economic costs of one accident run into the hundreds of billions, equaling or exceeding the entire cost of waste management and disposal.[31] The fourth largest utility in the world

[29] Hamal, 2011 p. 41 shows stranded waste costs of $477 million for a central storage facility taking 6000 MTU per year starting 2020 and $22.716 billion for a central storage facility taking 3000 MTU per year starting in 2090. The difference of $22.239 billion in 2009 dollars equals $24.4 billion in 2012 dollars.

[30] Hamal, 2011, p. 52.

[31] Cooper, Nuclear Safety, discusses the general magnitude of these costs. Gordon R. Thompson, "Risk-Related Impacts from Continued Operation of the Indian Point Nuclear Power Plants", November, 28, 2007 examines the potential economic cost of a severe onsite storage accident, showing it is similar in magnitude to the general accident risk.

was not thrown instantaneously into virtual bankruptcy by public health impacts, but it was destroyed by the economic cost of cleanup and compensation. While these are low probability events, keeping large quantities of nuclear waste onsite for long periods of time raises the probability of such an event.

In addition, the above analysis does not include any escalation in the cost of decommissioning reactors. Decommissioning costs theoretically are included in calculations of levelized cost. But these costs have been rising dramatically in recent years.[32] For the reactors that were retired in the past year, the total is approaching $1 billion per site, significantly above the amount originally estimated.[33]

However, it is also important to recognize that the storage of spent fuel is included in the decommissioning cost estimates, and I have already included those costs in this discussion. In the case of Kewaunee, the spent fuel storage costs are one-third of the total decommissioning cost. At half a billion dollars per nuclear reactor, the total cost for decommissioning the entire fleet could be $50 billion, which is quite significant, given the other costs that I have analyzed.

It appears that utilities are going to ask for rate increases to cover decommissioning costs, which means they have not been collecting enough. Given the rising costs of decommissioning, it remains to be seen if current cost estimates are adequate. For license renewals, there would be an additional question about whether extending the life of a reactor increases the decommissioning costs. In summary, I do not include decommissioning costs in this analysis, but these costs could well be another reason my estimate is low.

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[32] David A. Krause, "Historical NDT Fund Balances, Annual Contributions and Decommissioning Cost Estimates", Nuclear Regulatory Commission Workshop, March 2011.

[33] *Decommissioning Cost Analysis for the Vermont Yankee Nuclear Power Station*, February 2012; *Kewaunee Power Station Post-Shutdown Decommissioning Activities Report*, TLG Services, Inc., 2013; *Decommissioning San Onofre Fact Sheet,* 2013; Robert McCullough, et al*., Economic Analysis of the Columbia Generating Station,* December 2013, pp. 92-101, 110-130. "Decommissioning Cost Escalation is a Global Phenomenon: Nuclear Decommissioning Authority, *Managing Risk Reduction at Sellafield,* Report by the Comptroller and Auditor General*,* November 7, 2012.

III. TRANSLATING NUCLEAR WASTE MANAGEMENT COSTS INTO THE COST OF ELECTRICITY

In order to bring these waste management costs into the economic evaluation of nuclear power compared to other resources, I translate the aggregate estimates of costs into per kWh costs. This involves several challenges. The bottom row in Exhibit MNC-4 shows an effort to do so. There are two important issues that affect this calculation: output of nuclear reactors and a determination of the appropriate discount rate.

OUTPUT OF NUCLEAR REACTORS

The amount of power that the costs will be spread across is uncertain. The DOE's assumption is too high for several reasons. The DOE estimate shows a stream of output from nuclear reactors that start with a base in 2012 that is already 5% higher than the actual output.[34] The output is lower than expected because nuclear reactors were offline and have been retired early. That trend is likely to continue.

The DOE assumption of a very high load factor is inconsistent with historical experience. It took a long time to build up to a high load factor; therefore, any new reactors that come online should not be assumed to immediately jump to a high load factor. Moreover, capacity factors for existing reactors have begun to decline as reactors age. In a recent paper, I showed that including early retirements in the calculation of load factors yields a load factor that is one-sixth lower than the very high assumptions being used in much comparative economic analyses.[35] The output of the nuclear fleet in 2013 will have declined from the peak in 2010 to the level achieved in 2004.

DOE and many other analysts of waste management assume that reactor life will be 60 years.[36] While the license period might run that long, virtually all reactors that have been retired

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[34] DOE, 2013.

[35] Mark Cooper, Renaissance in Reverse: Competition Pushes Aging U.S. Nuclear Reactors to the Brink of Economic Abandonment, July 2013 (hereafter, Aging Reactors).

[36] DOE, 2013.

were retired before their licenses expired. The closure of Kewaunee and Vermont Yankee extend that pattern for reactors that were online when the retirement decision was made, while San Onofre and Crystal River extend the pattern of troubled reactors retiring early.

DOE assumes an increase in capacity of almost 10 percent due to large scale uprates at existing facilities,[37] but virtually all large scale uprates pending have been cancelled due to a severe deterioration in the comparative economics of nuclear power.[38]

DOE assumes early online status for new reactors under construction and an "unplanned addition" of a new reactor which would add 2 percent to nuclear capacity.[39] Given the historical experience of new reactor cancellations and construction delays, the "unplanned addition" should certainly be dropped.

Combining these observations, one can argue that the base case for NRC analysis should include actual 2013 output, which is 5% lower than the DOE analysis, an 80 percent load factor, without uprates and "unplanned additions." Under these assumptions, the output of the fleet would be at least 25% lower than assumed by DOE in its analysis of disposal system costs.[40]

Lower output might lower the variable cost of at-reactor storage. Whether it lowers the cost of a permanent repository depends on whether one assumes that only one repository will be constructed. If adding nuclear capacity causes the construction of a second repository, fixed costs will increase substantially. The GAO analysis, adjusted for the discount rate and inflation, suggests that the cost of operating two repositories would be 32% higher than one, adding $25 billion to the total cost.[41] This would offset a substantial part of the variable cost savings. Put in another way, if denying licenses or license renewals allows a second repository to be avoided, the reduction in cost

[37] DOE, 2013.
[38] Cooper, Aging Reactors.
[39] DOE, 2013.
[40] This result is consistent with all remaining reactors plus five new ones – Vogtle, Summer, Watts Bar – running for a full 60 years at 90 percent capacity factor.
[41] GAO, 2009.

would be substantial including both fixed costs for the reactor and variable cost for spent waste storage.

THE DISCOUNT RATE

There is a great deal of uncertainty and debate about the discount rate that should be used. In this case, as discussed below, it is my opinion that application of a discount rate is inappropriate. Therefore, the costs presented in Exhibit MNC-4 are not discounted.

For purpose of long term analysis, analysts generally believe discount rates should be quite low.[42] The fact that costs of waste management are incurred a long time (i.e., hundreds or thousands of years) after the useful life of the facility creates an intergenerational issue, since future generations will be incurring large costs without deriving any benefit. As GAO states:

> Although the concept of discounting is an accepted and standard methodology in economics, the concept of discounting values over a very distant future—known as "intergenerational discounting"—is still subject to considerable debate. Furthermore, no consensus exists among economists regarding the exact value of the discount rate that should be used to discount values that are spread over many hundreds or thousands of years.[43]

Therefore the appropriate discount rate is a significant issue that should be addressed in the NRC analysis of the cost of waste management.

In my opinion, there are two additional, important reasons why application of a zero discount rate is appropriate in these circumstances. First, the real increase in the cost of at-reactor storage and the permanent repository has been increasing substantially faster than the real, discount rate. Given the long time frames being considered, the real price increase can have a very large impact. An annual real rate of increase above the discount rate of one-half of one percent would more than double the cost of waste management.

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[42] Hamal, 2011.
[43] GAO, 2009, p. 28.

The second reason stems from the unique way that the financing of the repository is being handled. To the extent that the discount rate represents the time value of money (*i.e.,* the value of the opportunity to use the money), the public is bearing the burden on the revenue side. The DOE analysis of fund adequacy takes credit for the earning of interest on the funds collected. Because those funds are being banked to make the fund whole, then the funds are not available to be used for other purposes. Much the same is true of the Treasury funds being paid to utilities because of the failure of the federal government to take the spent fuel. Because taxpayers are already being denied the opportunity to use their funds for other purposes, to discount the cost would be a double burden. Taxpayers and ratepayers would be bearing the full cost of the waste management, having been denied the opportunity to use the repository funds of penalties for storage costs for other purposes.

Given these considerations, I believe it is reasonable to estimate the combined costs of at-reactor storage and a permanent repository in the range of $10 - $20/MWH ($0.01 to $0.02/kWh). I have rounded this estimate to one significant figure, to account for the uncertainties inherent in such estimations at the present time.

In absolute value, given the EIA estimate of $0.11/per kWh for the cost of nuclear power from new reactors, this is between 10% and 20% of the estimated cost.[44] That is a substantial portion of new reactor costs and therefore strongly merits consideration by the NRC in its economic analysis of the relative costs and benefits of new nuclear reactors as compared to energy efficiency and other energy sources.

For the above reasons, I believe that the bottom line in Exhibit MNC-5 provides cautiously low estimates of the cost of nuclear waste management. Therefore, in the remainder of this analysis

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[44] See EIA, 2013.

I use the cost range of $10/MWh to $20/MWh to assess the importance of including nuclear waste management costs in the NRC's economic analysis.

As discussed in more detail in Section IV, the cost of nuclear waste management is a much larger fraction of the cost of operating existing reactors than for new reactors. And it is large enough to affect the comparative cost of nuclear power from existing and new plants, relative to the available energy alternatives. Therefore, in the case of both new reactor licensing and license renewal for existing reactors, the costs of nuclear waste management could be high enough to affect decisions about which energy resources to develop.

IV. IMPACT OF NUCLEAR WASTE MANAGEMENT COST ON THE COMPARATIVE ECONOMICS IN RESOURCE SELECTION

In the previous section I showed that a very cautious estimate of waste management costs would be in the range of $0.01 to $0.02 per kWh. In this section I examine whether costs of that magnitude could affect the economic analysis of nuclear power compared to other resources. For the analysis of licenses for new reactors I examine the addition of waste management costs to the levelized cost of energy that are frequently used to evaluate new resources. For the analysis of the renewal of licenses for existing reactors I analyze the addition of waste management costs to the operating costs and margins of existing reactors.

LEVELIZED COST ANALYSIS FOR NEW REACTOR LICENSES

The traditional approach to comparative resource selection for new reactors relies on the calculation of the levelized cost of electricity.[45] For the purposes of this analysis, I start with the levelized cost of alternatives as estimated by EIA. I then add the cost of nuclear waste management

[45] Levelized cost is often cited as a convenient summary measure of the overall competiveness of different generating technologies. It represents the per-kilowatt-hour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle. Key inputs to calculating levelized costs include overnight capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type. http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

to those costs and observe, qualitatively, whether it would alter the evaluation of the cost of nuclear power compared to the other options available. Exhibit MNC-5 shows the results using the range of estimates in the EIA analysis.

Nuclear waste management costs of $20/MWH would change the location of nuclear in the relation to other resources significantly.

Nuclear moves:

- Out of the range of
    - Conventional coal costs
    - Gas Combined Cycle with CCS
    - Advanced gas turbines
- Into the range of
    - Advanced coal
    - Advanced coal with CCS
- Much closer to and
    - Slightly below gas turbines
    - Slightly above Biomass

Waste disposal costs of $10/MWH move nuclear costs in the same directions, but more modestly.

Exhibit MNC-6 shows levelized cost estimates for a similar set of resources from the Pennsylvania, Jersey, Maryland Power Pool (PJM), a major Regional Transmission Organization (RTO) in an area of the country that is not especially well endowed with renewable resources (e.g. compared to the Midwest with a great deal of wind or the Southwest with a great deal of solar, or the Northwest with a great deal of hydro). Exhibit MNC-7 shows estimates from Lazard, which is a financial analysis firm. I include these two estimates because they not only represent different institutional points of view but also because both include efficiency as a resource. Both estimates demonstrate that efficiency is the least-cost resource by far. In fact, a significant amount of efficiency could be delivered at a cost that is close to the cost of nuclear waste management alone.

Lazard also projects declining costs for solar, which I include in Exhibit MNC-7, which would make it cost competitive with even natural gas within a decade. As shown in Exhibit MNC-8, the cost trends for solar and offshore wind are expected to make them much more competitive over the next decade and would significantly affect all of the comparisons affecting nuclear power.

Adding $10 to $20 per MWh to the cost of nuclear power generation would make a material difference in its attractiveness. Nuclear becomes even less attractive when one considers that other energy sources have little risk due to the short time from start of construction to finish. Looking at the cost of nuclear compared to the more costly alternatives in these analyses, the $10 to $20/MWH certainly can make a difference. Nuclear, which is almost the most expensive resource, could become the most costly.

PORTFOLIO ANALYSIS

In the realm of electricity resource selection, I and many others have argued for an approach to analysis that deals more systematically with risk, uncertainty, vagueness, and ambiguity in the decision-making environment. I have developed a multi-criteria portfolio approach based on financial risk hedging and real option analysis, as well as a number of other efforts to deal with the challenge of ambiguity in the decision-making environment. For the purpose of incorporating the cost of nuclear waste management into the analysis, I will briefly describe the basic portfolio approach.

The top graph in Exhibit MNC-9 presents the basic approach to financial portfolio analysis, as a publication from the National Regulatory Research Institute (NRRI) attempted to introduce it to regulators.[46] As shown in the upper graph, investors want to be on the efficient frontier, where risk and reward are balanced. They can improve their expected returns if they can increase their reward without increasing their risk or if they can lower their risk without reducing their reward. In the financial literature, risk is measured by the standard deviation of the value of the reward.

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[46] Ken Costello, *Making the Most of Alternative Generation Technologies: A Perspective on Fuel Diversity*, NRRI, March 2005.

In applying this framework to the evaluation of generation options, analysts frequently measure reward as kilowatts per dollar (a measure of economic efficiency). Reward is the inverse of cost (i.e., the lower the cost the greater the reward). Indeed, they use efficiency and cost interchangeably.[47] The lower graph in Exhibit MNC-9 shows the cost/risk relationship. Options that would move the portfolio toward the origin should be adopted since they embody lower cost and/or risk. Movement along the risk-cost frontier is neutral. Movement away from the origin raises either the cost or the risk.

I use the array of resources to calculate a measure of the attractiveness of the reward. The distance of a resource from the origin measures the risk-cost characteristics of the resource (giving risk and cost equal weight). Resources that are farther from the origin (measured as the distance with each factor weighted equally) are less attractive. The distance from the origin can be expressed as the risk-adjusted cost or the expected cost.

Exhibit MNC-10 shows the result of applying my approach to the EIA cost estimates, assuming that waste costs increase both the point estimate and the standard deviation of the cost estimates. Exhibit MNC-10 provides quantitative estimates that support the observations in the previous section. Waste disposal costs of the magnitude I have estimated make nuclear a much "closer" call in comparison to other alternatives, and they even reverse the direction of the conclusion in several comparisons. The top graph in MNC-10 focuses on the comparisons between resource costs that would be most affected by inclusion of waste management costs in the NRC's economic analysis. The bottom graph includes all of the resources. There are nine comparisons in which nuclear would be seen as a significantly less attractive asset to include in a resource portfolio. Including the trends for wind and solar cost and the cost of waste management, nuclear becomes almost the least attractive resource.

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[47] J.C. Jansen, L.W. M. Beurskens, and X. van Tilburg, *Application of Portfolio Analysis to the Dutch Generating Mix,* ECN, February 2006, p. 13 argue for a risk-cost frontier.

ANALYSIS FOR LICENSE RENEWAL OF EXISTING REACTORS

I approach the analysis of the impact of waste management costs on the economics of aging reactors by examining these costs in relation to operating costs and margins. The economics of old reactors is already fraying and many are already on the economic "razor's edge."[48] Uprates are already being abandoned because they are too costly. Old reactors are being shuttered because they are no longer economic. Proper consideration of waste disposal costs could play a part in pushing them over the edge.

In my recent analysis of aging reactors I used a Credit Suisse analysis of operating costs and operating margins as the basic data to make the point that analysis of the economics of aging reactors that are still operating is challenging. Exhibit MNC-11 contains the estimated operating costs for almost all nuclear reactors online in 2012. Exhibit MNC-12 shows the "cash margins" that the reactors would yield, given the "round-the-clock prices" at different power hubs. It shows that in all but a few cases the cash margins – revenues per MWh in excess of the offered hub price – are less than $20 per MWh. It also shows that the cash margins are less than $10 per MWh in many cases. Exhibit MNC-12 also identifies reactors that have been retired recently or are scheduled to retire early, even though they were online and had significant periods before their licenses would expire. Major uprates that have recently been cancelled are also identified.

The exhibit makes the point that cash margins of about $9/MWH put reactors on the razor's edge because the cash margins are very thin.[49] Exhibit MNC-12 shows that 12 of the 18

[48] Cooper, Aging Reactors.

[49] Credit Suisse, 2013, pp. 11-17,"Using current 2014 power price forwards and unit economics, we see modest cash margin expectations... Layering in typical parent overhead of $5-7 / MWH, unit economics look even worse… We worry that rising operating and capital costs along with operational problems at some aging plants will force owners to continuously re-evaluate the useful lives of plants independent of license extensions especially as the time to absorb ongoing capex grows shorter."

license renewals pending or expected in the near future are on this razor's edge. The waste management costs identified above are clearly material in these circumstances.

Conclusion

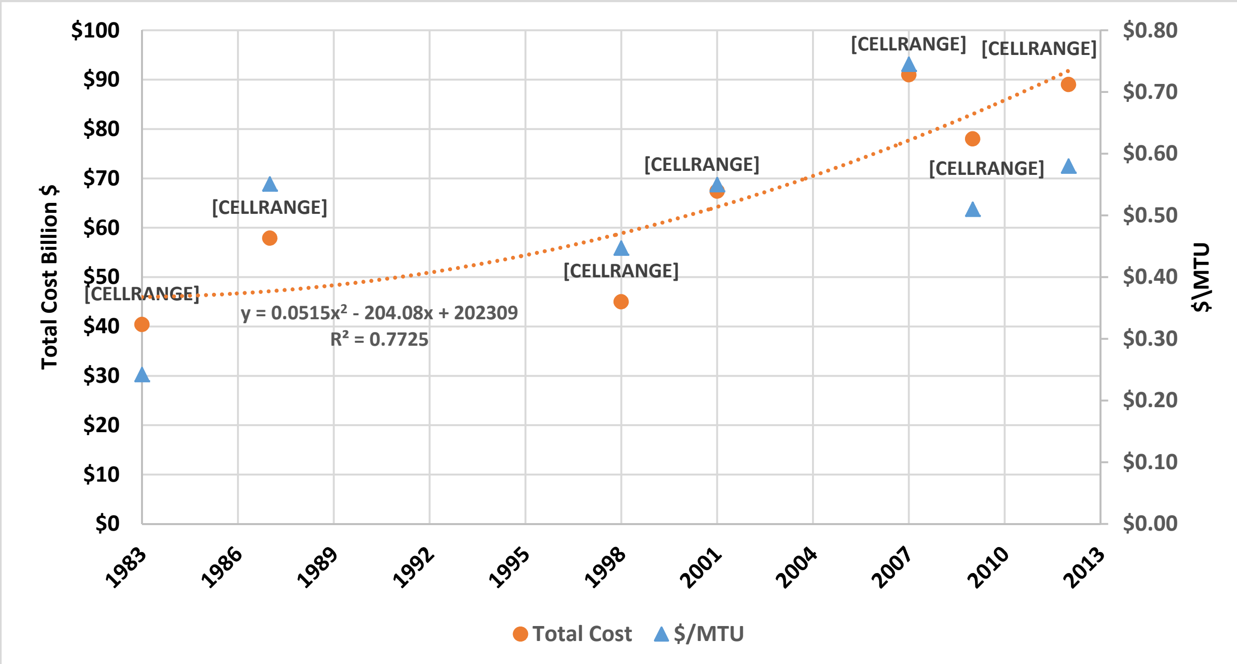
In conclusion, the calculations in this declaration indicate that spent fuel storage and disposal costs could be high enough to materially affect energy choices when the costs of new reactors or extension of the operating life of existing reactors are compared with energy efficiency and alternative energy sources. Therefore, in my opinion, the NRC should consider these costs in its licensing decisions for new reactors and renewal of existing reactor licenses.

I declare that the foregoing statements of fact are true and correct to the best of my knowledge and that the statements of opinion expressed above are based on my best professional judgment.

Mark Cooper

Date: December 16, 2013

EXHIBIT MNC-1, Page 1 of 1
REPOSITORY COST ESTIMATES ACROSS TIME



Sources:

GAO 1998: "Nuclear Waste: Fourth Annual Report on DOE's Nuclear Waste Program," United States General Accounting Office, GAO/FECD-88-131, September 1988.

DOE 1998: "Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program," DOE/RW-510, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Washington, DC-20586, December 1998.

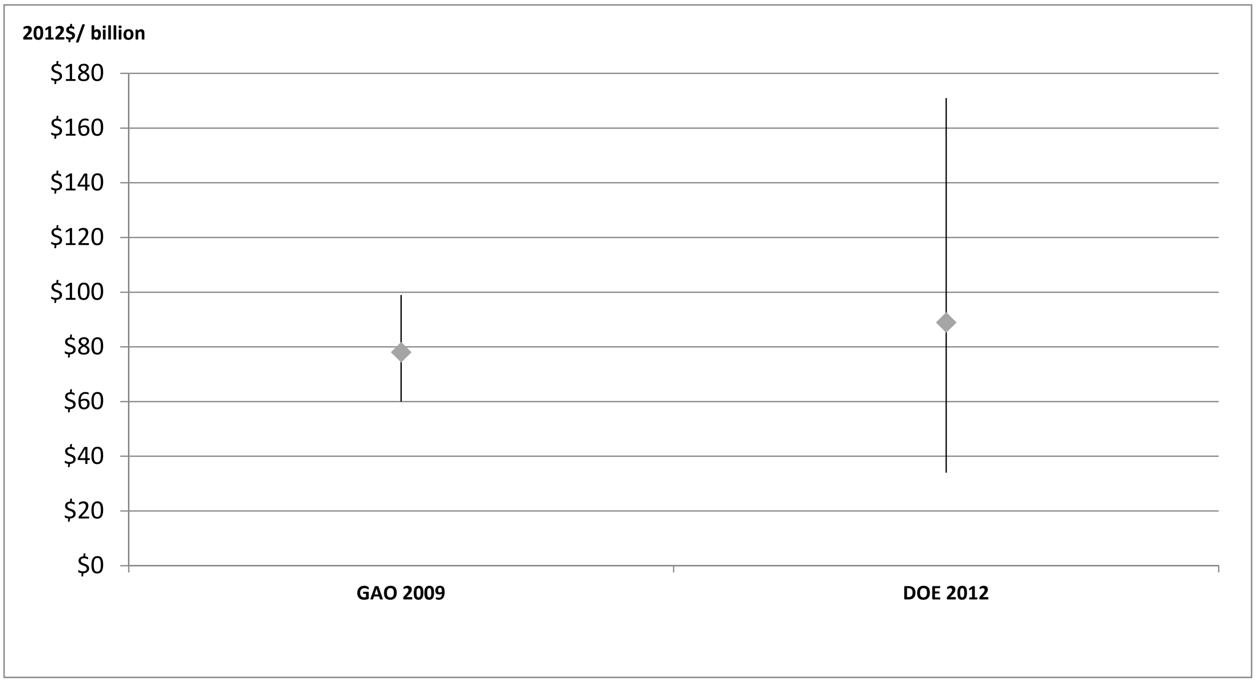
DOE 2008: "Analysis of the Total System Lifecycle Cost of the Civilian Radioactive Waste Management Program," Fiscal Year 2007, DOE/RW-0591, Washington, D.C., July 2008.

GAO 2009: "Nuclear Waste Management; Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives," Government Accountability Office, GAO-10-48, November 2010.

Using the "best estimate" identified by Cliff W. Hamal, Julie M. Carey and Christopher L. Ring, Navigant, *Spent Nuclear Fuel Management: How Centralized Interim Storage Can Expand Options and Reduce Costs,* for the Blue Ribbon Commission on America's Nuclear Future, May 16, 2011.

DOE 2013: U.S. Department of Energy, "Nuclear Waste Fund Fee Adequacy Assessment Report," January 2013.

EXHIBIT MNC-2, Page 1 of 1
RANGE OF REPOSITORY COST ESTIMATES WITHIN STUDIES



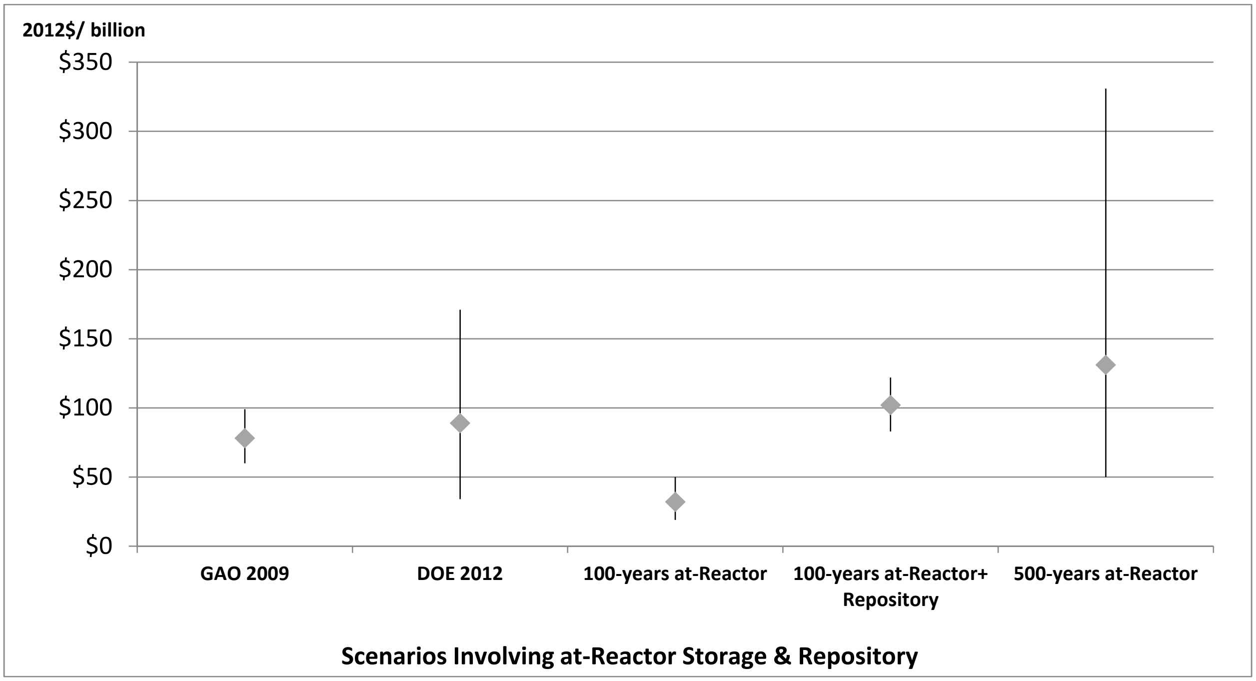
Sources:

GAO 2009: "Nuclear Waste Management; Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives," Government Accountability Office, GAO-10-48, November 2010 (p.71).

Using the "best estimate" identified by Cliff W. Hamal, Julie M. Carey and Christopher L. Ring, Navigant, *Spent Nuclear Fuel Management: How Centralized Interim Storage Can Expand Options and Reduce Costs,* for the Blue Ribbon Commission on America's Nuclear Future, May 16, 2011 (p.27), which is 1.34 times the GAO mean. Estimates are adjusted from 2009 to 2012 dollars using the Producer Price Index for Intermediate materials and supplies (PPI change factor = 1.096). Storage costs are excluded.

DOE 2013: U.S. Department of Energy, "Nuclear Waste Fund Fee Adequacy Assessment Report," January 2013.

EXHIBIT MNC-3, Page 1 of 1
AT-REACTOR STORAGE + REPOSITORY COST SCENARIO



Sources:

GAO 2009: "Nuclear Waste Management; Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives," Government Accountability Office, GAO-10-48, November 2010 (p.71).

Using the "best estimate" identified by Cliff W. Hamal, Julie M. Carey and Christopher L. Ring, Navigant, *Spent Nuclear Fuel Management: How Centralized Interim Storage Can Expand Options and Reduce Costs,* for the Blue Ribbon Commission on America's Nuclear Future, May 16, 2011 (p.27), which is 1.34 times the GAO mean. Estimates are adjusted from 2009 to 2012 dollars using the Producer Price Index for Intermediate materials and supplies (PPI change factor = 1.096).

DOE 2013: U.S. Department of Energy, "Nuclear Waste Fund Fee Adequacy Assessment Report," January 2013.

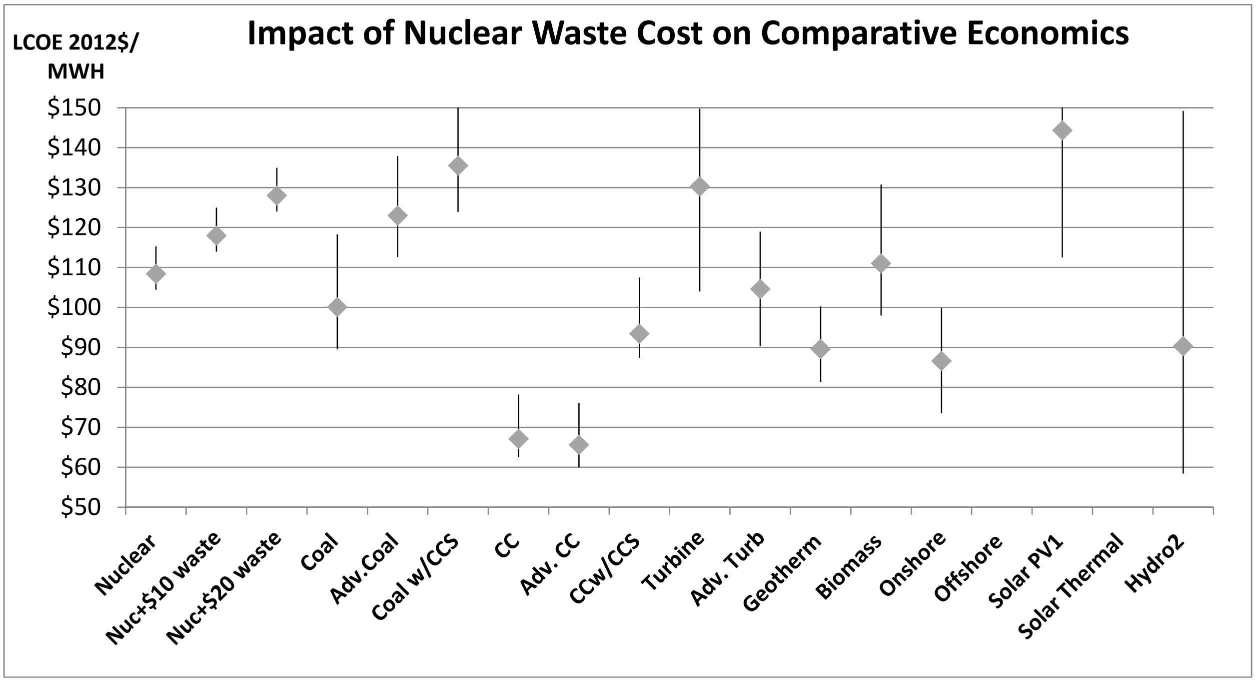
EXHIBIT MNC-4, Page 1 of 1
NUCLEAR WASTE MANAGEMENT COST ESTIMATES

Cost Category	DOE Repository + At-Reactor Storage Cost in Billions of 2012 Dollars	
	Low	High
Repository	$34	$171
Stranded Waste 300 years	$105	$105
3 repacks over 300 years	$75	$75
Total	**$214**	**$351**

Cost in $/KWH		
DOE Assumption (29,000 TWH)	$0.0074	$0.012
DOE Corrected (22,000 TWH)	$0.0097	$0.016

Source: see text for discussion. Repository costs are the most recent DOE estimates. Stranded waste costs are based on the Hamal, 2011, estimate that shows stranding adds $22 billion over the first 70 years. Repackaging costs are estimated by multiplying the cost per cask ($1.6 million) times the number of casks (15,000). The output of the nuclear fleet is assumed to be 25% lower than estimated by DOE based on declining load factors, early retirements, and abandoned uprates not considered by DOE. This is also consistent with all remaining reactors plus five new ones – Vogtle, Summer, Watts Bar – running for a full 60 years at 90 percent capacity factor.

EXHIBIT MNC-5, Page 1 of 1
IMPACT OF WASTE MANAGEMENT COSTS ON RESOURCE COST COMPARISONS

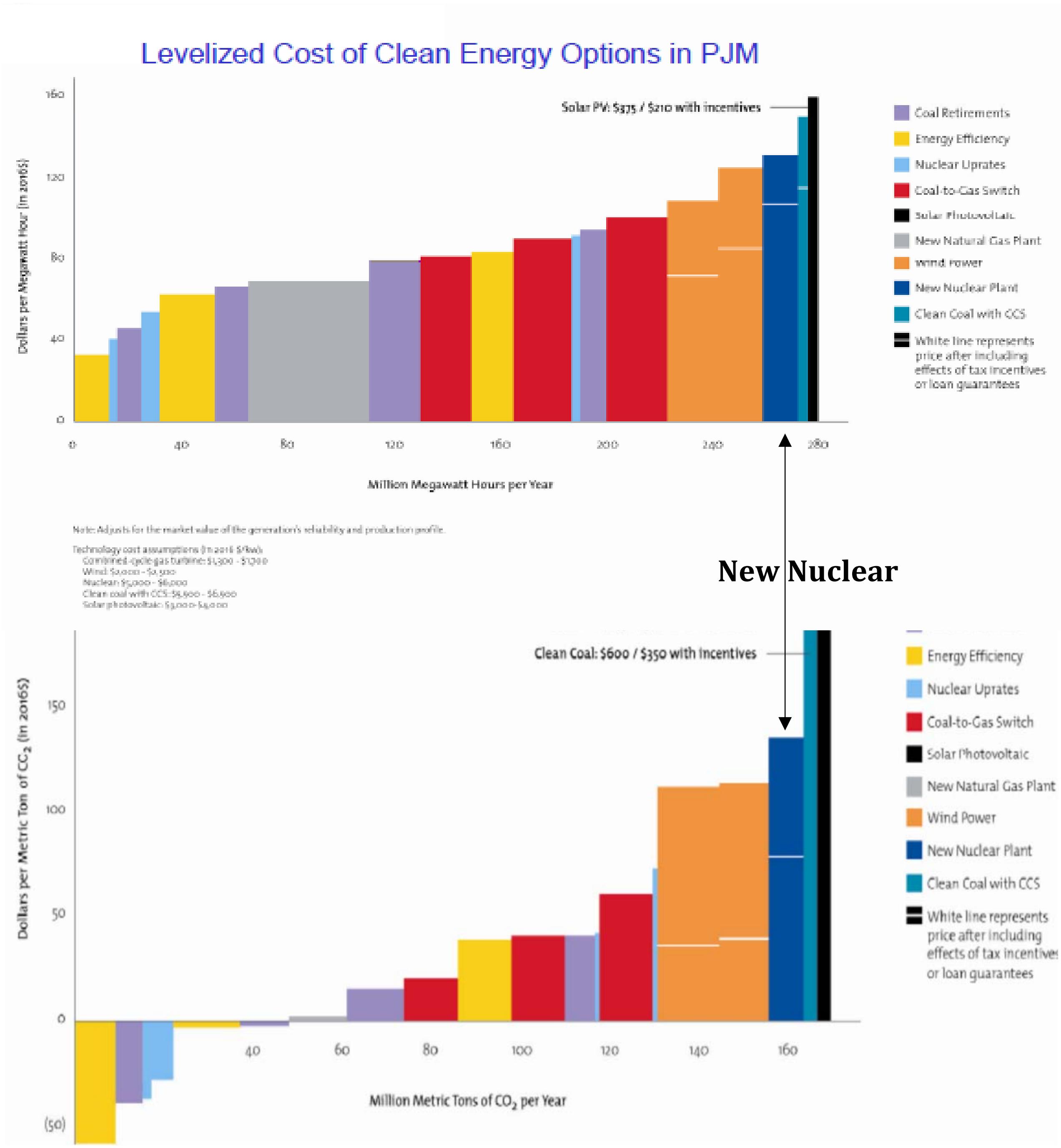


Source: Energy Information Administration, "Levelized Cost of New Generation Resources in the Annual Energy Outlook," ***Annual Energy Outlook*****, 2013.**

PJM RESOURCE CURVE

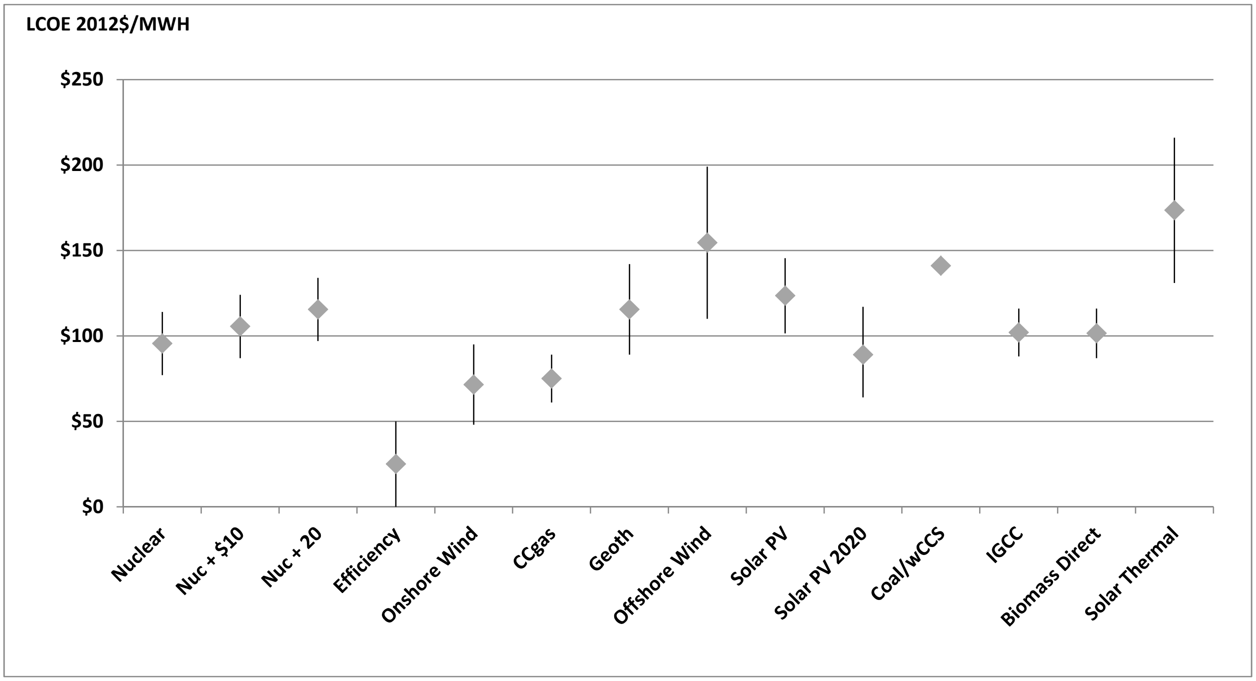
There are Cheap Ways and Costly Ways to Clean the Generation Fleet

5



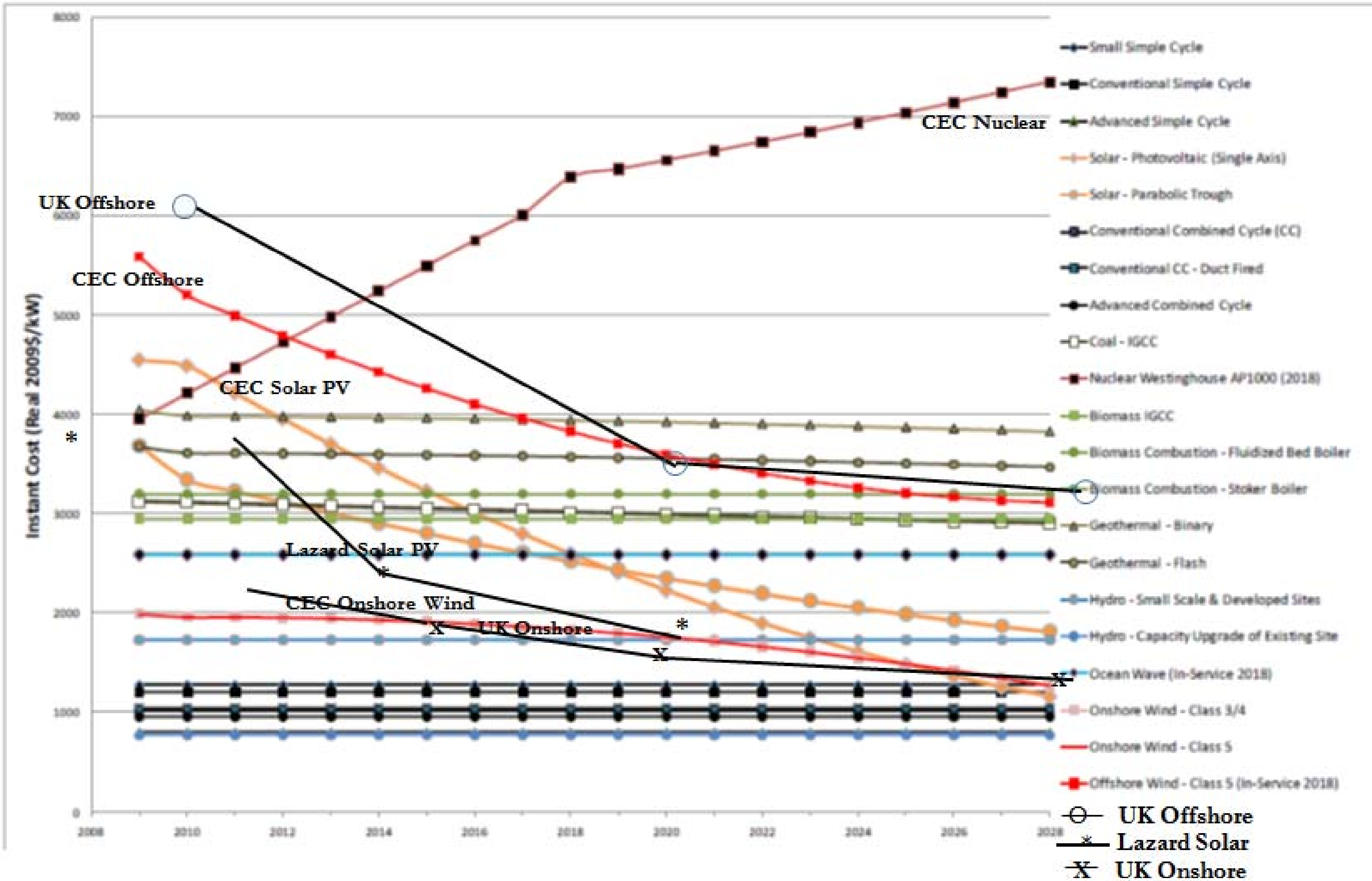
Source: John Rowe, *Energy Policy: Above All, Do No Harm,* American Enterprise Institute, March 8, 2011.

EXHIBIT MNC-7, PAGE 1 OF 1
LAZARD, LEVELIZED COST OF ELECTRICITY



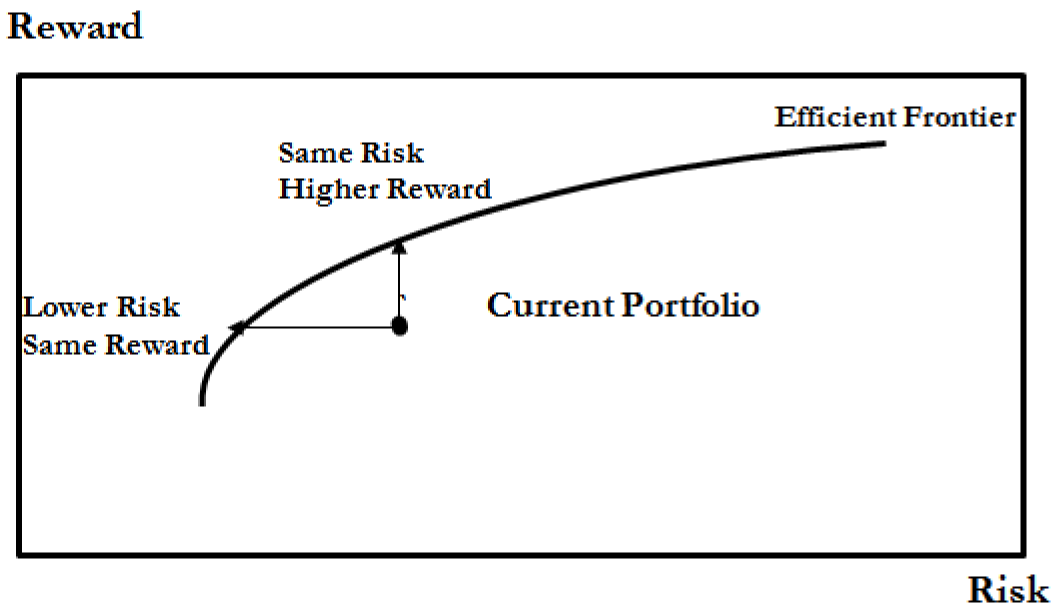
Sources: Lazard, Levelized Cost of Electricity 6.0 for all except solar PV 202, which is Lazard, Levelized Cost of Electricity 5.0.

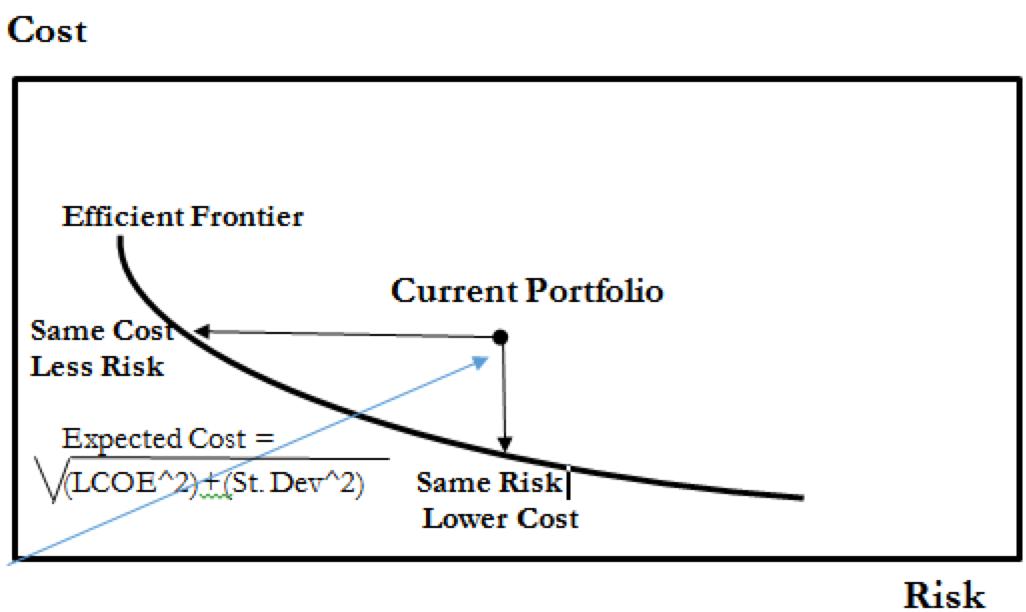
EXHIBIT MNC-8, PAGE 1 OF 1
OVERNIGHT COST TRENDS IN THE U.S. AND UK



Source: California Energy Commission, *Cost of Central Station Generation,* January 2010; Mott MacDonald, *Cost of Low-carbon Generation Technologies:* 2011; Lazard, *Levelized Cost of Energy Analysis* – Version 5.0, June 2011.

EXHIBIT MNC-9, PAGE 1 OF 1
PORTFOLIO ANALYSIS OF RISK/COST REWARD ANALYSIS

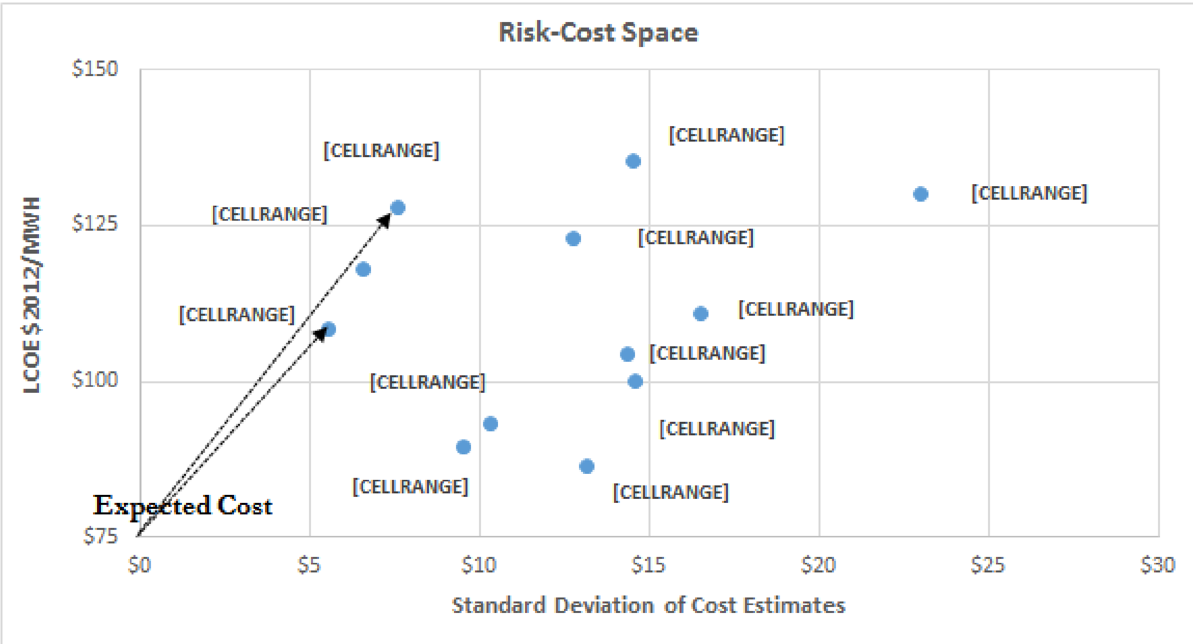




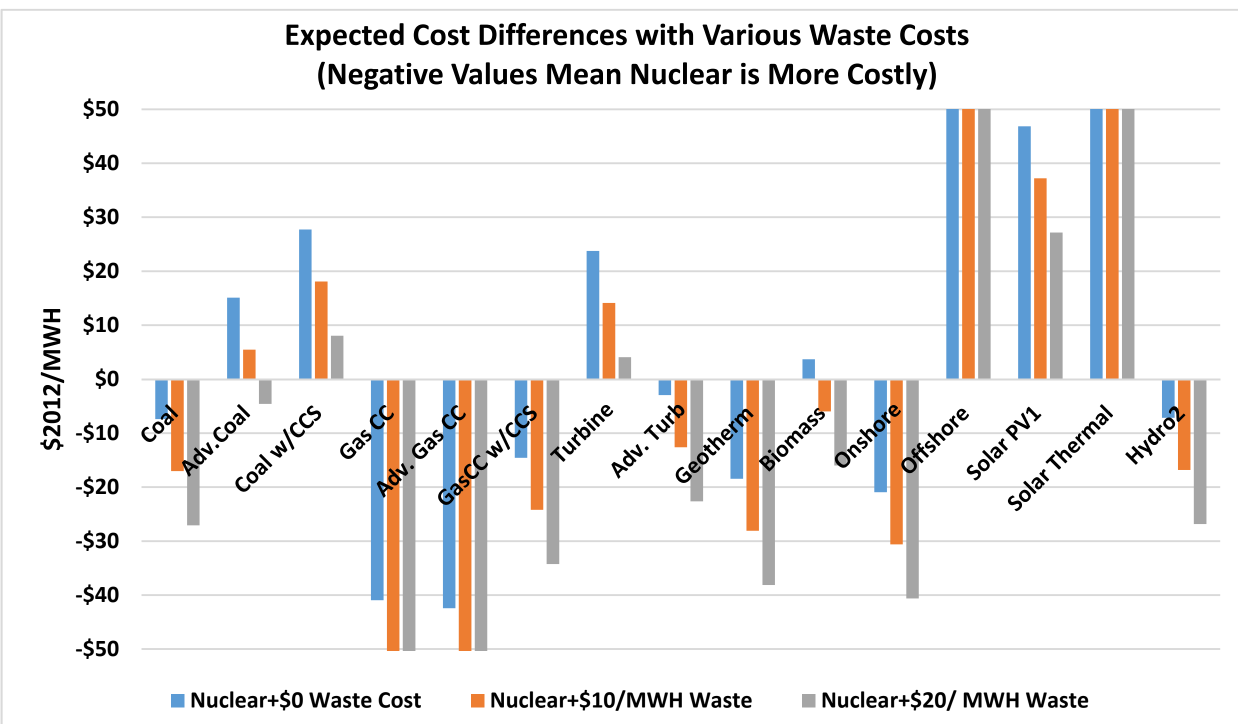
Source: Ken Costello, *Making the Most of Alternative Generation Technologies: A Perspective on Fuel Diversity,* NRRI, March 2005), p. 12, upper graph

EXHIBIT MNC-10, Page 1 of 1

RISK FRAMEWORK EXPECTED COST WHERE WASTE COSTS AFFECT PERCEIVED ATTRACTIVENESS OF RESOURCES

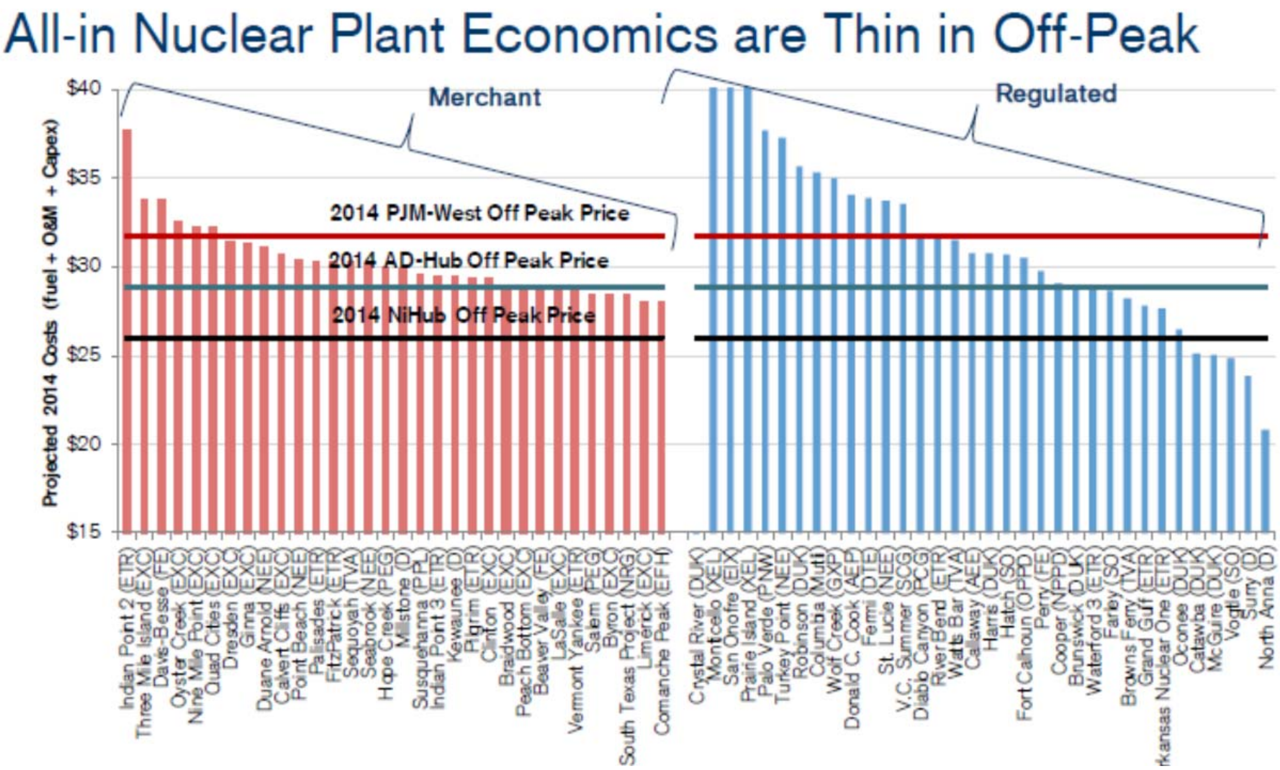


Source: Expected cost is distance from the origin. See text for discussion.



Source: Expected cost is distance from the origin. See text for discussion.

EXHIBIT MNC-11, PAGE 1 OF 1
CREDIT SUISSE ANALYSIS OF AGINING REACTOR ECONOMICS



Source: Credit Suisse, *Nuclear… The Middle Age Dilemma?, Facing Declining Performance, Higher Costs, Inevitable Mortality,* February 19, 2013, p. 10.

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University of Maryland, M.A., 1973, Sociology

City College of New York, B.A., 1968, English

PROFESSIONAL EXPERIENCE:

President, Citizens Research, 1983 - present

Research Director, Consumer Federation of America, 1983-present

Associated Fellow, Columbia Institute on Tele-Information, 2003-present

Fellow, Donald McGannon Communications Research Center, Fordham University, 2005-present

Senior Fellow for Economic Analysis, Institute for Energy and the Environment, Vermont Law School, 2009-present

Fellow, Silicon Flatirons, University of Colorado, 2009-present

Fellow, Stanford Center on Internet and Society, 2000-2010

Principle Investigator, Consumer Energy Council of America, Electricity Forum, 1985-1994

Director of Energy, Consumer Federation of America, 1984-1986

Director of Research, Consumer Energy Council of America, 1980-1983

Consultant, Office of Policy Planning and Evaluation, Food and Nutrition Service, United States Department of Agriculture, 1981-1984

Consultant, Advanced Technology, Inc., 1981

Technical Manager, Economic Analysis and Social Experimentation Division, Applied Management Sciences, 1979

Research Associate, American Research Center in Egypt, 1976-1977

Research Fellow, American University in Cairo, 1976

Staff Associate, Checchi and Company, Washington, D.C., 1974-1976

Consultant, Division of Architectural Research, National Bureau of Standards, 1974

Consultant, Voice of America, 1974

Research Assistant, University of Maryland, 1972-1974

TEACHING EXPERIENCE:

Lecturer, Washington College of Law, American University, Spring, 1984 - 1986, Seminar in Public Utility Regulation

Guest Lecturer, University of Maryland, 1981-82, Energy and the Consumer, American University, 1982, Energy Policy Analysis

Assistant Professor, Northeastern University, Department of Sociology, 1978-1979, Sociology of Business and Industry, Political Economy of Underdevelopment, Introductory Sociology, Contemporary Sociological Theory; College of Business Administration, 1979, Business and Society

Assistant Instructor, Yale University, Department of Sociology, 1977, Class, Status and Power

Teaching Assistant, Yale University, Department of Sociology, 1975-1976, Methods of Sociological Research, The Individual and Society

Instructor, University of Maryland, Department of Sociology, 1974, Social Change and Modernization, Ethnic Minorities

Instructor, U.S. Army Interrogator/Linguist Training School, Fort Hood, Texas, 1970-1971

PROFESSIONAL ACTIVITIES:

Member, Advisory Committee on Appliance Efficiency Standards, U.S. Department of Energy, 1996 - 1998

Member, Energy Conservation Advisory Panel, Office of Technology Assessment, 1990-1991

Fellow, Council on Economic Regulation, 1989-1990

Member, Increased Competition in the Electric Power Industry Advisory Panel, Office of Technology Assessment, 1989

Participant, National Regulatory Conference, The Duty to Serve in a Changing Regulatory Environment, William and Mary, May 26, 1988

Member, Subcommittee on Finance, Tennessee Valley Authority Advisory Panel of the Southern States Energy Board, 1986-1987

Member, Electric Utility Generation Technology Advisory Panel, Office of Technology Assessment, 1984 - 1985

Member, Natural Gas Availability Advisor Panel, Office of Technology Assessment, 1983-1984

Participant, Workshop on Energy and the Consumer, University of Virginia, November 1983

Participant, Workshop on Unconventional Natural Gas, Office of Technology Assessment, July 1983

Participant, Seminar on Alaskan Oil Exports, Congressional Research Service, June 1983

Member, Thermal Insulation Subcommittee, National Institute of Building Sciences, 1981-1982

Round Table Discussion Leader, The Energy Situation: An Open Field For Sociological Analysis, 51st Annual Meeting of the Eastern Sociological Society, New York, March, 1981

Member, Building Energy Performance Standards Project Committee, Implementation Regulations Subcommittee, National Institute of Building Sciences, 1980-1981

Participant, Summer Study on Energy Efficient Buildings, American Council for an Energy Efficient Economy, August 1980

Member, University Committee on International Student Policy, Northeastern University, 1978-1979

Chairman, Session on Dissent and Societal Reaction, 45th Annual Meeting of the Eastern Sociological Society, April, 1975

Member, Papers Committee, 45th Annual Meeting of the Eastern Sociological Society, 1975

Student Representative, Programs, Curricula and Courses Committee, Division of Behavioral and Social Sciences, University of Maryland, 1973-1974

President, Graduate Student Organization, Department of Sociology, University of Maryland, 1973-1974

HONORS AND AWARDS:

Ester Peterson Award for Consumer Service, 2010

American Sociological Association, Travel Grant, Uppsala, Sweden, 1978

Fulbright-Hayes Doctoral Research Abroad Fellowship, Egypt, 1976-1977

Council on West European Studies Fellowship, University of Grenoble, France, 1975

Yale University Fellowship, 1974-1978

Alpha Kappa Delta, Sociological Honorary Society, 1973

Phi Delta Kappa, International Honorary Society, 1973

Graduate Student Paper Award, District of Columbia Sociological Society, 1973

Science Fiction Short Story Award, University of Maryland, 1973

Maxwell D. Taylor Award for Academic Excellence, Arabic, United States Defense Language Institute, 1971

Theodore Goodman Memorial Award for Creative Writing, City College of New York, 1968

New York State Regents Scholarship, 1963-1968

National Merit Scholarship, Honorable Mention, 1963

PUBLICATIONS:

ENERGY

Books and Chapters

"Recognizing the Limits of Markets, Rediscovering Public Interest in Utilities," in Robert E. Willett (ed), *Electric and Natural Gas Business: Understanding It!* (2003 and Beyond) (Houston: Financial Communications: 2003)

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"Prudent Resource Acquisition in a Complex Decision Making Environment: Multidimensional Analysis Highlights the Superiority of Efficiency," *Current Approaches to Integrated Resource Planning, 2011 ACEEE National Conference on Energy Efficiency as a Resource*, Denver, September 26, 2011

"The Implications of Fukushima: The US perspective**,"** Bulletin of the Atomic Scientists July/August 2011 67: 8-13

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"Too Much Deregulation or Not Enough," *Natural Gas and Electricity*, June 2005

"Real Energy Crisis is $200 Billion Natural Gas Price Increase," Natural Gas and Electricity, August 2004

"Regulators Should Regain Control to Prevent Abuses During Scarcity," Natural Gas, August 2003

"Economics of Power: Heading for the Exits, Deregulated Electricity Markets Not Working Well," *Natural Gas*, 19:5, December 2002

"Let's Go Back," Public Power, November-December 2002

"Conceptualizing and Measuring the Burden of High Energy Prices," in Hans Landsberg (Ed.), High Energy Costs: Assessing the Burden (Washington, D.C.: Resources For the Future, 1982)

"Energy Efficiency Investments in Single Family Residences: A Conceptualization of Market Inhibitors," in Jeffrey Harris and Jack Hollander (Eds.), *Improving Energy Efficiency in Buildings: Progress and Problems* (American Council for An Energy Efficient Economy, 1982)

"Policy Packaging for Energy Conservation: Creating and Assessing Policy Packages," in Jeffrey Harris and Jack Hollander (Eds.), *Improving Energy Efficiency in Buildings: Progress and Problems* (American Council for An Energy Efficient Economy, 1982)

"The Role of Consumer Assurance in the Adoption of Solar Technologies," *International Conference on Consumer Behavior and Energy Policy,* August, 1982

"Energy and the Poor," *Third International Forum on the Human Side of Energy*, August, 1982

"Energy Price Policy and the Elderly," *Annual Conference, National Council on the Aging*, April, 1982

"Energy and Jobs: The Conservation Path to Fuller Employment," *Conference on Energy and Jobs conducted by the Industrial Union Department of the AFL-CIO,* May 1980

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Record Prices, Record Oil Company Profits: The Failure Of Antitrust Enforcement To Protect American Energy Consumers (Consumer Federation of America, Consumers Union, September 2004)

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Spring Break in the U.S. Oil Industry: Price Spikes, Excess Profits and Excuses (Consumer Federation of America, October 2003)

How Electricity Deregulation Puts Pressure On The Transmission Network And Increases It's Cost (Consumer Federation of America, Consumers Union and U.S. PIRG, August 2003)

A Discouraging Word (or Two, or Three, or Four) About Electricity Restructuring in Texas, Pennsylvania, New England and Elsewhere Consumer Federation of America, U.S. Public Interest Research Group and Consumers Union, March 2003)

All Pain, No Gain: Restructuring and Deregulation in the Interstate Electricity Market (Consumer Federation of America, September 2002)

U.S. Capitalism and the Public Interest: Restoring the Balance in Electricity and Telecommunications Markets (Consumer Federation of America, August 2002)

Electricity Deregulation and Consumers: Lesson from a Hot Spring and a Cool Summer (Consumer Federation of America, August 30, 2001)

Ending the Gasoline Price Spiral: Market Fundamentals for Consumer-Friendly Policies to Stop the Wild Ride (Consumer Federation of America, July 2001)

Analysis of Economic Justifications and Implications of Taxing Windfall Profits in the California Wholesale Electricity Market (Consumer Federation of America and Consumers Union, June 13, 2001)

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A Consumer Issue Paper on Electric Utility Restructuring (American Association of Retired Persons and the Consumer Federation of America, January, 1997)

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The Past as Prologue II: The Macroeconomic Impacts of Rising Energy prices, A Comparison of Crude Oil Decontrol and Natural Gas Deregulation, March, 1982

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Natural Gas Decontrol: A Case of Trickle-Up Economics, January 1982

A Comprehensive Analysis of the Costs and Benefits of Low Income Weatherization and Its Potential Relationship to Low Income Energy Assistance, June 1981

Summary of Market Inhibitors, February 1981

Program Models and Program Management Procedures for the Department of Energy's Solar Consumer Assurance Network Project: A Rapid Feedback Evaluation, February 1981

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COMMUNICATIONS AND MEDIA

Books and Chapters

The Future of Journalism: Addressing Pervasive Market Failure with Public Policy," in R.W. McChesney and Victor Picard (eds.), Will the Last Reporter Turn out the Lights (New York: New Press, 2011)

"Broadband in America: A Policy of Neglect is not Benign," in Enrico Ferro, Yogesh K. Dwivedi, J. Ramon Gil-Garcia, and Michael D. Williams, Eds., *Overcoming Digital Divides: Constructing an Equitable and Competitive Information Society,"* IGI Global Press, 2009.

"Political Action And Internet Organization: An Internet-Based Engagement Model," in Todd Davies and Seeta Pena Gangaharian, Eds., *Online Deliberation: Design, Research and Practice,* CSLI press.

"When Counting Counts: Marrying Advocacy and Academics in the Media Ownership Research Wars at the FCC," forthcoming in Lynn M. Harter, Mohan J. Dutta, and Courtney Cole, Eds., *Communicating for Social Impact: Engaging Communication Theory, Research, and Pedagogy***,** Hampton Press.

The Case Against Media Consolidation (Donald McGannon Communications Research Center, 2007)

Open Architecture as Communications Policy (Stanford Law School, Center for Internet and Society: 2004)

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Cable Mergers and Monopolies: Market Power In Digital Media and Communications Networks (Washington, D.C.: Economic Policy Institute, 2002)

"When Law and Social Science Go Hand in Glove: Usage and Importance of Local and National News Sources, Critical Questions and Answers for Media Market Analysis," forthcoming in, Philip Napoli, Ed. *Media Diversity and Localism: Meaning and Metrics, (*Lawrence Erlbaum, 2007)

"The Importance of Open Networks in Sustaining the Digital Revolution," in Thomas M. Lenard and Randolph J. May (Eds.) *Net Neutrality or Net Neutering* (New York, Springer, 2006)

"Reclaiming The First Amendment: Legal, Factual And Analytic Support For Limits On Media Ownership," Robert McChesney and Benn Scott (Eds), *The Future of Media* (Seven Stories Press, 2005)

"Building A Progressive Media And Communications Sector," Elliot Cohen (Ed.), News Incorporated: Corporate Media Ownership And Its Threat To Democracy (Prometheus Books, 2005)

"Hyper-Commercialism In The Media: The Threat To Journalism And Democratic Discourse," Snyder-Gasher-Compton-(Eds), *Converging Media, Diverging Politics: A Political Economy Of News In The United States And Canada* (Lexington Books, 2005)

"The Digital Divide Confronts the Telecommunications Act of 1996: Economic Reality versus Public Policy," in Benjamin M. Compaine (Ed.), *The Digital Divide: Facing a Crisis or Creating a Myth?* (Cambridge: MIT Press, 2001)

Articles and Papers:

"The Long History and Increasing Importance of Public Service Principles For 21st Century Public Digital Communications Networks," *Journal on Telecommunications and High Technology Law*, forthcoming

"From the Public Switched Telephone Network to the Public Digital Communications Network: Interconnection, Interoperability, Universal Service & Innovation at the Edge," *Interconnection Policy for the Internet Age, The Digital Broadband Migration: The Future of Internet-Enabled Innovation, Silicon Flatirons,* February 10-11, 2013

"Why Growing Up is Hard to Do: Institutional Challenges for Internet Governance in the "Quarter Life Crisis of the of the Digital Revolution," *Journal on Telecommunications and High Technology Law,* 2013. 11(1).

"Structured Viral Communications: The Political Economy and Social Organization of Digital Disintermediation," *Journal on High Telecommunications and High Technology Law,* 9:1, 2011.

"Crowd Sourcing Enforcement: Building a Platform for Participatory Regulation in the Digital Information Age," presentation at *The Digital Broadband Migration: The Dynamics of Disruptive Innovation*, *Silicon Flatirons Ctr*. Feb. 12, 2011

"The Central Role of Wireless in the 21st Century Communications Ecology: Adapting Spectrum and Universal Service Policy to the New Reality," *Telecommunications Policy Research Conference*, September 2011

"Round #1 in the Digital Intellectual Property Wars: Economic Fundamentals, Not Piracy, Explain How Consumers and Artists Won in the Music Sector," Telecommunications Policy Research Conference, September 2008.

"When The Market Does Not Reign Supreme: Localism And Diversity In U.S. Media Policy," *International Communications Association*, forthcoming, May 2008

"Minority Programming: Still at The Back of the Bus," *International Communications Association*, May 2008, with Adam Lynn

"Traditional Content Is Still King as the Source of Local News and Information," *International Communications Association*, forthcoming, May 2008

"Junk Science And Administrative Abuse In The Effort Of The FCC To Eliminate Limits On Media Concentration," *International Communications Association,* May 2008.

"Contentless Content Analysis: Flaws In The Methodology For Analyzing The Relationship Between Media Bias And Media Ownership," forthcoming, *International Communications Association,* May 2008.

"Network Neutrality," *Toll Roads? The Legal and Political Debate Over Network Neutrality,* University of San Francisco Law School, January 26, 2008

"The Lack of Racial and Gender Diversity in Broadcast Ownership and The Effects of FCC Policy: An Empirical Analysis," *Telecommunications Research Policy Conference*, September 2007, with Derek Turner

"New Media and Localism: Are Local Cable Channels and Locally Focused Websites Significant New and Diverse Sources of Local News and Information? An Empirical Analysis," *Telecommunications Research Policy Conference*, September 2007, with Adam Lynn

"A Case Study of Why Local Reporting Matters: Photojournalism Framing of the Response to Hurricane Katrina in Local and National Newspapers," *International Communications Association*, May 2007.

"Will the FCC Let Local Media Rise from the Ashes of Conglomerate Failure," *International Communications Association*, May 2007.

"The Failure of Federal Authorities to Protect American Energy Consumers From Market Power and Other Abusive Practices," *Loyola Consumer Law Review,* 19:4 (2007)

"The Central Role of Network Neutrality in the Internet Revolution," *Public Interest Advocacy Center*, Ottawa Canada, November 24, 2006

"Governing the Spectrum Commons," September 2006. *Telecommunications Policy Research Conference*, October 2006

"Accessing the Knowledge Commons in the Digital Information Age," *Consumer Policy Review,* May/June 2006

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"Direct Testimony and Exhibits of Dr. Mark N. cooper on Behalf of the Division of consumer Advocacy," In the Matter of Public Utilities Commission Instituting a Proceeding on Communications, Including an Investigation of the Communications Infrastructure in Hawaii, docket No. 7701, March 24, 1995

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"Statement of Dr. Mark N. Cooper," DPUC Investigation into The Southern New England Cost of Providing Service, Docket No. 94-10-01, January 31, 1995

"Statement of Dr. Mark N. Cooper," DPUC Exploration of Universal Service Policy Options, Docket No. 94-07-08, November 30, 1994

"Statement of Dr. Mark N. Cooper," DPUC Investigation of Local Service Options, including Basic Telecommunications Service Policy Issues and the Definition of Basic Telecommunications Service, Docket No. 94-07-07, November 15, 1994

"Testimony of Dr. Mark N. Cooper on Behalf of Attorney General of the Commonwealth of Kentucky, Utility and Rate Intervention Division, before the Public Service Commission, Commonwealth of Kentucky, Case No. 94-121, August 29, 1994

"Testimony of Dr. Mark N. Cooper on Behalf of the American Association of Retired Persons," before the Public Utilities Commission of Ohio, In the Matter of the Application of the Ohio Bell Telephone Company for Approval of an Alternative Form of Regulation and In the Matter of the Complaint of the Office of Consumers' Counsel, v. Ohio Bell Telephone Company, Relative to the Alleged Unjust and Unreasonable Rates and Charges, Case Nos. 93-487-TP-ALT, 93-576-TP-CSS, May 5, 1994

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"Comments of Dr. Mark N. Cooper on Behalf of the American Association of Retired Persons," Before the Tennessee Public Service Commission, Inquiry for Telecommunications Rule making Regarding Competition in the Local Exchange, Docket No. 94-00184, March 15, 1994

"Rebuttal Testimony of Dr. Mark N. Cooper on Behalf of the Virginia Citizens Consumer Council, Inc., before the State Corporation Commission at Richmond, Commonwealth of Virginia, In the Matter of Evaluating Investigating the Telephone Regulatory Case No. PUC930036 Methods Pursuant to Virginia Code S 56-235.5, March 15, 1994

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"Direct Testimony of Dr. Mark N. Cooper on Behalf of the Office of Consumer Counsel," before the Public Utilities Commission of the State of Colorado, In the Matter of the Investigatory Docket Concerning Integrated Service Digital Network, Docket No. 92I-592T

"Direct Testimony of Dr. Mark N. Cooper on Behalf of the People's Counsel," before the Florida Public Service Commission, Comprehensive Review of the Revenue Requirement and Rate Stabilization Plan of Southern Bell Telephone and Telegraph Company, Docket No. 900960-TL, November 16, 1992

"Direct Testimony of Dr. Mark N. Cooper on Behalf of the American Association of Retired Persons," before the Florida Public Service Commission, Comprehensive Review of the Revenue Requirement and Rate Stabilization Plan of Southern Bell Telephone and Telegraph Company, Docket No. 900960-TL, November 16, 1992

"Testimony of Dr. Mark N. Cooper" before the Regulatory Flexibility Committee, General Assembly, State of Indiana, August 17, 1992

"Testimony of Dr. Mark N. Cooper On Behalf of the Consumer Advocate," before the Public Service Commission of South Carolina, Petition of the Consumer Advocate for the State of South Carolina to Modify Southern Bell's Call Trace Offering, Docket No. 92-018-C, August 5, 1992

"Telecommunications Infrastructure Hoax," before the Public Service Commission of Colorado, Conference on ISDN for the Rest of Us, April 23, 1992

"Testimony of Dr. Mark N. Cooper on Behalf of the Consumer Federation of America," before the Corporation Commission of the State of Oklahoma, In the Matter of the Corporation Commission's Notice of Inquiry Regarding Telecommunications Standards in Oklahoma, Cause No. PUD 1185, February 28, 1992

"Testimony of Dr. Mark N. Cooper on Behalf of the Consumer Federation of America," before the Georgia Public Service Commission, In the Matter of A Southern Bell Telephone and Telegraph Company Cross-subsidy, Docket No. 3987-U, February 12, 1992

"Testimony of Dr. Mark N. Cooper on Behalf of the Consumer Federation of America," before the Arkansas Public Service Commission, in the Matter of an Inquiry into Alternative Rate of Return Regulation for Local Exchange Companies, Docket No. 91-204-U, February 10, 1992

"Statement on Behalf of the Consumer Federation of America on HB 1076," before the Missouri General Assembly, January 29, 1992

"Testimony on behalf of the American Association of Retired Persons and the Consumer Federation of America," before the Legislative P.C. 391 Study Committee of the Public Service Commission of Tennessee, January 13, 1992

"Direct Testimony on Behalf of the "Consumer Advocate," Public Service Commission State of South Carolina, In the Matter of the Application of Southern Bell Telephone and Telegraph Company for Approval of Revision to its General Subscribers Service Tariff (Caller ID), Docket No. 89-638-C, December 23, 1991

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"Comments of the Consumer Federation of America," Before the Public Service Commission, State of Maryland, In the Matter of a Generic Inquiry by the Commission Into the Plans of the Chesapeake and Potomac Telephone Company of Maryland to Modernize the Telecommunications Infrastructure, Case No. 8388, November 7, 1991

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"On Behalf of the Office of Consumer Advocate," before the State of Iowa, Department of Commerce, Utilities Division, In Re: Caller ID and Related Custom Service, Docket No. INU-90-2, December 3, 1990

"On Behalf of the Office of Public Counsel," before the Florida Public Service Commission, In Re: Proposed Tariff Filings by Southern Bell Telephone and Telegraph Company When a Nonpublished Number Can be Disclosed and Introducing Caller ID to Touchstar Service, Docket No. 891194-TI, September 26, 1990

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"On Behalf of Mississippi Legal Services Coalition, in the Matter of Notice by Mississippi Power and Light of Intent to Change Rates" Before the Mississippi Public Service Commission, April 15, 1985

"On Behalf of the Universal Service Alliance, in the Matter of the Application of New York Telephone Company for Changes in it Rates, Rules, and Regulations for Telephone Service, State of New York Public Service Commission, Case No. 28961, April 1, 1985

"On Behalf of North Carolina Legal Services, in the Matter of Application of Continental Telephone Company of North Carolina for an Adjustment of its Rates and Charges, Before the North Carolina Utilities Commission, Docket No. P-128, Sub 7, February 20, 1985

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"On Behalf of Mississippi Legal Services Coalition in the Matter of the Citation to Show Cause Why the Mississippi Power and Light Company and Middle South Energy Should not Adhere to the Representation Relied Upon by the Mississippi Public Service Commission in Determining the Need and Economic Justification for Additional Generating Capacity in the Form of A Rehearing on Certification of the Grand Gulf Nuclear Project," Before the Mississippi Public Service Commission, Docket No. U-4387, August 13, 1984

"On Behalf of the Mississippi Legal Services Corporation Re: Notice of Intent to Change Rates of South Central Bell Telephone Company for Its Intrastate Telephone Service in Mississippi Effective January 1, 1984," before the Mississippi Public Service Commission, Docket No. U-4415, January 24, 1984

"The Impact of Rising Energy Prices on the Low Income Population of the Nation, the South, and the Gulf Coast Region," before the Mississippi Public Service Commission, Docket No. U4224, November 1982

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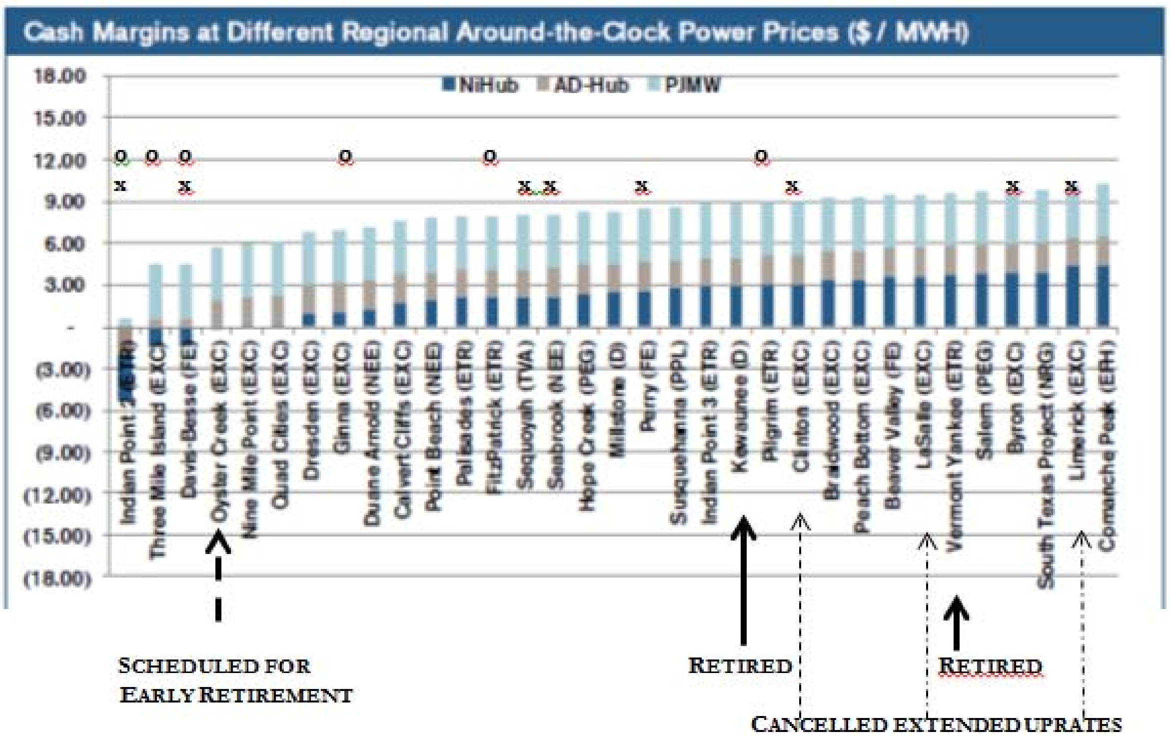
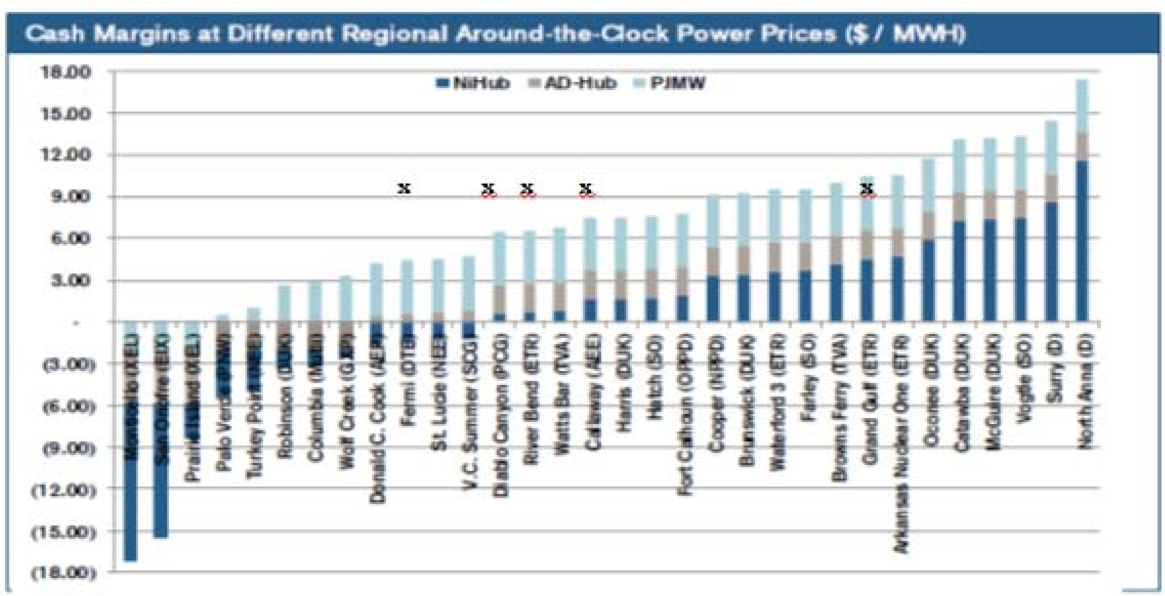
"The Impact of Rising Utility Rates on he Budgets of Low Income Households in the Region of the United States Served by the Mississippi Power Company and South Central Bell Telephone Company," before the Chancery Court of Forrest County, Mississippi, October 6, 1982

"The Impact of Rising Energy Prices on the Low Income Population of the Nation, the South and the Gulf Coast Region," before the Mississippi Public Service Commission, Docket No. U-4190, August 1982

MERCHANT 'CASH MARGINS' AT DIFFERENT POWER HUBS



REGULATED 'CASH MARGINS' AT DIFFERENT POWER HUBS



Legend: o= reactors that are being considered for early shut down
x= license renewals pending or expected in the near future.

Source: Credit Suisse, *Nuclear… The Middle Age Dilemma?, Facing Declining Performance, Higher Costs, Inevitable Mortality,* February 19, 2013, p. 11.

Comments by Alliance for Nuclear Accountability, Beyond Nuclear, Blue Ridge Environmental Defense League, Center for a Sustainable Coast, Citizens Allied for Safe Energy, Citizens Environmental Alliance, Don't Waste Michigan, Ecology Party of Florida, Friends of the Earth, Georgia Women's Action for New Directions, Hudson River Sloop Clearwater, Missouri Coalition for the Environment, NC WARN, Nevada Nuclear Waste Task Force, New England Coalition, Nuclear Information and Resource Service, Nuclear Watch South, Physicians for Social Responsibility, Public Citizen, Riverkeeper, San Luis Obispo Mothers for Peace, SEED Coalition, Sierra Club Nuclear Free Campaign, and Southern Alliance for Clean Energy on Scope of Waste Confidence Environmental Impact Statement

January 2, 2013

I. INTRODUCTION

Alliance for Nuclear Accountability, Beyond Nuclear, Blue Ridge Environmental Defense League, Center for a Sustainable Coast, Citizens Allied for Safe Energy, Citizens Environmental Alliance, Don't Waste Michigan, Ecology Party of Florida, Friends of the Earth, Georgia Women's Action for New Directions, Hudson River Sloop Clearwater, Missouri Coalition for the Environment, NC WARN, Nevada Nuclear Waste Task Force, New England Coalition, Nuclear Information and Resource Service, Nuclear Watch South, Physicians for Social Responsibility, Public Citizen, Riverkeeper, San Luis Obispo Mothers for Peace, SEED Coalition, Sierra Club Nuclear Free Campaign, and Southern Alliance for Clean Energy ("the Organizations") hereby submit comments in response to the U.S. Nuclear Regulatory Commission's "Request for comments on the notice of intent to prepare and (sic) environmental impact statement and notice of public meetings", 77 Fed. Reg. 65,137 (Oct. 25, 2012) ("Scoping Notice" or "Notice"). All of the Organizations are neighbors of existing or proposed nuclear power plants, and most have either intervened or plan to intervene in NRC proceedings for the licensing or re-licensing of nuclear power plants.

These comments are supported by the technical and factual declarations of Dr. Arjun Makhijani, Dr. Gordon R. Thompson, and Phillip Musegaas, as follows:

- Declaration of Dr. Arjun Makhijani Regarding the Scope of Proposed Waste Confidence Environmental Impact Statement (Jan. 1, 2013) (Attachment 1);

- Declaration of 2 January 2013 by Gordon R. Thompson: Recommendations for the US Nuclear Regulatory Commission's Consideration of Environmental Impacts of Long-Term, Temporary Storage of Spent Nuclear Fuel or Related High-Level Waste (Attachment 2); and

- Declaration of Phillip Musegaas Regarding the Scope of the Proposed Waste Confidence Environmental Impact Statement (Jan. 2, 2013) (Attachment 3).

These declarations are attached and incorporated herein by reference.

II. FACTUAL BACKGROUND

In June 2012, in *State of New York v. NRC,* 681 F.3d 471 (D.C. Cir. 2012)*,* the U.S. Court of Appeals for the D.C. Circuit vacated the Nuclear Regulatory Commission's 2010 Waste Confidence Decision ("WCD") and Temporary Storage Rule ("TSR") (75 Fed. Reg. 81,037 and 75 Fed. Reg. 81,032 (Dec. 23, 2010), respectively) and remanded them to the agency for study of the environmental impacts of storing spent fuel indefinitely if no permanent repository is licensed or if licensing of a repository is substantially delayed. As the Court held, "the Commission's evaluation of the risks of spent nuclear fuel is deficient" because "the Commission did not calculate the environmental effects of failing to secure permanent storage – a possibility that cannot be ignored." 681 F.3d at 473. *See also id.* at 478 ("We hold that the WCD must be vacated as to its revision of Finding 2 because the WCD fails to properly analyze the environmental effects of its permanent disposal conclusion."); and *id.* at 479 ("The Commission apparently has no long-term plan other than hoping for a geologic repository. If the government continues to fail in its quest to establish one, then [spent nuclear fuel] will seemingly be stored on site at nuclear plants on a permanent basis. The Commission can and must assess the potential impacts of such a failure.").

The Court also ordered the NRC to study the "future dangers and key consequences" of spent fuel pool fires and to evaluate the risks of spent fuel pool leakage during sixty years after the expiration of the plant's license. *Id.* at 479. With respect to these risks, the Court concluded that that "the Commission's EA and resulting FONSI are not supported by substantial evidence on the record because the Commission failed to properly examine the risk of leaks in a forward-looking fashion and failed to examine the potential consequences of pool fires." *Id.* The Court ordered the NRC to conduct a proper environmental analysis, and "examine both the probability of a given harm occurring and the consequences of that harm if it does occur." *Id* at 482.

On October 27, 2012, a few months after the Court of Appeals issued its decision in *State of New York*, the NRC issued the Scoping Notice, which provided that the agency intended to prepare an environmental impact statement (the "Waste Confidence EIS") to support its update of the WCD and TSR. The Notice, however, gives very little information regarding the NRC's current thinking about the appropriate scope of the Waste Confidence EIS. According to the Notice, the purpose of the proposed EIS is to respond to the decision in *State of New York.* The Notice also states that the EIS will "form the technical basis for the revision of the Waste Confidence Decision and Rule." 77 Fed. Reg. at 65,138. But contrary to NRC regulation 10 C.F.R. § 51.27(a)(2), the Notice does not identify the "proposed action" that is to be evaluated in the EIS. In a subsequent letter, Chairman Macfarlane asserted that the "proposed action" is the update to the WCD. Waste Confidence Rule. Letter from Allison M. Macfarlane to Diane Curran (Dec. 5, 2012) ("Macfarlane Letter") (ML 12319A309).

The Notice also fails to comply with NRC regulations that require a notice of intent to prepare an EIS to identify "possible alternatives," to the extent sufficient information is available. 10 C.F.R. § 51.27(a)(2). Indeed, the Scoping Notice does not identify a single alternative, nor does it explain the reason for the omission. Subsequently, in her letter of December 5, 2012, the NRC Chairman stated that the no action alternative is "a decision not to prepare the rule and instead to conduct a site-specific analysis of post-licensed life spent fuel storage for each NRC licensing action that relies on Waste Confidence." Macfarlane Letter at 1.

The Notice is deficient in other ways as well. For example, it asserts that "[p]ossible" scenarios to be analyzed in the EIS "include temporary spent fuel storage after cessation of reactor operation until a repository is made available in either the middle of the century or at the end of the century, and storage of spent fuel if no repository is made available by the end of the century." 77 Fed. Reg. at 65,138. But it does not identify the time frame covered by the third scenario, *i.e.,* "storage of spent fuel if no repository is made available by the end of the century." This should be taken to mean an analysis of the impacts of storage in case no repository ever becomes available. Such an intent for the third scenario was indicated by the NRC Staff in the material presented at the public meeting on November 14, 2012. One of the scenarios was described in the slides as: "Continued storage in the event a repository is *not available*."[1]

The Notice also gives an extremely brief description of the "affected environment," stating that the affected environment "may include a set of general characteristics and associated ranges to bound the environmental analysis of spent fuel storage throughout the United States." *Id.* at 65,138. The NRC does not provide any of these characteristics, but merely emphasizes that the focus of the EIS will be "generic." *Id.*

The Notice then provides a list of nine tasks that it will use the scoping process to accomplish:

a. Define the proposed action that is to be the subject of the EIS;

b. Determine the scope of the EIS and identify the significant issues to be analyzed in depth, including potential spent fuel storage scenarios for evaluation, such as availability of a delayed permanent repository towards the end of the century;

c. Identify and eliminate from detailed study those issues that are peripheral or that are not significant. . .;

d. Identify any environmental assessments and other EISs that are being or will be prepared that are related to but are not part of the scope of the EIS being considered;

e. Identify other environmental review and consultation requirements related to the proposed action;

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[1] U.S. Nuclear Regulatory Commission. Office of Nuclear Material Safety and Safeguards. Waste Confidence Directorate. *Scoping Process for the Waste Confidence Environmental Impact Statement*. Washington, DC: NRC, November 14, 2012. On the Web at http://pbadupws.nrc.gov/docs/ML1231/ML12314A352.pdf. [Slide presentation], Slide 20, italics in the original

f. Indicate the relationship between the timing of the preparation of the environmental analyses and the Commission's tentative planning and decision-making schedule;

g. Identify any cooperating agencies and, as appropriate, allocate assignments for preparation and schedules for completing the EIS to the NRC and any cooperating agencies;

h. Describe how the EIS will be prepared, including any contractor assistance to be used . . . ; and

i. Obtain public input on potential locations for future public meetings on the draft EIS.

77 Fed. Reg. at 65,138-39. Notably, this task list does not include the identification of alternatives, although NRC regulations list it as one of the objectives of a scoping progress. 10 C.F.R. § 51.27(a)(2).

Given these deficiencies, a group of environmental organizations and individuals requested the NRC Commissioners to withdraw the Scoping Notice.[2] They contended that the NRC had violated the National Environmental Policy Act ("NEPA") and NRC implementing regulations (including, 10 C.F.R. § 51.27(a)) by failing to describe the proposed action or to identify alternatives. Therefore, they argued that the Scoping Notice failed to give the public sufficient information on which to develop comments on the appropriate scope of the EIS proposed by the NRC. The NRC Commissioners rejected the request to withdraw the Notice in the Macfarlane Letter. According to the Macfarlane Letter, the Scoping Notice was not required to comply with 10 C.F.R. § 51.27(a) because the NRC Staff director did not determine that the EIS should be prepared; rather, the Commission exercised its discretion in directing the Staff to prepare the EIS to support an update to the Waste Confidence Rule. Macfarlane Letter at 2. The letter did not provide which regulations, if any, should therefore govern the NRC's Scoping Notice.

The NRC held scoping meetings at NRC headquarters on November 14, 2012 and December 5, 2012, and provided for remote participation through webcasts. In the scoping meetings the NRC Staff presented slides with a schedule for completion of the EIS. Scoping Process for the Waste Confidence Environmental Impact Statement (Nov. 14, 2012)

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[2] Letter from Diane Curran, Geoff Fettus, and Mindy Goldstein to NRC Commissioners (Nov. 8, 2012) (ML12340A149). The organizations and individuals represented in the letter were: Beyond Nuclear, Blue Ridge Environmental Defense League, Center for a Sustainable Coast, Citizens Allied for Safe Energy, the Ecology Party of Florida, Friends of the Coast, Friends of the Earth, Georgia Women's Action for New Directions, Hudson River Sloop Clearwater, Institute for Energy and Environmental Research, Dan Kipnis, Missouri Coalition for the Environment, Natural Resources Defense Council, National Parks Conservation Association, NC Waste Reduction and Awareness Network, Nevada Nuclear Waste Task Force, New England Coalition, Northwest Environmental Advocates, Nuclear Information and Resource Service, Mark Oncavage, Physicians for Social Responsibility, Riverkeeper, the SEED Coalition, San Luis Obispo Mothers for Peace, and Southern Alliance for Clean Energy.

(ML12314A352). The schedule predicts that a draft Waste Confidence EIS will be issued in the fall of 2013, a final Waste Confidence EIS will be issued in August 2014, and the final Waste Confidence Rule will be issued in September 2014. *Id.,* slide 24.

III. COMMENTS

A. Defining the Proposed Action and its Alternatives

1. The proposed action is to update the WCD to permit reactor licensing and re-licensing

The Organizations agree with the NRC that the proposed action is the update of the WCD. 77 Fed. Reg. at 65,138; Macfarlane Letter at 1. But updating the WCD is not the entirety of the action. In addition, the action is a safety determination that permits the licensing and re-licensing of reactors. As stated in the Scoping Notice, "Waste Confidence, though applicable only to the period after the licensed life of a reactor, is part of the basis for agency licensing decisions on new reactor licensing, reactor license renewal, and independent spent fuel storage installation licensing." 77 Fed. Reg. at 65,138. *See also State of New York,* 681 F.3d at 476 (the WCD is a part of every reactor licensing decision, and may not be treated as "separate from the individual licensing decisions it enables.")

The WCD constitutes the aspect of reactor licensing decisions that involves predictive determinations of whether there is reasonable assurance that spent reactor fuel can be safely stored and disposed of. These findings are necessary under the Atomic Energy Act ("AEA") before reactors may be licensed. *Denial of Petition for Rulemaking (Natural Resources Defense Council),* 42 Fed. Reg. 34,391 (July 5, 1977), *aff'd, Natural Resources Defense Council v. NRC,* 582 F.2d 166, 169 (2d Cir. 1978). If the Commission lacks sufficient information to make these reasonable assurance findings, it may not issue new reactor licenses or re-license operating reactors. *Id. See also* 42 U.S.C. § 2133 (forbidding issuance of a reactor license if, in the opinion of the Commission, it would be "inimical to the public health and safety").

As discussed in more detail below, the no action alternative to this proposed action would simply preserve the status quo, in which all reactor licensing and re-licensing decisions have been suspended pending the updating of the WCD. *Calvert Cliffs Nuclear Project, L.L.C.* (Calvert Cliffs Nuclear Power Plant, Unit 3), et al., CLI-12-16 , __ NRC __ (slip op.) (Aug. 7, 2012). Under the AEA, licensing and re-licensing could not resume unless and until the NRC had issued an adequately supported WCD.

2. The no-action alternative is not to issue a WCD and not to license or re-license reactors.

As the courts have long recognized, "the requirement for a thorough study and a detailed description of alternatives" is the "linchpin" of an EIS. *Monroe County Conservation Council, Inc. v. Volpe*, 472 F.2d 693, 697-8 (2nd Cir. 1972) (internal citations omitted). This emphatic characterization of the importance of alternatives in an EIS is rooted in the Council of Environmental Quality regulations, which describe the alternatives requirement as the "heart" of the environmental impact statement. 40 C.F.R. § 1502.14; *see also* 10 C.F.R. Part 51, Subpt. A, App. A (5). NEPA thus requires the NRC to include in its Waste Confidence EIS a thorough and detailed review of alternatives to issuance of a generic WCD, including the alternative of not issuing the decision at all (the "no-action alternative"). *See* 40 C.F.R. § 1502.14(d) and 10 C.F.R. Part 51, Subpt. A, App. A (4).

In her December 5, 2012 letter, Chairman Macfarlane asserts that the "no action alternative is a decision not to prepare the rule and instead to conduct a site-specific analysis of post-licensed life spent fuel storage for each NRC licensing action that relies on Waste Confidence." *Id.* at 1. The Macfarlane Letter suggests that the only reason the NRC might be unable to issue an updated WCD is that it raises too many site-specific issues.

The Organizations agree that conducting a site-specific analysis is necessary with respect to some aspects of the environmental impacts of spent fuel storage. *See* discussion below in Section C; *see also,e.g.,* Makhijani Declaration at Section 9 and Musegaas Declaration at 4(d). Many of the important environmental issues related to long-term spent fuel storage, such as degradation of spent fuel during prolonged storage, are generic, however. Therefore it is not the principal reason that the NRC is unlikely to be able to issue an updated WCD in the proposed timeframe.

The single greatest reason that the NRC will not be able to complete a scientifically valid EIS and therefore issue an updated WCD based on a sound environmental impact analysis is that it has not given itself enough time to conduct the necessary research and analyses to support reasonable assurance findings with respect to the safety of long-term spent fuel storage. As discussed above, the Commission expects to issue a draft Waste Confidence EIS in the fall of 2013. That is only enough time, however, to summarize currently available information about the risks of long-term spent fuel storage. But the existing information is grossly inadequate to support any reasonable predictive findings about the safety of such long-term spent fuel storage. There is no existing environmental or other study that has even attempted to predict the environmental impacts of storing spent fuel on site for hundreds of years, or perhaps indefinitely. Indeed, all other studies have been premised on the opposite conclusion – that a repository will be available in the relative near future. We are aware of only one study that even commenced the work of evaluating such matters: the "Long-Term Waste Confidence Update Project," in which the NRC proposes to assess the environmental impacts of storing spent fuel for 200 years after cessation of licensing. *See* the WCD, 75 Fed. Reg. at 81,040.[3] But as the Commission is well aware, work on the Long-Term Waste Confidence Update Project had only just begun at the time of the D.C. Circuit's decision, and it is far from complete.

The NRC Staff estimates that the Long-Term Waste Confidence Update Project EIS will take until 2019 to finish. COMSECY-12-0016, Memorandum from R.W. Borchardt to NRC Commissioners re: Approach for Addressing Policy Issues Resulting from Court Decision to Vacate Waste Confidence Decision and Rule at 3 (July 9, 2012) ("COMSECY-12-0016"). Two preliminary studies issued as part of the Project support the Staff's seven-year time estimate by

[3] As the Court observed in *State of New York,* that rulemaking may address "some or all of the problems" that it remanded to the agency. 681 F.3d at 483.

demonstrating (a) the complexity of the issues raised by long-term and indefinite spent fuel storage and (b) the Commission's lack of knowledge on the subject. The first study, issued for comment in December 2011, sets forth a series of topics that must be addressed in the Long-Term Waste Confidence Update Project EIS, including the degree to which nuclear power will be used in the future, the nature of future dry cask storage and transportation technology, prospects for long-term maintenance of institutional and regulatory control, and accidents to be considered. Draft Report for Comment: Background and Preliminary Assumptions for an Environmental Impact Statement – Long-Term Waste Confidence Update (Dec. 2011) (the "Preliminary Assumptions Document"). While the NRC proposed, as a preliminary matter, to make assumptions about many of these topics, comments show that they may not be assumed and instead should be the *subject* of the EIS for the Long-Term Waste Confidence Update Project. *See* comments by Institute for Energy and Environmental Research, Blue Ridge Environmental Defense League, Natural Resources Defense Council, Riverkeeper, and Southern Alliance for Clean Energy on NRC Report Updating Preliminary Assumptions for an EIS on Long-Term Spent Fuel Storage Impacts (Feb. 17, 2012) (copy attached as Attachment 4).

The second study, issued for comment in May 2012, identifies an array of technical issues regarding dry storage and transportation impacts on which the NRC must collect additional data before it can evaluate dry cask long-term integrity and cask vulnerability to degradation and accidents. Draft Report for Comment: Identification and Prioritization of the Technical Information Needs Affecting Potential Regulation of Extended Storage and Transportation of Spent Nuclear Fuel (May 2012) ("Technical Needs Document").

Therefore, and as discussed in Sections 4 and 5, of Dr. Makhijani's Declaration, the NRC has years of research to do in order to gather sufficient data regarding spent fuel degradation and transportation and handling risks. It will take a long time, potentially well over a decade, to collect the data needed to make scientifically valid impact analyses for high burnup fuel stored for long periods. Necessary research tasks include development of a sound database for a scientifically valid evaluation of the environmental impacts of prolonged storage of spent fuel, including high burnup spent fuel up to 62.5 GWd/MTU and MOX spent fuel. In addition, there are essentially no data available for high burnup spent fuel that has been stored in dry casks for extended periods of time. *See* Makhijani Declaration, Sections 4 and 10. As discussed in Dr. Makhijani's declaration, the significant dearth of information set forth above will take years to surmount.[4]

[4] Perhaps because the NRC Staff was aware of the need to gather the required information quickly, in COMSECY-12-0016 it considered whether the Long-Term Waste Confidence Update Project could be modified and shortened for purposes of the remanded proceeding, but concluded that the time frame could be reduced only by two years – thus estimating *five* years rather than seven. *Id.* at 6. Nowhere in COMSECY-12-0016 does the Staff come close to suggesting that the Waste Confidence EIS and rulemaking can be completed within just two years. In fact, the Staff's suggestions at how the study might be abbreviated are troubling. The Staff proposes to shorten the study by making "assumptions" about environmental impacts in the far future rather than to study them. *Id.* But to assume the very results that an EIS is intended to determine – the likelihood of future events and their effects upon the environment – defeats the very purpose of the EIS. The types of assumptions suggested by the Staff at page 5 of COMSECY-12-0016 –

Moreover, there are other areas where the NRC Staff is undertaking data collection and analyses that are necessary to prepare an adequate Waste Confidence EIS in response to the Court's decision in *State of New York*, and that are unlikely to be finished within a two-year time frame. For example, the NRC's receipt of post-Fukushima seismic geologic data and analyses regarding seismic risks to nuclear reactor and spent fuel storage sites is crucially important to a host of issues that must be addressed in the Waste Confidence EIS. . Under the schedule established by the NRC Staff in a March 2012 Request for Information, reactor licensees are not due to supply this information until September 2013 for reactor sites in the eastern and central U.S. and March 2015 for western reactor sites. Request for Information Pursuant to title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident (Mar. 12, 2012). While it is possible that those September 2013 and March 2015 timelines could be shortened, that is a matter for the NRC Staff and the Commission to address. Given the significant role played by seismic events in accidents ranging from spent fuel pool leaks to pool fires and their potential effects on long-term storage sites, this information is crucial to the NRC's ability to take a "hard look" at all three topics remanded by the Court. 681 F.3d at 480. With respect to the environmental impacts of pool fires, the Waste Confidence EIS should also take into account the lessons that have been learned from the Fukushima accident regarding the potential for and consequences of spent fuel pool fires, which the NRC is still evaluating.

While NEPA may allow for agencies to reach decisions based on incomplete or unavailable information in certain circumstances (*see, e.g.* 40 § C.F.R. § 1502.22), the Atomic Energy Act (the "AEA") does not. Indeed, as the Court of Appeals explained in *Natural Resources Defense Council*, reactor licensing can proceed only "so long as the Commission can be *reasonably confident* that permanent disposal (as distinguished from continued storage under surveillance) can be accomplished safely when it is like to become necessary." 582 F.2d at 169 (emphasis added). *See also* 42 U.S.C. § 2133 (forbidding issuance of a reactor license if, in the opinion of the Commission, it would be "inimical to the public health and safety"). Thus, if the NRC lacks sufficient technical information to support the WCD's findings of reasonable assurance regarding the safety of long-term spent fuel storage, then the AEA gives the NRC no choice but to suspend all licensing and re-licensing actions.

Given that the Commission has allowed only about one year for an effort that should take seven years, it appears impossible for the Waste Confidence EIS to provide an adequate level of technical support to justify the reasonable assurance findings in the WCD. Thus, if the NRC issues the Waste Confidence EIS in 2014 without completing the research and analyses necessary to support the WCD's safety findings, the no action alternative – no issuance of a WCD and no further reactor licensing or reactor license extensions – must be treated as the preferred alternative. Indeed, under the circumstances it appears to be the only viable alternative under the Atomic Energy Act.

"that ISFSIs [independent spent fuel storage installations] are continuously maintained and monitored, with major maintenance and replacement at regular intervals" – must be evaluated.

If the NRC wishes to have enough information to support the issuance of an updated Waste Confidence EIS, it should complete the research and analysis tasks laid out in the Technical Needs Document. And as discussed in Dr. Thompson's Declaration at Section I and Recommendation #1, the NRC's Preliminary Assumptions Document should be a point of departure for determining the scope of the proposed Waste Confidence EIS, especially in regard to storage after the end of the 21st century.

3. The EIS should consider mitigation alternatives

NEPA mandates that in undertaking environmental reviews, agencies must "discuss the extent to which adverse effects can be avoided" so that "the agency [and] other interested groups and individuals can properly evaluate the severity of the adverse effects." NRC has the unequivocal obligation to *consider and discuss* relevant mitigation options that are available, and to weigh the costs and benefits of such options. *See Robertson v. Methow Valley Citizens Council,* 490 U.S. 332, 351-52 (1989).

In particular, federal regulations require that reviewing agencies consider and assess mitigation measures in an EIS. 40 C.F.R. § 1508.25(b)(3); *see also* 10 CFR Part 51, Subpart A, App. A ("appropriate mitigating measures of the alternatives will be discussed"). The President's Council on Environmental Quality defines mitigation as:

> (a) Avoiding the impact altogether by not taking a certain action or parts of an action.
> (b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.
> (c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.
> (d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
> (e) Compensating for the impact by replacing or providing substitute resources or environments.

40 C.F.R. § 1508.20.

As discussed in the attached declarations by Dr. Makhijani, Dr. Thompson, and Mr. Musegaas, the EIS should consider the following mitigation alternatives:

a. Mitigation of long-term spent fuel storage and pool fire risks

As discussed in Section VII of Dr. Thompson's declaration, the choice of storage modes for spent fuel and high level waste could have significant implications with respect to the risks they pose. For instance, the EIS should consider placement of spent fuel or high level waste below ground level. *Id.,* ¶¶ VII-9, VII-10. In addition, the potential for pool fires could be effectively eliminated by eliminating high-density storage of spent fuel in pools. *Id.,* ¶¶ VII-12 – VII-14. Storage casks could also be protected from attack by using robust design. *Id.,* ¶ VII-9.

As Dr. Thompson recommends, a range of storage scenarios should be considered in order to help assess the comparative radiological risk posed by alternative options for storing spent fuel or high level waste.

b. Mitigation of spent fuel pool leakage risks

The EIS must also include a comprehensive assessment of all relevant measures that may mitigate adverse environmental consequences of future spent fuel pool leaks and any resulting contamination of the environment. Musegaas, Declaration, ¶ 7. Various feasible measures are available that would avoid, minimize, rectify, reduce, or eliminate the environmental impacts of future radiological spent fuel pool leaks and contamination associated with such leaks. The EIS should include an assessment of the feasibility and efficacy of all reasonable measures to mitigate the impacts of future spent fuel pool leaks on the environment. *Id.*

c. Mitigation in the event of loss of institutional control

The NRC should explicitly consider storage design concept and measures that would mitigate the impact of leaks, fires, and malevolent acts in the event of a loss of institutional control. Makhijani Declaration, Section 6.

B. Scenarios and Impacts That Should be Considered

As the Court concluded in *State of New York,* "[u]nder NEPA, an agency must look at both the probabilities of potentially harmful events and the consequences if those events come to pass." 681 F.3d at 478-79 (citing *Carolina Envtl. Study Grp. v. U.S.,* 510 F.2d 796, 799 (D.C. Cir. 1975)). Only if the probability of an environmental impact is so low as to be "remote and speculative," or if the combination of probability and harm is "sufficiently minimal," can an agency avoid analyzing the impacts. *Id.* (citing *City of New York v. Dep't of Transp.,* 715 F.2d 732, 738 (2d Cir. 1983) ("The concept of overall risk incorporates the significance of possible adverse consequences discounted by the improbability of their occurrence.")). Therefore, for each of the categories of spent fuel storage risks remanded by the Court of Appeals to the NRC – *i.e,* long-term storage risks, spent fuel pool fire risks, and spent fuel pool leakage risks – the NRC must evaluate both the probability and the consequences of these environmental impacts.

1. Time-frame for consideration of impacts

In *State of New York,* the Court found that "a 'reasonable assurance' that permanent storage will be available is a far cry from finding the likelihood of nonavailability to be 'remote and speculative,'" and that the NRC had "failed to examine the environmental consequences of failing to establish a repository when one is needed." *Id.,* 681 F.3d at 478-79 (quoting *City of New York,* 715 F.2d at 738). The Court unequivocally ordered the NRC to evaluate the environmental impacts that could occur if a repository is never sited. *Id.* at 473, 478, and 479. But the Court did not thereby allow the NRC to forego the required evaluation of the impacts of the eventual siting of a repository. Rather, in order to comply with NEPA, the EIS must make a reasoned and supported prediction of when (and if) a repository will be available. That prediction must be based, to a significant extent, on the feasibility of safe disposal in a range of geological media and the availability of suitable sites.

Rather than proposing to evaluate the likelihood that a repository will be available in any particular time frame, the NRC appears to treat the question of the availability of a repository as a series of "scenarios" that will be assumed to occur. Thus, it states in the Scoping Notice:

> Possible scenarios to be analyzed in the EIS include temporary spent fuel storage after cessation of reactor operation until a repository is made available in either the middle of the century or at the end of the century, and storage of spent fuel if no repository is made available by the end of the century.

77 Fed. Reg. at 65,138. *See also* Transcript of Nov. 14, 2012 Scoping Meeting for Waste Confidence EIS at 20 (ML12331A347) ("Transcript 1") , in which NRC Staff member Michalak made the following statement:

> We've developed these scenarios during internal scoping. The first scenario is a repository available at the middle of the century. That scenario would assume transportation of spent fuel to the repository beyond that approximately 2050 point, because it doesn't go there instantaneously. So, the first scenario goes out about 100 years, approximately, approximately 50 to half the storage facility, and then another 50 to really get all the waste there, approximately. The second scenario assumes that a repository wouldn't be available until the end of the century. Okay, so we're looking at about 90 years out, a repository would be available, and then again another 40 or 50-odd years to get all that waste or all that spent fuel to the repository. The third scenario was part of the remand. We are going to evaluate no available repository . . . . The EIS will address the environmental impacts associated with each scenario. So a scenario where middle of the century, end of the century, no available storage. So we will be evaluating the environmental impacts across resource areas, like air, and water, and transportation across those three scenarios.

While analysis of a range of scenarios may be a useful tool in preparing the EIS, the EIS should address the *probability* that these scenarios will occur, not merely assume their occurrence. In making that evaluation, the feasibility of spent fuel disposal is a relevant consideration. *See* Makhijani Declaration, Section 7.

The EIS must also assess the *consequences* of each scenario. As further discussed in Dr. Makhijani's Declaration, the NRC no longer has a technical basis to assume that spent fuel disposal in a repository will cause no radiological releases and therefore will have no significant adverse environmental impacts. *Id.,* Section 8.

In assessing these probabilities and consequences, the EIS should clarify the third scenario, *i.e.,* "storage of spent fuel if no repository is made available by the end of the century." If no repository is available by the end of the century, what is the NRC's prediction regarding when a repository *will* be available? As discussed in Dr. Thompson's Declaration, ¶ I-5, the

NRC's Preliminary Assumptions Document assumed that under the third scenario, a repository will be available by 2250.

In addition, as recommended by Dr. Thompson, consideration of spent fuel storage impacts should begin at the time of discharge from the reactor. *Id.,* ¶ I-9 and Recommendation #3.

And, as a final note, in *State of New York,* the Court found that the NRC failed to adequately evaluate the environmental impacts of spent fuel pool fires and spent fuel pool leakage out to 60 years past the cessation of reactor operations. 681 F.3d at 479. That does not mean, however, that these impacts are irrelevant with respect to long-term storage. The EIS must consider the probability and consequences of spent fuel pool leaks and fires occurring under each of its scenarios.

2. Environmental impacts that should be considered in the EIS

While the subject matter of each of the issues remanded by the Court of Appeals varies, there is substantial overlap. It is important to evaluate these issues in an integrated and internally consistent manner. This is reflected in the recommendations of Dr. Makhijani, Dr. Thompson, and Mr. Musegaas. Their recommendations, which the Organizations adopt and incorporate by reference, can be summarized as follows:

- In view of the NRC's own preparations to analyze storage for up to 300 years in the Long-Term Waste Confidence Update, the scope of the Waste Confidence EIS should include a scenario of 300 years of onsite storage followed by repository disposal. This scenario should include at least one inter-cask transfer in this period, followed by transfer to a multipurpose or transportation cask at 300 years. Of course, transportation risks and repository site and disposal risks should be included in this scenario (as with every scenario that includes an assumption of deep geologic disposal and/or an assumption of transfer of spent fuel to an offsite storage location). Makhijani Declaration, Section 3 and ¶ 3.5.

- In order to fully evaluate each long-term spent fuel storage scenario considered in the EIS, the NRC should include consideration of (a) the reasonableness of NRC's prediction that a repository will become available in any of those three time frames and (b) the environmental impacts of disposing of spent fuel once it is placed in a repository. Makhijani Declaration, Section 7 and ¶ 7.1. The evaluation must include radiation doses to workers, the onsite and offsite environmental impacts during the period of preparation, as well as the post-closure environmental impacts up to and including the time of peak radiation dose. *Id.,* ¶ 7.5. The EIS must also explore all reasonable combinations of geology, engineered barriers, sealing systems, and disposal casks to predict bounding doses.

- For scenarios that include repository disposal, the scope of the EIS should also include the calculation of surface impacts at the site (including those from storage, unloading, repackaging, etc.) and post-closure repository impacts. In regard to post-closure repository impacts, the NRC cannot rely on the estimated zero radiation doses from salt disposal as specified in Table S-3 in 10 C.F.R. § 51.51(b) because (i) the NRC itself has admitted that salt disposal is inappropriate for spent fuel, (ii) all other media will have non-zero impact, and (iii) the impact is highly dependent on the combination of site, engineered barriers (including disposal casks), and sealing systems that are presumed to be used.

- The EIS should analyze, in depth, the environmental impacts of uranium spent fuel degradation. After a total storage period of up to 300 years (i.e. out to the year 2250), there is a far greater likelihood of casks deteriorating to an extent that transfers from one cask to another of much, most, or all of the spent fuel would be required. Transportation accidents involving degraded spent fuel should be evaluated. The impacts on transfer of degraded high burnup spent fuel at the repository site should also be evaluated. Makhijani Declaration, Section 4 and ¶¶ 4.1, 4.23, 11.2.

- The EIS should analyze, in depth, the impacts of transporting and handling spent fuel, and of storing it at repository sites. Spent fuel that has been stored onsite or at an offsite location for prolonged periods is subject to degradation, some of which could be severe enough to breach both the cladding and the canister. Transfer to transportation casks could therefore pose risks that have not yet been encountered in practice. Similarly the impacts of transfer to disposal containers, storage at the repository location, and handling during placement of degraded spent fuel need to be evaluated. Likewise, the consequences of transportation accidents that involved degraded fuel or canisters could be significantly higher than indicated by present understanding of accidents with intact fuel and canisters. Again, this will require significant additional research. Makhijani Declaration, Section 5 and ¶¶ 5.1, 5.5.

- The EIS should not only address the storage of spent nuclear fuel, but also the potential storage of high level radioactive waste from reprocessing of spent nuclear fuel. Thompson Declaration, Section I and Recommendation 2.

- The EIS should consider the radiological risk posed by storage of spent nuclear fuel from the moment of its discharge from a reactor. Thompson Declaration, Section I and Recommendation 3.

- Assessment of radiological risk should be a major function of the proposed EIS, this category of risk being defined as the potential for harm to humans as a result of unplanned exposure to ionizing radiation. Thompson Declaration, Section IV and Recommendation 4.

- The EIS should assess the radiological risk arising from a range of conventional accidents or attacks that could affect stored spent nuclear fuel or high level radioactive waste. Thompson Declaration, Section IV and Recommendation #5.

- The comparative radiological risk posed by a range of alternative options for storing spent nuclear fuel or high level radioactive waste should be assessed in the proposed EIS as a major indicator of the comparative impacts of these alternatives. Thompson Declaration, Section IV and Recommendation 6.

- Risk assessment in the proposed EIS should be supported by a set of indicators that express the dynamic aspects of the potential risk environment across the time period and suite of scenarios considered in the EIS. Thompson Declaration, Section V and Recommendation 7.

- The EIS should analyze, in depth, the reliability of institutional controls, because there is extensive evidence that it is not prudent to rely on active institutional controls for more than 100 years after a facility ceases functioning for its principal purpose. Makhijani Declaration, Section 6 and ¶ 6.1. The EIS should take account of the technical basis for NRC's low-level waste disposal regulations at 10 C.F.R. § 61.7(b)(4) and (b)(5). These regulations effectively assume that active controls (as defined in 10 C.F.R. § 61.2) will fail after 100 years. Intruder barriers, which are passive controls, are assumed in the rule to last at most 500 years. *Id.* at ¶ 6.3.

- The scenarios considered in the proposed EIS should cover a range of potential outcomes regarding the role of nuclear power, including: (i) shrinkage in the number of operating reactors, with potential shutdown of all reactors by the middle of the 21^{st} century; (ii) expansion in the number of operating reactors; and (iii) introduction of new technology. Thompson Declaration, Section VI and Recommendation 8.

- The scenarios considered in the proposed EIS should cover future societies exhibiting a range of variation in prosperity, technological capability, and the quality of governance. Thompson Declaration, Section VI and Recommendation 9.

- The scenarios considered in the proposed EIS should cover a range of potential future outcomes regarding the propensity for violent conflict, and should cover situations in which stored spent nuclear fuel or high level radioactive waste would experience attacks involving states or non-state actors. Thompson Declaration, Section VI and Recommendation 10.

- The proposed EIS should take a dynamic view of the potential inventories and modes of storage of spent nuclear fuel and high level radioactive waste, by considering a range of storage scenarios. Thompson Declaration, Section VII and Recommendation 11.

- The proposed EIS should use a range of storage scenarios as vehicles to help assess the comparative radiological risk posed by alternative options for storing spent nuclear fuel or high level radioactive waste. Thompson Declaration, Section VII and Recommendation 12.

- In assessing the comparative radiological risk posed by alternative options for storing spent nuclear fuel or high level radioactive waste, the proposed EIS should regard retrievable emplacement in a repository as a mode of storage. Thompson Declaration, Section VII and Recommendation 13.

- In assessing the comparative radiological risk posed by alternative options for storing spent nuclear fuel or high level radioactive waste, the proposed EIS should give special attention to the potential for radioactive release from stored spent nuclear fuel as a result of a pool fire or a cask fire. Thompson Declaration, Section VII and Recommendation 14.

- The spent nuclear fuel storage scenarios to be considered in the proposed EIS should include: (i) an Extended Status Quo scenario; (ii) a Nuclear Power Rundown with Spent Nuclear Fuel Risk Minimization scenario; and (iii) a range of other scenarios. Thompson Declaration, Section VII and Recommendation 15.

- In assessing the potential for radioactive release from stored spent nuclear fuel as a result of a pool fire, the proposed EIS should rely on an updated, transparent, fully published body of analytic and empirical investigation that adequately describes all relevant phenomena, including: (i) the dynamics of cladding self-ignition across a range of water-loss and fuel-loading scenarios; (ii) propagation of exothermic reactions between fuel assemblies; (iii) hydrogen generation; (iv); heat generation; and (v) atmospheric release of radioactive material. Thompson Declaration, Section VIII and Recommendation 16.

- In assessing the potential for initiation of a pool fire at a given facility, the proposed EIS should account for factors including: (i) the potential occurrence of a range of conventional accidents or attacks at the facility; (ii) a range of water-loss and fuel-loading scenarios; and (iii) the potential occurrence of degraded-site conditions due to an incident at an adjacent facility (e.g., a reactor). Thompson Declaration, Section VIII and Recommendation 17.

- In assessing the potential for radioactive release from stored spent nuclear fuel as a result of a cask fire, the proposed EIS could rely on a body of analytic and empirical information that is not fully published, provided that the NRC has engaged an independent Red Team to determine through representative tests whether a cask fire can be initiated and, if so, what release of radioactive material would be likely to occur. Thompson Declaration, Section VIII and Recommendation 18.

- In assessing the likelihood of a radiological incident, the proposed EIS should rely on diverse sources of information, and should not rely solely upon the findings of probabilistic risk assessment. Thompson Declaration, Section IX and Recommendation 19.

- In assessing the impacts of a potential radiological incident involving atmospheric release, the proposed EIS should consider types of impact including: (i) plume exposure; (ii) ground contamination and resulting exposure; (iii) exposure via food and water pathways; (iv) health effects pursuant to total exposure; (v) abandonment of assets; (vi) cleanup costs; (vii) direct and indirect economic impacts; and (viii) social impacts. Thompson Declaration, Section IX and Recommendation 20.

- In considering radiological risk, the proposed EIS should repudiate the arithmetic definition of risk. Thompson Declaration, Section IX and Recommendation 21.

- In assessing the overall impacts of storing spent nuclear fuel or high level radioactive waste, the proposed EIS should consider the implications of alternative storage options for a national strategy of protective deterrence. Thompson Declaration, Section IX and Recommendation 22.

- The NRC's EIS must analyze in-depth the probability that densely packed spent fuel pools at reactor sites will leak toxic radionuclides to the environment following the cessation of plant operations. Musegaas Declaration, ¶ 4.

- The EIS must analyze in-depth the probability of future spent fuel pool leaks in light of the established practices that challenge and prevent full and timely detection of such leaks. Musegaas Declaration, ¶ 4(b).

- The EIS must undertake a comprehensive, in-depth assessment, with due consideration of site-specific factors, of the probability of spent fuel pool leaks during post-operation on-site storage of spent nuclear fuel. Musegaas, Declaration, ¶ 4(e).

- The EIS must analyze the full range of potential consequences stemming from the probability that densely packed spent fuel pools at reactor sites will leak toxic radionuclides to the environment after cessation of plant operations. Musegaas, Declaration, ¶5.

- In relation to spent fuel pool leaks, the NRC must fully analyze the cumulative impacts resulting from past, present, and reasonably foreseeable future radiological leaks from non-spent fuel pool systems, structures, and components. In its analysis, NRC should consider the potential impacts to groundwater resources, surface water resources, and public health. Musegaas, Declaration, ¶ 6.

- The NRC must assess the extent to which the probability and environmental consequences of spent fuel pool leaks, may be affected by licensee decommissioning activities that are, or may be, undertaken during post-operation timeframes. NRC must assess (1) how future SFP leaks (and the direct, indirect, and cumulative impacts of these leaks) will affect the overall feasibility and cost of decommissioning reactor sites; (2) the impacts of any residual SFP leak contamination that may be left unremediated after decommissioning; and (3) the extent to which decommissioning actions are relevant to the consideration of potential mitigation measures. Musegaas, Declaration, ¶ 8.

C. The NRC Should Make Provision for Site-specific Analysis of Some Issues.

While the Organizations believe that many of the issues related to long-term storage of spent reactor fuel are generic in nature, that is not the case uniformly. Makhijani Declaration, Section 9 and ¶ 9.3. With respect to long-term spent fuel storage impacts, there are a number of impacts that must be addressed on a site-specific basis or with a bounding analysis that takes into account the degree of risk at the most adversely affected site. For instance:

- Health and property damage impacts, which are likely to be bounded by high density population sites with high property value concentrations like Indian Point in the suburbs of New York City or Limerick, near Philadelphia, Pennsylvania. Makhijani Declaration, ¶ 9.3.

- Impacts on river systems may be bounded by sites that are quite different in character. For instance, large scale dispersal of radioactivity from spent fuel storage at Prairie Island could create long-term damage to the entire Mississippi River system, including agricultural lands around it, cities that are vulnerable to flooding on its shores, barge traffic that is a major artery of commerce, and so on. Agricultural impacts alone may be bounded by sites like Fort Calhoun or Duane Arnold in Iowa. Makhijani Declaration, ¶ 9.4.

- It is impossible to bound ecological impacts in a generic manner. They will require site specific discussion. For instance, the Calvert Cliffs reactors in Maryland are situated in one of the most sensitive and unique ecosystems of the United States – the Chesapeake Bay. The impacts of a major radioactivity release into the Chesapeake Bay ecosystem are likely to be quite different than those of a similar release at Turkey Point in Florida, which has barrier islands and Biscayne National Park a few miles away or Diablo Canyon, in California, where a major release could severely impact the unique ecosystem in the Monterey Canyon. It is important to remember in this context that the inventory of long-lived radioactivity in spent fuel pools in the United States is generally far larger than that in Chernobyl Unit 4, which had a severe accident and radioactivity releases in 1986. It is essential that the scenarios other than the no-action alternative consider the ecosystem impacts on a site specific basis unless it can classify sites based on types of ecosystems and address bounding impacts for similar sites. None of the sites mentioned in this paragraph could be put into a group with any other by that criterion. Makhijani Declaration, ¶ 9.5.

The EIS must include bounding estimates for (i) the number of cancers caused by a worst case release of radionuclides from any plant; (ii) the worst case damage to riverine ecosystems, such as the Great Lakes, the Mississippi River or the Columbia River; (iii) the worst case loss of agricultural land and production; (iv) the ecosystem damage to each unique ecosystem, including the Chesapeake Bay, the Monterey Trench, the Mississippi River Delta, the Columbia River, and (v) the worst case property damage. These evaluations should include not just today's source term but the projected source terms based on the dates of the expiry of the licenses and the total accumulated spent fuel at that time.

It is also essential for the scope of the EIS to include environmental justice impacts. Many of them are also site-specific. For instance, a spent fuel accident at the Columbia Generating Station in Washington State would seriously compromise the treaty rights, cultural values, and diets of the Yakama as well as other Indian tribes in the area. Such environmental justice impacts must be included in the scope of the EIS if it is to apply generally to future licensing actions.

With respect to spent fuel pool leaks, determining the probability of future leaks clearly necessitates a consideration of site-specific factors. To begin with, special consideration must be afforded to spent fuel pools that have already leaked. With respect to any known incidents of spent fuel pool leakage, the circumstances surrounding such leakage, the licensee and NRC response to such leakage, the adequacy of any such response, the current and likely future status of such leakage, and other such issues must be analyzed before determining the likelihood of future leakage from these spent fuel pools. For example, at Indian Point, site-specific circumstances (including the facts that the Unit 2 spent fuel pool is still actively leaking), result in site-specific conclusions regarding the likelihood that the Unit 2 spent fuel pool will continue to leak in the future. Musegaas Declaration, ¶ 4(d).

In addition, other site-specific factors must also be considered in order to assess the probability of future spent fuel pool leaks at nuclear power plants. This includes the impact of natural disasters (i.e., earthquakes, hurricanes, floods, etc.) on the integrity of spent fuel pools, and the probability that any such events may create or exacerbate existing spent fuel pool degradation and leaks. Such impacts must take into account current information regarding seismicity in regions where nuclear power plants are located, as well as the most current scientific knowledge regarding sea level rise and other impacts of climate change, including the increased frequency of severe weather events that result in storm surges, flooding, and extended power outages that could compromise safe storage of spent fuel at reactor sites. Site-specific review related to these kinds of external circumstances is necessary since new information reveals such issues can be problematic and since different regions in the U.S. face different geological conditions and weather patterns. Musegaas Declaration, ¶ 4(d).

D. Potential Location for Future Public Meetings

In the Scoping Notice, the NRC requested comments on potential locations for future public meetings on the draft EIS. Given the potentially significant and long-lasting effects of extended spent fuel storage at reactor sites, we request that public comment hearings be held in each community housing a nuclear reactor. Unfortunately, however, it seems as though NRC has rejected this option before even receiving scoping comments. *See e.g.,* statement by NRC Staff member Andy Imboden, Transcript 1 at 16 ("In scoping we're asking broad questions, what scenarios in environmental issues should we consider, and one important question that we're asking is *we will be holding regional meetings* in the draft stage, and we'd like your feedback on where those meetings should be held. But *we can't hold them everywhere*, but if there are some areas of particular interest, we'd like to know that.")(emphasis added); and NRC Staff member Chip Cameron, Transcript 1 at 40 ("And I've just reminded with the tribal government and state government presentations that one of the specific issues that the staff would look for comment on is *locations of the regional meetings*.")(emphasis added).

In light of NRC's refusal to conduct meetings at every reactor site, we request, in the alternative, in-person meetings in Maryland (at NRC headquarters), in California, and in each of the following regions: the Northeast, the mid-Atlantic region, the Southeast, the Midwest, and the West. These locations would roughly correspond to the locations of the NRC's headquarters and its four regional offices (in Pennsylvania, Georgia, Illinois and Texas), plus California, New York and the New England states. The meetings could be held at the NRC's offices or at a public facility that is located equidistant between the multiple facilities in the region. Webcasts are simply not a substitute for live meetings, especially because many individuals living near these facilities do not have access to the internet. Thus, to afford the concerned public a reasonable opportunity to participate, meetings in each region housing a nuclear facility are required.

Respectfully submitted,

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