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 21st 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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Declaration of Dr. Arjun Makhijani Regarding the Scope of Proposed Waste Confidence 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 has been doing nuclear-related studies for about twenty-five years and is 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.

1.2. 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.

1.3. As demonstrated in my attached curriculum vitae (CV), I am qualified by training and experience as an expert in the fields of plasma physics, electrical engineering, nuclear engineering, and energy-related technology and policy issues. I have extensive professional experience and am qualified as an expert in radioactive waste disposal, standards for protection of human health from radiation, and the relative costs and benefits of nuclear energy and other energy sources. I have served as an expert witness in numerous lawsuits and testified on a variety of issues including releases of radioactivity from nuclear facilities. In addition to my CV, the following paragraphs provide information regarding my qualifications to address the issues regarding the environmental impacts of spent fuel storage and disposal.

1.3. Over more than 25 years, I have developed extensive experience with nuclear fuel cycle-related issues, including standards 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 other energy-related issues. 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.

1.4. An extensive part of my work has been to analyze various issues related to radioactive waste management, classification, and disposal. This includes studies on low-level waste, high-level waste, spent fuel disposal, geologic repositories, and research related to geologic repositories. I have studied radioactive waste in both the commercial and military sectors. I was the director of a team 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). 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 included an analysis of U.S. waste classification regulations. I am the principal author of an assessment of the radioactive waste management and disposal costs of depleted uranium from the National Enrichment Facility (2004 and 2005).

1.5. 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 have 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 have 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 on the EPA's Advisory Subcommittee on cleanup standards, which was part of the National Advisory Committee on Environmental Policy and Technology. In addition, I have served as an expert consultant to numerous organizations.

1.6. 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 on *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 have 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), which is, to the best of my knowledge, 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. I have 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 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.

1.9. I have reviewed the NRC's 2010 "Waste Confidence Decision Update"[1] and prepared expert comments on the NRC's 2008 Proposed Waste Confidence Decision Update.[2] I have also reviewed the NRC's 2010 final rule: "Consideration of Environmental Impacts of Temporary Storage of Spent Fuel After Cessation of Reactor Operation."[3] In addition, I am familiar with the NRC's uranium fuel cycle rule and relevant associated reference documents. And I am familiar with relevant aspects of governing law and guidance, including the National Environmental Policy Act and relevant NRC implementing regulations.

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 scope of the Environmental Impact Statement (EIS) it has proposed to prepare in response to the June 8, 2012, decision of the United States Court of Appeals for the District of Columbia in *State of New York v. NRC*.[4] In response to the NRC's Federal Register notice seeking comments on the scope of the EIS (Scoping Notice), my declaration provides my expert opinion regarding the scope of the EIS that is necessary to address the environmental impacts of long-term and perhaps indefinite storage of spent reactor

[1] NRC 2010a
[2] NRC 2008, Makhijani 2009
[3] NRC 2010b
[4] U.S. Court of Appeals 2012 pp. 6, 7, and 21

fuel.[5] To briefly summarize my declaration, I believe the scope of the EIS should include two major issues that are not addressed in the Scoping Notice: (i) the impacts of storing spent fuel for a total period of 300 years followed by transportation to a repository location and (ii) the impacts of disposing of spent fuel in a deep geologic repository. It is also my expert opinion that the NRC currently lacks sufficient information to reach scientifically well-founded conclusions about either of these issues or about the effects of storage of high burnup spent fuel for prolonged periods, and that the NRC will not be able to gather it within the two-year time frame the NRC has provided for study of the environmental impacts of extended spent fuel storage. Finally, in my expert opinion there are a number of site-specific issues related to the long-term storage of spent fuel that are not susceptible to resolution in a generic analysis. Therefore, it is my conclusion that the NRC lacks a factual basis for a finding of confidence that spent fuel can be safely stored for an extended period or disposed of safely. Under the circumstances, it is imperative for the scope of the EIS to include consideration of the alternative of not re-issuing the Waste Confidence Rule and suspending all future licensing. This no-action alternative should also be the preferred alternative since it is the only technically supportable one given the scope of the information that is lacking for assessing environmental impacts of prolonged storage and of deep geologic disposal of spent fuel.

2.2. My declaration is organized as follows. In Section 3, I will discuss the major scenarios that should be addressed in the EIS. These include the environmental impacts of storing spent fuel for up to 300 years followed by disposal in a deep geologic repository. I will also identify the principal impacts of concern for a 300-year storage period: spent fuel degradation during prolonged storage; risks of transportation, handling, and storage of spent reactor fuel at a repository site; and loss of institutional controls. In Sections 4, 5, and 6, I will discuss the necessary scope of the EIS with respect to each of these principal impacts. In Section 7, I will discuss the need to evaluate the environmental impacts of spent fuel disposal in a repository. In Section 8, I will discuss the current availability of information to address the environmental impacts of extended spent fuel storage and disposal of spent fuel in a repository. In Section 9, I will discuss site-specific issues that are not amenable to resolution in a generic manner. Finally, in Section 10 I will discuss why it is my opinion that the NRC currently lacks a sufficient basis for a waste confidence finding or finding of no significant impact and therefore should suspend licensing and re-licensing of reactors until it has collected the necessary information. Section 11 contains a summary of the main points.

3.0 The EIS should analyze, in depth, various spent fuel storage scenarios, including the scenario that a repository does not become available until the middle of the 23rd century.

3.1. In the Scoping Notice, the NRC has stated that it would consider three scenarios for storage – one in which a repository is available in the middle of this century, one in which it is available at the end of this century, and one in which "no repository is made available by the end of this century."[6] It amplified this during the public meeting held on the scope of the EIS on

[5] NRC 2012d, pp. 65137, 65138.
[6] NRC 2012d, p. 65138.

November 14, 2012. Specifically, the NRC slides prepared for that meeting show the following "potential scenarios" in the EIS:

> – Storage until a repository becomes available at the *middle* of the century
> – Storage until a repository becomes available at the *end* of the century
> – Continued storage in the event a repository is *not available*[7]

3.2. I concur that these three scenarios should be prepared, but with due attention to the technical details and constraints discussed in the rest of this declaration. Specifically, the first two of them will require that the NRC evaluate the impacts of transportation of spent fuel to a geologic repository, the impacts of handling and storage at that location, and the post-closure impacts of repository disposal, as discussed in Sections 5 and 7. Further, in the third scenario as specified in the scoping notice and in the November 14, 2012 slides should be taken to mean that no repository ever becomes available. This problem statement would be roughly similar to the No-Action Alternative in the DOE's Yucca Mountain EIS (DOE 2002) in which the DOE considered the problem of storage for up to 10,000 years in the absence of a geologic disposal option. However, would be scientifically incorrect to use the analysis and conclusions of the No-Action Alternative in the DOE's Yucca Mountain EIS for a variety of reasons, including those discussed in Sections 6 and 8 below.

3.3. It will not be sufficient to develop the three scenarios above. It is also essential to include one additional scenario in the scope of the proposed EIS, as discussed in the rest of this section.

3.4. In view of its admission that it could not estimate the date when a repository might become available, the NRC, in its Final Waste Confidence Rule, NRC raised the possibility that storage beyond sixty years may become necessary. In the Final Rule the NRC had expressed confidence in the safety of storage for up to sixty years.[8] As a result the NRC directed its staff to prepare an EIS for longer term storage. It is not clear from the NRC scenarios cited in Section 3.1 above that the NRC plans to evaluate the full range of scenarios for storage and (implicitly) for the timing of repository availability that it has itself considered credible enough for an EIS analysis in the recent past. The staff made a preliminary assessment (in a draft report) that the NRC should evaluate the environmental impacts of storage for 200 years beyond the middle of the present century, in other words, spent fuel storage up to the year 2250. This means almost 300 years of storage in all, a fact noted by the NRC staff:

> The staff selected a 200-year span for the EIS because that is approximately when this oldest fuel will approach 300 years of storage. The 300-year period is the timeframe being used by NRC and others in technical analyses to identify spent fuel aging issues.[9]

3.5. An examination of prolonged storage well beyond sixty years past license expiration, is necessary because the NRC, in its Final Waste Confidence Decision Update admitted that it could not estimate when a repository might become available. The reason provided was the

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[7] NRC 2012c, Slide 20, italics in the original
[8] NRC 2010a, p. 81040
[9] NRC 2011, p. 6

NRC "cannot have confidence in a target date because it cannot predict when the societal and political obstacles to a successful repository program will be overcome."[10] Consideration of prolonged storage well beyond 120 years (sixty years of licensed reactor operation followed by sixty years of storage) prior to transport to a repository is needed because many of the problems of very long term storage are likely to be much more severe than those that might be experienced to the end of this century. For instance, the extent of degradation, transportation risks, risks of handling and storage at the repository site, risks of loss of institutional control, and risks of inter-cask transfer, would be considerably different and in most cases much higher for storage that extends to 300 years from initial reactor discharge. These issues are discussed in more detail in Sections 4, 5, and 6 below. For these reasons, the NRC staff issued a draft report outlining the data requirements for storage periods up to 300 years because it is "a reasonably long performance period" to evaluate for an EIS.[11] I agree. No one can foresee whether 300 years of total storage will be required prior to transportation, but it is prudent to evaluate it. Such a scenario is also broadly compatible with institutional control considerations discussed in Section 6 below.

3.6. Other impacts also become more extreme over an extended period of time. For instance, the Nuclear Waste Technical Review Board has found that the radiation barrier declines rapidly after about 100 years. By about 300 years, the original cesium-137 inventory, which presents the main long-term radiation barrier, would have declined by a factor of about 1,000. In such a situation the risk of theft of spent fuel would increase qualitatively. As the NWTRB put it, after sufficiently prolonged storage (well over 100 years) the spent fuel "may no longer pose a deterrent to individuals approaching CSNF [commercial spent nuclear fuel]."[12] Another example is that the probability of natural phenomena such as flooding, hurricanes, and tornadoes, and earthquakes, of a given level of intensity increases as the period of time increases. Another way of putting it is that "The longer the expected period of dry storage, generally, the more severe the natural event loading will be that should be employed in analysis."[13] When climate change is added to this picture, a scenario that extends out to 300 years prior to transport to a repository would likely have much greater environmental impacts at the site (or, for that matter, at an offsite location for spent fuel storage).

3.7. In view of the NRC's own preparations to analyze storage for up to 300 years, the scope of the EIS should include a scenario of 300 years of onsite storage followed by transportation and 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 also in every scenario that includes an assumption of deep geologic disposal and/or an assumption of transfer of spent fuel to an offsite storage location.

[10] NRC 2010a, p.81041
[11] NRC 2012a, p. 1-2.
[12] NWTRB 2010, p. 82
[13] NWTRB 2010, p. 80

4.0 The EIS should analyze, in depth, the environmental impacts of spent fuel degradation.

4.1. 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. This could pose major problems in case the spent fuel has degraded to the point of leaking radioactivity, especially since the NRC has no experience in unloading damaged commercial spent fuel bundles or in regulating the means and processes needed to do so. By its 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.[14]

The NRC also at present has no basis in data or experience in estimating how much additional damage such procedures might create. This would apply even to damaged medium burnup fuel stored for short or moderate periods of 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.

4.2. The NRC 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*.[15] This report catalogs what is known, as

[14] NRC 2001, emphasis added
[15] NRC 2012a

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.

4.3. NRC 2012a 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:

> ….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).[16]

Note that the existing licensing and license extension procedures are based on examination of single cask of relatively low burnup uranium dioxide fuel 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[17] – 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;[18]
- spent fuel burnups up to 62.5 GWd/MTU,[19] 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.[20]

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[16] NRC 2012a, p. 1-1; italics added
[17] NRC 2012a, p. 1-2
[18] The wet storage time was about 3.7 years (Einziger et al. 2003, p. 1989); it has been rounded to four years for this calculation.
[19] NRC 2012a, p. 3-1
[20] NRC 2012a, p. A2-2, A2-4, and A4-3, for instance

- “new cladding, fuel compositions, and assembly designs that have been and will continue to be put into use.”[21]

4.4. According to a 2010 report by the Nuclear Waste Technical Review Board, of spent fuel integrity and degradation, “[o]nly 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*.”[22] Hence, there are no U.S. data available at present 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 EIS cannot be validated with scientific data or observations with presently available information. Such validation is essential for reliable and scientifically valid estimates of environmental and health impact of long-term storage and transportation.

4.5. The data requirements are extensive even by the NRC staff’s own accounting. According to Table 6-1 in NRC 2012a, there are 23 different degradation phenomena that have a ranking of “high” in terms of “the need for further research”[23] in addition to the data available from the lower burnup/short storage time evaluations. The table 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.

[21] NRC 2012a, p. 3-1
[22] NWTRB 2010, p. 11, italics added
[23] 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)

4.6. 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.

4.7. All of the categories of "regulatory significance" of these 23 degradation phenomena – confinement, criticality, retrievability, shielding, structural, and thermal – listed in the NRC table reproduced above are relevant to estimating environmental impacts, some of which could be severe. Others could contribute to severe degradation outcomes.

4.8. For instance, in the case of microbiologically induced corrosion the table 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.

4.9. As another example, consider phenomena listed near the top of the table: stress corrosion cracking, delayed hydride cracking, and low temperature creep. The NRC draft report 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."[24] In other words, the NRC does not know at present whether corrosion of seals or the canister body may or may not 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 cask itself degrades. If data indicate little likelihood of corrosion or creep for high burnup fuel storage for decades or centuries, the impacts would be materially different and lower that if these two mechanisms produce significant degradation. At present, any impact calculation for high burnup spent fuel would be based on speculation rather than data.

4.10. Consider the state of knowledge for the interactions between different degradation mechanisms as well as the possible effect of high burnup, according to the Nuclear Waste Technical Review Board:

> 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.[25]

[24] NRC 2012a, p. 6-2
[25] NWTRB 2010, p. 11, italics added

Hence high burnup could well combine with other factors to create conditions that would result in severe, if not catastrophic, releases of radioactivity. Further, the NWTRB considers the three phenomena discussed above -- hydriding, creep, and stress corrosion cracking – to be "[t]he most significant potential degradation mechanisms affecting the fuel cladding during extended storage."[26]

4.11. 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 1 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.[27] Similarly Figure 2 shows that the maximum wall thickness hydrogen content increases from 200 ppm to 800 ppm at discharge over approximately the same burnup range. In both cases the variability is also much greater at the higher burnup. High 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 degradation that is to be expected based on currently available information of in-reactor performance.

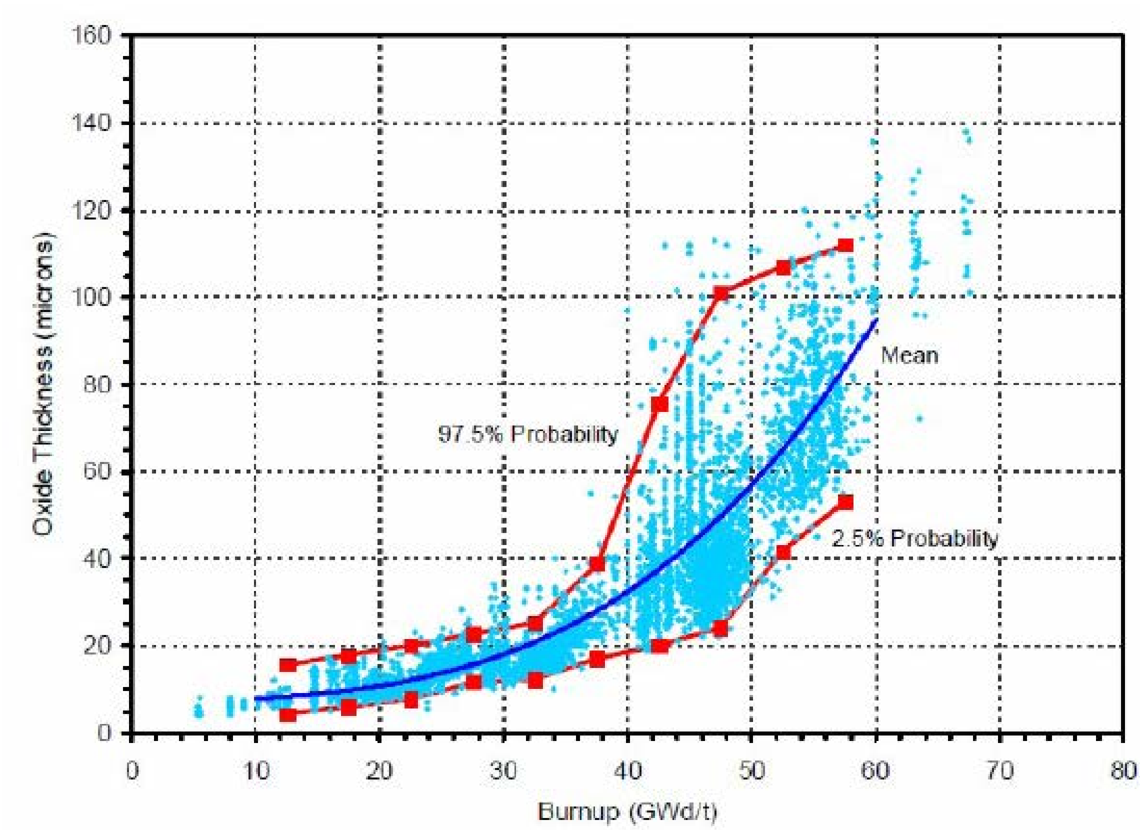

Figure 1. Cladding outer surface oxide thickness layer versus rod average burnup (Reproduced from NWTRB 2010, Figure 20 (p.56))

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[26] NWTRB 2010, p. 10. Visual extrapolation of the line showing the mean.

[27] The range of blue data points at about 63 GWd/MTU is from about 70 microns to about 130 microns.

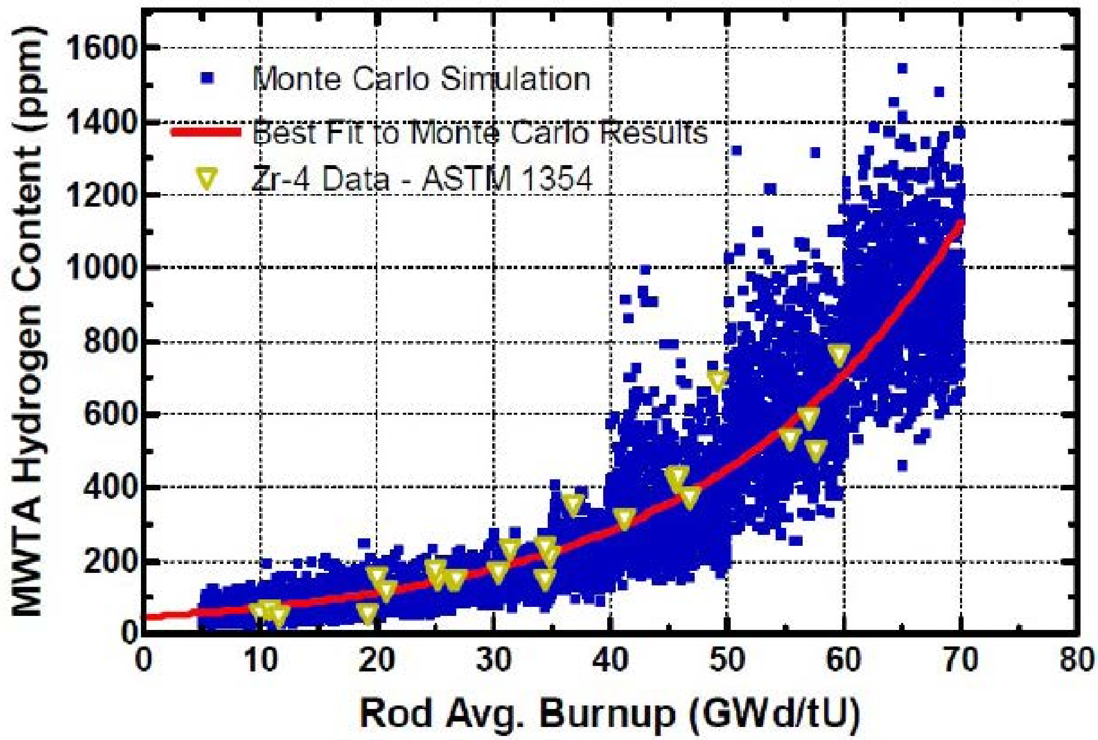

Figure 2. Maximum Wall Thickness Average Hydrogen Content in Low-Tin Zircaloy-4 Cladding (Reproduced from NWTRB 2010, Figure 21 p.56))

4.12. It is also important to have 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[28]). There are practically no such data. Indeed, even the research has been focused mainly on in-reactor behavior of high burnup fuels:

> 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.[29]

4.13. The spent fuel from Surry that was examined after about 15 years of dry storage was found upon inspection to be functionally undamaged.[30] 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 burnups, or during spent fuel pool storage. Lack of

[28] NWTRB 2010, p. 72
[29] NWRTB 2010, p. 52
[30] Einziger et al. 2003, p. 186

damage during much more prolonged dry storage of high burnup fuel also cannot be assumed based on the Surry study:

> 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*.[31]

4.14. The extent and types of degradation during storage can have profound consequences for health and environmental impacts in a number of ways. They affect the probability of releases as a result of aging. They will affect the extent of environmental impacts during transfer from one cask to another. They will affect the impacts of transportation accidents. They will affect radiation doses to workers who are handling the spent fuel on site. If the spent fuel is transported to a repository location (in the relevant scenarios), it will affect environmental impacts and offsite and worker radiation dose estimates at that location prior to disposal. These and other issues are discussed at length in NWRTB 2010, which sets forth an extended research program to address the problem of the lack of data. While the intent of those recommendations was to "prevent problems" by conducting the R&D, the same recommendations are also relevant for estimating impacts since the data to do so are currently largely unavailable. The NWTRB research and development recommendations include:[32]

- 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

[31] NWTRB 2010, p. 60, italics in the original
[32] 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

4.15. In sum at present the NRC lacks a realistic basis to assess degradation of high burnup spent fuel storage over long periods, the onsite and offsite radiological impacts of unloading damaged spent fuel, repackaging it as needed, and reloading it into a new cask.

4.16. The research outlined in the table in Section 4.5 above was part of the plan for the long-term storage EIS, which was supposed to be completed in the year 2019.[33] The research and modeling specified by the NWTRB in the list in paragraph 4.14 above are likely to take considerably longer to complete. The Commission's September 2012 decision to complete a waste confidence related EIS in just two years[34] leaves no time to pursue, let alone complete the work for making a scientifically valid assessment of the impacts of long term storage or of indefinite storage even for fuel from existing reactors.

4.17. The considerations in the paragraphs above in this section also apply to various designs of small modular reactors that are being proposed if their fuel designs and burnup are similar to presently licensed commercial reactors. If not, the considerations in the paragraphs below in this section would apply.

4.18. The above analysis and conclusions apply mainly to uranium spent fuel, for which there are at least some data for relatively low burnup spent fuel in dry storage for 15 years.[35] The problem of the lack of adequate data is even larger in terms of the needed research for mixed oxide (MOX) spent fuel and for spent fuel from Generation IV reactors.

4.19. 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 NRC staff will have to gather and develop data for extended storage of MOX spent fuel and extrapolate from reactor-grade MOX spent fuel to that resulting from irradiation of MOX fuel made with weapons grade plutonium. Inclusion of MOX spent fuel in the scope of the EIS may necessitate an even longer period of data gathering before a scientifically valid evaluation of environmental impacts, accident probabilities, and consequences of possible malevolent acts can be made.

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[33] Borchardt 2012, p. 3
[34] Vietti-Cook 2012
[35] NRC 2012a and Einziger 2003

4.20. The NRC scoping notice also includes spent fuel from Generation IV reactors. This covers a wide range of possible reactor types with very different kinds of spent fuel. For instance, the pebble bed reactor, which has been considered from time to time, has fuel elements that have a graphite outer coating.[36] The risks arising from storage of such fuel, the accident scenarios, and the design of the storage facilities would likely be fundamentally different than those associated with zircaloy fuel rods used in light water reactors. Sodium-cooled reactors present a completely different set of issues, as would liquid thorium fuel reactors, where the fuel is a molten salt. Pilot or demonstration machines of various reactors have been built. But there is as yet no relevant analysis of extended storage of spent fuel generated under commercial reactor operating conditions (high burnup at or near rated power levels). Inclusion of Generation IV spent fuel in the scope of the EIS will necessitate an even longer period of data gathering before a scientifically valid evaluation of environmental impacts, accident probabilities, and consequences of possible malevolent acts can be made.

4.21. Stainless steel fuel cladding was used as fuel cladding early in the history[37] of U.S. commercial reactors. By 1994, only one reactor had any stainless steel clad fuel in its core.[38] By 1992, a total of 679 metric tons spent fuel (uranium heavy metal content) had been generated from the stainless steel clad fuel.[39] 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.[40] The degradation characteristics of stainless steel fuel are different than zircaloy fuel and need to be explicitly included in the scope of the EIS. All scenarios need to explicitly consider the impacts of stainless steel cladding, including the cladding that was known to be degraded during irradiation.

4.22. New cladding materials, such as silicon carbide, are being researched in part due to the desire to reduce fuel costs and increase fuel burnup. The long term performance of such cladding in storage and after repository disposal also needs to be addressed within the scope of the EIS.

4.23. Without extensive additional data on degradation mechanisms and their interactions, central and critical aspects of the EIS will be based largely on speculation and would have little or no valid scientific foundation, notably for high burnup spent fuel that has been stored for several decades or centuries, not to speak of indefinitely, for small modular reactors, for MOX spent fuel (notably MOX fuel made from weapons grade plutonium) and for spent fuel from Generation IV reactor designs.

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[36] DOE 2010, p. 18
[37] EIA 1994, p. 23
[38] EIA 1994, p. 23
[39] EIA 1994, Table 9 (p. 27) and Table 10 (p. 28)
[40] Rivera and Meyer 1980, p. 1

5.0 The EIS should analyze, in depth, the impacts of transporting and handling spent fuel, and of storing it at repository sites.

5.1. 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 of such spent fuel 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 high burnup fuel or degraded canisters could be significantly higher than indicated by present understanding of accidents with intact fuel and canisters.

5.2. The considerations in Section 4, notably in paragraphs 4.1 to 4.14, indicate that degradation of high burnup spent fuel stored for prolonged periods (several decades to a few hundred years) needs to be taken into account during transportation. Specifically, the consequences of transportation accidents and any malevolent acts during transportation that breach the cask are may be much more severe than with lower burnup spent fuel stored for modest periods of time. For instance, if the cladding and canister are not intact, then a material breach of a transportation cask would result in releases of radioactivity. Releases due to an accident involving a fire could be severe to catastrophic. In contrast, if a canister is not degraded, then an additional barrier to radioactivity releases is available even if the transportation cask is breached.

5.3. The NWTRB has evaluated the issue of fuel degradation and its potential impact on transportation risks. Specifically, it has pointed out the need for additional analysis and modeling will be needed to analyze aging issues:

> Currently, if used fuel is stored in a dual-purpose storage system, transportation certification requires that the applicant show that the stored fuel and container is safe for transport. Given that fuel may be stored for decades before it is transported, and the possibility of degradation of fuel and corrosive deterioration of canisters over this time, applicants for transportation certificates will need to rigorously analyze such "aging" problems, which they have not needed to do in the past. It is possible that either the dual-purpose canister or the transportation overpack will have aged over its life. If so, the former numerical analysis and scale modeling of such transport packages may not reflect the actual behavior of aged fuel and packages.[41]

5.4. The aging analysis recommended by the NWTRB cannot be reliably carried out unless the degradation studies for high burnup fuel stored for several decades have been completed.

[41] NWTRB 2010, pp. 43-44

5.5. The NWTRB has also pointed out the inadequacies of current regulations and assumptions made by the NRC in addressing the problem of the integrity of spent fuel that has been stored for long periods:

> The NRC transportation requirements, as described above, appear to have been written for transportation of CSNF after a relatively short storage period because degradation of fuel rods and fuel assemblies is not clearly accounted for. Meeting the current specified packaging requirements after a period of extended dry storage involves satisfaction of four objectives of safe radioactive material transport: containment, shielding, criticality safety, and heat management. The focus of the regulations in 10 CFR 71 is largely on the integrity of the shipping cask and avoiding criticality, and not necessarily on the condition of the used fuel inside, provided certain performance requirements are met. However, current certification practice of transport packages requires applications to show that most fuel rods cannot be classified as damaged after transport. Consequently, it is important that at the time of transport, and after extended dry storage, (1) the initial condition and mechanical properties of the fuel and fuel-assembly structural elements are sufficiently characterized and (2) the behavior of fuel rods and fuel assemblies during normal and accident transport conditions can be sufficiently modeled to know whether transport requirements will be met.[42]

Both the requirements in the last part of this paragraph necessitate detailed knowledge of degradation phenomena before the analysis of normal transport and accident consequences can be carried out. Subsequent to those studies, transportation accident tests can be designed to examine whether proposed transports would comply with regulations for normal transport and under accident conditions.

5.6. The scope of the EIS should include impacts of transportation of high burnup fuel that has been stored for the periods of time relevant for each scenario prior to transportation to a repository location. The times for the two scenarios planned by the NRC are: transfer starting in 2050 and transfer starting in 2100. The start of the transfer for the additional scenario recommended here would be in about the year 2250.

5.7. Considerations similar to handling and inter-cask transfer of spent fuel after prolonged storage at the reactor site also apply to the handling of spent fuel once it is at the repository site. The impacts of handling, transfer, storage, and disposal during repository operation need to be examined in detail for high burnup spent fuel that has been stored for prolonged periods.

[42] NWTRB 2010 p. 44

6.0 The EIS should analyze, in depth, the reliability of institutional controls.

6.1. 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. Most consideration of institutional controls has been in the context of radioactive waste disposal in shallow or deep disposal facilities. We take a brief look at the relevant literature in this area first.

6.2. Many authorities, including the National Research Council, have concluded that 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.**
> […]
> *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.*[43]

6.3. The EIS should take account of the technical basis for NRC's 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 regulations are also consistent with EPA regulations for managing and disposing of high-level waste and transuranic waste. [44] For instance, scenarios could assume that the ability to do inter-cask transfers would lapse 100 years after reactor operation ceases. This assumption would be the same as that in the Department of Energy's Yucca Mountain Final EIS "no-action" alternative "Scenario 2"[45] Similarly, regulations of the Environmental Protection Agency for "Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" at 40 CFR 191 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.

[43] NAS-NRC 2000, pp. 3 and 5. Original italics; bold added.
[44] 40 CFR 191.14(a), 2011
[45] DOE 2002, Vol. I, p. 2-70

6.4. The problem is more complex in the case of commercial nuclear reactors partly because of the considerable uncertainty about the future of nuclear energy; this uncertainty therefore extends to any specific assumption about the end date for institutional control. For instance, new reactors have recently been licensed; they may operate to close to the end of this century. Hence, the 100-year assumption of lapse of controls in 10 CFR 61 and 40 CFR 191 would extend the date of control out to about the middle of the 23rd century when operational and licensed storage are considered for sixty years each.[46] In this scenario, transportation to a repository site would follow after 2250. Hence, this would require an extension of a storage license for the period over which transportation would take place. If more reactors are licensed in this century, that would extend the date when controls might be assumed to lapse out even farther, using the same 100-year criterion as in 10 CFR 61 and 40 CFR 191. For the purposes of the waste confidence EIS, an exact date of a lapse of institutional controls is not as critical as two other institutional control issues. First, it is unreasonable and technically and historically unsupportable to assume institutional control for thousands of years, as the DOE did in Scenario 1 of the Yucca Mountain EIS, for instance (see Section 8 below). Any assumption about institutional controls should respect the depth and breadth of historical evidence about the vulnerability of human institutions to upheaval and collapse over the decades and centuries. In other words, uncertainties about the future cannot be a license for arbitrary or ahistorical assumptions. Second, scenarios involving prolonged storage over many decades or hundreds of years must account for the reality that the worst case incidents and events (whether natural or malevolent) would increase in severity as the assumed storage period is lengthened. For instance, a hundred-year flood is worse than a ten-year flood; this reality must be taken into account in the analysis of impacts in the various scenarios in which storage periods are different. For the purposes of the waste confidence EIS my recommendation is to assume storage up to about the year 2250 followed by the time needed for transportation of spent fuel to and its disposal in a geologic repository location as the longest period for the duration of institutional controls. This should also be the guide for the assumption about the lapse of institutional controls for the scenario in which a repository is never available. History and science should provide a guide as to the severity of events to be considered over such a period of time.[47]

6.5. At least one scenario (indefinitely long periods of storage in the event of a repository never becoming available) requires consideration of times longer than those for which institutional control can reasonably be assumed. Therefore it is essential that the EIS consider storage design alternatives that would mitigate the impacts in the event that institutional control is lost. Loss of such control would significantly increase the risks of risks of malevolent acts, dispersal of radioactivity, public radiation exposure due to inadvertent intrusion on to the site, theft of nuclear materials, etc.

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[46] End of reactor operation for newly licensed reactors is assumed to be about 2080; sixty years after that extends the institutional control date to about 2140. Adding 100 years of control after lapse of the last license takes us to the middle of the 23rd century.

[47] See also Thompson 2013.

7.0 The EIS should analyze, in depth, impacts of deep geologic disposal of spent fuel.

7.1. Two of the three scenarios identified in the NRC scoping notice and during the public meeting (see paragraph 3.1 above) involve disposal of spent fuel in a deep geologic repository – *i.e.,* disposal in the middle of this century or at the end of it. The additional scenario that should be added to the list discussed above also involves an assumption of disposal in a deep geologic repository after prolonged onsite storage up to about the year 2250. In order to fully evaluate each scenario, the EIS 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.

7.2. There is at present no designated deep geologic disposal location that is either being investigated or considered for licensing. The Department of Energy has withdrawn its license application for Yucca Mountain. While the matter is still in litigation, Congress has not appropriated any funds to pursue the licensing process. The EIS cannot reasonably assume that Yucca Mountain will be the designated repository.

7.3. The NRC also cannot assume that the impacts of deep disposal of high level waste as specified in Table S-3 in 10 CFR 51.51 would be a reasonable estimate of the impacts of deep disposal of spent fuel. For one thing, Table S-3 assumes disposal in bedded salt and the NRC 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 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.[48]

7.4. Since both Yucca Mountain and disposal in salt (assumed in Table S-3) are ruled out for spent fuel disposal (though for different reasons), the EIS scope must include a process that is scientifically reasonable for estimating the impacts of deep geologic disposal of spent fuel in a generic manner.

7.5. For each scenario that includes disposal in a deep geologic repository, the NRC must estimate the radiation doses to workers, the onsite and offsite environmental impacts during the period of operation as well as the post-closure environmental impacts up to and including the time of peak radiation dose.

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

7.6. Since the analysis of disposal impacts will necessarily be generic, a process for bounding the dose will have to be developed. A bounding dose is a scientifically well-founded upper limit of exposure to individuals (workers, residents near the repository, a farming family far into the future that goes to live on the site after loss of institutional controls). This process will depend at least in part on the condition of the spent fuel to be disposed of and on the nature of the disposal casks and engineered barriers. The research described in Sections 4.1 to 4.14 will be important to making scientifically valid estimates of post-closure impacts and of peak radiation dose from uranium spent fuel. Additional work will be needed to estimate the impact of MOX spent fuel, for which a source term will also have to be developed. The NRC does not at present have the data needed to estimate the condition of the spent fuel that would be disposed of in a repository.

7.7. Deep geologic disposal impacts depend on the combined performance of the spent fuel and the disposal cask, the engineered barriers, the repository sealing system, and the near-field and far-field geologic, seismic, and hydrogeologic features of the site. In addition, assumptions are needed about the use of resources and defining the maximally exposed individual, normally taken to be a resident farmer family. The EIS must explore all reasonable combinations of geology, engineered barriers, sealing systems, and disposal casks to explore bounding dose.

7.8. Since the process for characterizing repository locations other than Yucca Mountain was abandoned early in the siting process (the Nuclear Waste Policy Act was passed on 1982 and the characterization was narrowed to Yucca Mountain in 1987) it will take a considerable amount of scientific effort and therefore time and resources to develop credible bounding doses so that a generic determination of upper limit impacts can be made for each scenario involving a deep disposal assumption.

8.0 The NRC currently lacks sufficient information to make a positive waste confidence finding or a finding of no significant impact from extended spent fuel storage or spent fuel disposal.

8.1. The NRC has indicated that it will use existing studies and analyses to prepare the Waste Confidence EIS,[49] including the Yucca Mountain EIS when "applicable and relevant."[50] For a number of reasons, the Yucca Mountain EIS is not adequate to support the Waste Confidence EIS. First, the scope of the Yucca Mountain EIS is, by its own terms, inadequate to cover the scope of inquiry necessary for the Waste Confidence EIS. Second, by the NRC's own admission, it has a great deal of additional research to do in order to understand the environmental risks posed by storage, handling and transportation of spent fuel over the long-term.

Inadequacy of Yucca Mountain EIS

8.2. In 2002, the Department of Energy issued a final Environmental Impact Statement for the then-proposed Yucca Mountain deep geologic repository for spent fuel and high level waste.

[49] Vietti-Cook 2012
[50] NRC 2012b. p. 24

The no-action alternative in the Yucca Mountain EIS was that the Yucca Mountain repository would not be licensed. As part of this alternative, the DOE considered onsite storage with institutional controls for 10,000 years ("Scenario 1"), during which "storage facilities would be completely replaced every 100 years" as well as onsite storage with institutional controls failing after 100 years ("Scenario 2"), allowing intruders, cask deterioration, etc. after that time.[51] DOE recognized that Scenario 1 would mean that sufficient political stability would exist for 10,000 years sufficient "to monitor and maintain the spent nuclear fuel and high-level radioactive waste to protect the public and the waste for 10,000 years."[52]

8.3. Scenario 2 of DOE's "no-action alternative" -- institutional controls lapse after 100 years – is reasonable. It has some basis in experience; it is also in conformity with existing NRC and EPA regulations, as discussed in Section 6 above. In the context of NRC licensing, it is plausible at least to consider controls up to at most the year 2250, as discussed in Section 6, though with the caveats discussed below in paragraphs 8.4 to 8.6.

8.4. Assuming institutional controls for 10,000 years – a period longer than recorded history and far longer than any human institution has existed – is without foundation in fact, experience, or common sense. It requires stability over a period 60 times longer than the period since March 1861 when the transfer of power to newly-elected President Lincoln brought secessionist sentiment in the South to a boil and triggered a Civil War a little more than a month later. It is also contrary to the NRC's own regulations for *low-level* waste disposal and the EPA's guidance in 40 CFR 191.

8.5. In addition, over the last 250 years, the United States has experienced the Revolutionary War, the War of 1812, innumerable violent conflicts with Native Americans, the U.S.-Mexican War, the 1941 Japanese attack on Pearl Harbor, and the 9/11/2001 terrorist attacks that destroyed the World Trade Center in New York and a significant portion of the Pentagon.

8.6. To its credit, 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. Throughout history, governments have ended abruptly, resulting in social instability, including some level of lawlessness and anarchy."[53] The DOE recognized that 10,000 years of institutional control is "unlikely"[54] but did not note that an assumption of 10,000 years of political stability has no foundation in fact, history, or experience. Indeed, there is no significant fact that would make such an assumption even remotely plausible.

8.7. The above considerations reinforce the facts and analysis in Section 6.0 that institutional controls should not go beyond about the year 2250 in the case of storage; intruder barriers cannot be assumed to last for more than 500 years. For storage times beyond 100 years, it would be important to include an analysis of social upheavals or malevolent acts in the analysis.[55]

[51] DOE 2002, Vol. I, pp. 2-70 to 2-71
[52] DOE 2002, Vol. II, Appendix K, p. K-35
[53] DOE 2002, Vol. II, Appendix K, p. K-35
[54] DOE 2002, Vol. I, pp. 2-64 to 2-65.
[55] See also Thompson 2013.

8.8. While it is of course useful to look at existing analyses, including the Yucca Mountain EIS, the NRC cannot use the specific environmental impact calculations in the no-action alternative scenarios of the Yucca Mountain EIS. Many of the assumptions in both Scenario 1 and Scenario 2 of the Yucca Mountain EIS No-Action Alternative are scientifically inappropriate for the Waste Confidence EIS.

8.9. A central reason that the Waste Confidence EIS cannot use the onsite storage impact calculations and conclusions in the Yucca Mountain EIS is that the DOE explicitly and deliberately underestimated the impacts of the no-action alternative scenarios in a number of ways. This is because the DOE 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. For instance, the DOE evaluated a scenario with 300 years of institutional control at the repository location but not in the no-action (onsite storage) alternative for this very reason:

> …DOE did not evaluate the 300-year institutional control case for the No-Action Alternative. **The primary reason** for not updating this part of the analysis [from the Draft EIS stage] was because if the institutional control period for the analysis of the No-Action Alternative were extended to 300 years, the short-term environmental impacts would have increased by as much as 3 times. **DOE did not want to overstate the environmental impacts of the No-Action Alternative.**[56]

8.10. Another example shows that DOE deliberately ignored some impacts in the No-Action Alternative:

> The Department 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 under Scenario 2. This decision is consistent with the Department's position **that care should be taken not to overestimate impacts from the No-Action Alternative.**[57]

8.11. The DOE took so much care not to overestimate impacts from the No-Action Alternative, that it ignored some of them altogether. For instance, in Scenario 1 of the No-Action Alternative (repackaging every 100 years for 10,000 years), the impacts of air pollution from casks transfer were assigned a zero value in cancer fatality calculations though they are not estimated because of the variability of canister degradation "from site to site" and the difficulty of dealing with the problem:

> Very small air quality impacts would be likely from repackaging materials removed from dry storage containers that could degrade to the point that they no longer met licensing requirements. However, overall impact estimates did not include these impacts because long-term dry **storage canister degradation would be highly variable and difficult to estimate from site to site and DOE**

[56] DOE 2002, Vol. I, pp. 7-9 and 7-10, emphasis added
[57] DOE 2002, Vol. I, p. 7-35, emphasis added

> **did not want to overestimate the accompanying air quality impacts from repackaging.**[58]

These are remarkable semantic acrobatics to avoid difficult problems in order to systematically underestimate impacts using the euphemism that "DOE did not want to overestimate" impacts. Whatever the rationale in the Yucca Mountain EIS for this systemic problem, it would be entirely inappropriate to adopt it or to use the estimates in the No-Action Alternative in DOE 2002 in the Waste Confidence EIS.

8.12. The Yucca Mountain No-Action Alternative estimated doses from drinking water in Scenario 2 of the No-Action Alternative, in which institutional control is lost after 100 years. The "latent cancer fatalities" were estimated at a total of 3,300 over almost 10,000 years, or just one in three years, compared to a total of 900 million from all other causes.[59]

8.13. The DOE calculated some cancer impacts, such as from contamination of surface water, but concluded that they would be small – less than 10 percent of the cancers it did calculate.[60]

8.14. 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.[61]

8.15. When food pathways other than drinking water are considered, the radiation doses and hence fatalities were estimated to triple. 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 is 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 a narrow view of latent cancer fatalities may indicate.

8.16. Even the estimates of latent cancer fatalities are presented in a very skewed way. Cladding degradation once the spent fuel is put into dry storage is assumed to begin after thousands of years and "less than 0.01 percent" of the cladding would fail in the first 10,000 years![62] Yet, the

[58] DOE 2002, Vol. I, p. 7-26, emphasis added
[59] DOE 2002, Vol. II, Appendix K, p. K-28
[60] DOE 2002, Vol. II, Appendix K, p. K-32
[61] DOE 2002, Vol. II, Appendix K, p. K-29
[62] DOE 2002, Vol. II, Appendix K, p. K-11

DOE acknowledges the centrality of this assumption by stating that different corrosion assumptions could reduce the dose estimates by a factor of 2 or increase them by thousands of times (or more):

> If the No-Action analysis had assumed larger or smaller deterioration rates [of zirconium alloy cladding], LCFs [latent cancer fatalities] could have **increased by several orders of magnitude** or decreased by less than a factor of 2.[63]

8.17. 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. Indeed, the practice of high burnup was only in its early stages in 2002 when the Yucca Mountain EIS was published. Given the evidence that oxidation, hydriding, and other degradation phenomena are far more severe with high burnup fuel, the No-Action Alternative analysis in the Yucca Mountain EIS must be regarded as fundamentally deficient and unusable even on those limited scientific grounds alone.

8.18. Critical uncertainties were not evaluated in the Yucca Mountain EIS. Perhaps the most important for the No-Action Alternative is the problem of climate change. It is reasonably clear that it is prudent and scientifically appropriate to assume more frequent and more severe storms, more frequent flooding or droughts, depending on the location of the nuclear power plant, and possibly more intense and frequent tornadoes.

8.19. Whatever uncertainties there may have been a decade ago about the severity of climate change, the picture is much clearer now and more data and analyses exist. The Waste Confidence EIS must consider and model climate factors in detail because they are likely to be among the most important factors in causing or aggravating damage from prolonged storage of spent fuel. The Yucca Mountain No-Action Alternative recognized that serious climate change impacts are highly likely over long periods of storage but failed to quantify the impacts." This is another reason that the NRC cannot rely upon the Yucca Mountain EIS's No-Action Alternative.

9.0 The EIS should acknowledge that certain impacts cannot be analyzed in a generic manner.

9.1. The scoping notice has ruled out "site specific issues or concerns" from the scope of the EIS and proposed to "bound the environmental analysis" based on "a set of general characteristics" alone.[64]

9.2. While some issues are generic and can, given adequate data, be bounded on that basis – as for instance, the impacts of transferring spent fuel from one cask to another – others 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.

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[63] DOE 2002, Vol. II, Appendix K, p. K-38, emphasis added
[64] NRC 2012d, p. 65138

9.3. Consider health and property damage impacts. They will likely 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.

9.4. 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 in Nebraska or Duane Arnold in Iowa.

9.5. 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 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 that the NRC 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.

9.6. From the above examples, it is clear that no scientifically valid examination of environmental impacts of prolonged storage can be done on a generic basis alone. While it is acceptable to bound each type of damage, separate estimates must be made for each type that is incommensurate with others. At a minimum, the EIS 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.

9.7. 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.

10.0 The EIS should analyze, in depth, the alternative of not issuing a new Waste Confidence Decision and Rule.

10.1. As discussed above in Section 4, the NRC, by its own admission, has years of research to do in order to develop a sound database that is needed for a scientifically valid evaluation of the environmental impacts of prolonged storage of high burnup spent fuel. The NWTRB has also discussed the types of research and modeling that remain to be done as discussed in Sections 4 and 5 above. This agenda will likely take considerably longer. The data for MOX spent fuel and for Generation IV reactor types are far thinner for these designs than for light water reactor uranium spent fuel; as a result the task of estimating the impacts will likely be lengthier and more complex than for the current crop of commercial reactors.

10.2. The considerations, facts, and analysis in Sections 4.1 to 4.14 above, including the descriptions of data requirements and research by the NRC staff in NRC 2012a and by the NWTRB (2010), apply to essentially all operating commercial reactors in the United States and to new commercial light water reactors that the NRC may consider for licensing. Burnups have been increasing in the last decade. There are essentially no data available for high burnup spent fuel that has been stored in dry casks for extended periods of time. Reactor operators have been moving to higher burnup for over a decade; that trend is expected to continue at least for pressurized water reactors, as can be seen from the data and projections in Figure 3.

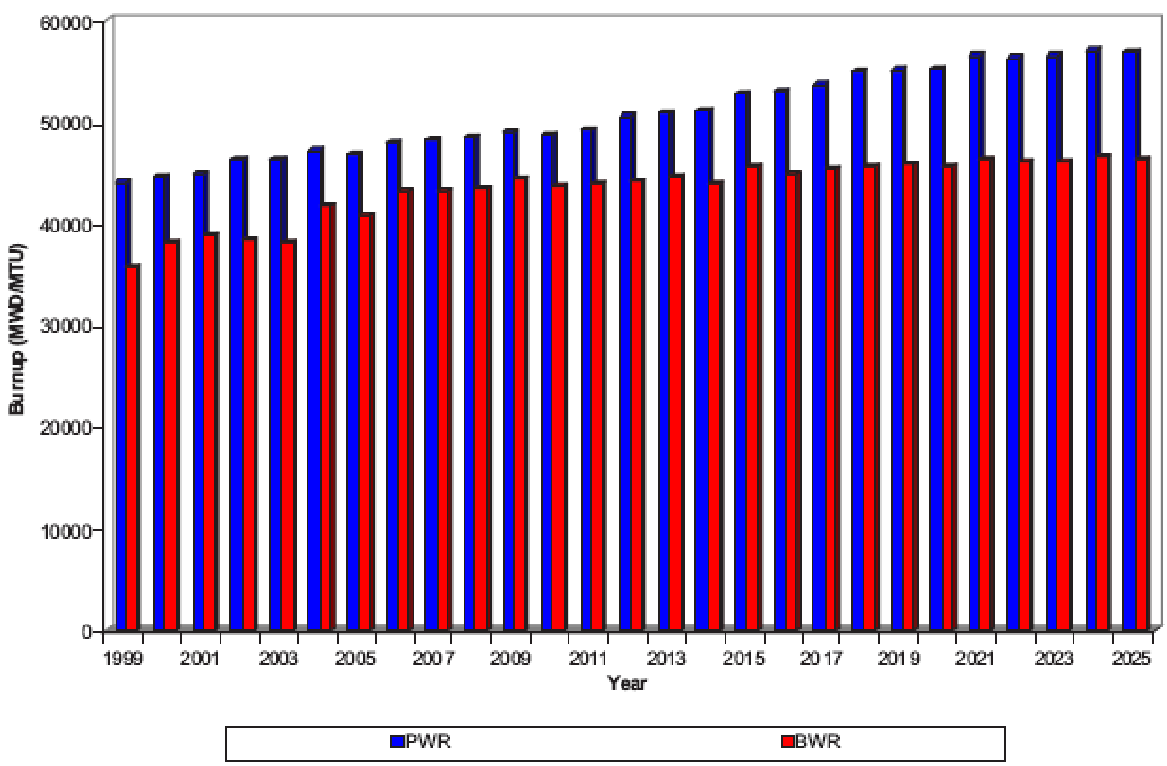

Figure 3. Burnup trends for PWR and BWR reactors in the United States (Reproduced from IAEA 2011, Fig. 6 (p. 9), with note: Courtesy of Energy Resources International)

10.3. In the absence of data on high burnup fuels stored for prolonged periods (discussed in Sections 4.1 to 4.14), it will be impossible to do a scientifically valid environmental impact evaluation whether it is generic for all commercial reactors or for one or more reactors particular to a single site.

10.4. In view of the above considerations, the no-action alternative that the EIS should clarify that a site-by-site analysis will also not be possible in the absence of data that is also needed for a generic waste confidence decision.

11.0 Summary and Scoping Recommendations

11.1. The data requirements for conducting a scientifically sound or even minimally valid waste Confidence EIS are varied and vast. It will take a long time, mostly likely well over a decade, to collect the data and do the needed modeling based on that data to make scientifically valid impact analyses for high burnup fuel stored for long periods. The NRC staff itself has laid out the data requirements and low knowledge base in many critical areas even for currently licensed reactors. The NWTRB has also discussed this issue, as noted in Sections 4 and 5 above. For new types of fuel and reactors, the needed research has not even been properly mapped out.

11.2. The NRC should add a scenario in which spent fuel is stored on site for 300 years from the first such storage (that is storage until about the year 2250) before being transported to a repository. 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.

11.3. Some aspects of impacts can be evaluated on a generic basis but there are a variety of impacts that cannot be so evaluated. For instance, damage to riverine and/or estuarine ecosystems is qualitatively different than that arising from severe accidents or radioactivity dispersal in highly populated areas, such as the suburbs of New York City or Philadelphia. These must be evaluated on a site-specific basis or by a bounding approach to each type of damage, for instance: number of cancers, property damage, aquifers and irrigation systems damaged, drinking water affected, unique ecosystems affected, etc. No single nuclear power plant or group of plants will provide the bounding result for all these types of damage.

11.4. NRC waste regulations provide a good starting point for institutional control periods that are consistent with other regulations, analysis and guidance. For instance, assuming loss of significant institutional control 100 years after license expiry would be compatible with the NRC low level waste disposal rule (10 CFR 61) and EPA's rule for deep geologic repositories (40 CFR 191). The problem is complicated by uncertainties about the future of nuclear energy, among other things. Whatever the uncertainties, it is unreasonable and technically unsupportable to assume institutional control for thousands of years as the DOE did in one of its Yucca Mountain EIS scenarios. For the purposes of the waste confidence EIS my recommendation is to assume storage up to about the year 2250 followed by the time needed for transportation of spent fuel to and its disposal in a geologic repository location as the longest period for the duration of institutional controls. This should also be the guide for the assumption about the lapse of institutional controls for the scenario in which a repository is never available.

History and science should provide a guide as to the severity of events to be considered over such a period of time. Resident farmer families should be used to estimate maximum individual doses after loss of institutional control. Environmental justice aspects needed to be considered; the resident farmer scenario will likely need to be modified in some of these cases.

11.5. 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 CFR 51.51(b) because (i) the NRC itself has admitted that salt disposal is inappropriate for spent fuel and (ii) all other media will have non-zero impact, and (iii) the impact is highly dependent on the combination of site characteristics, engineered barriers (including disposal casks), and sealing systems that are presumed to be used.

11.6. The EIS should have a no-action alternative that would be the non-issuance of a waste confidence decision and rule and a continued suspension of new reactor licensing and existing reactor license extension actions until data to make scientifically valid impact estimates of the consequences of long-term storage of high burnup spent fuel are collected and analyzed.

11.7. The No-Action Alternative should not rely on the No-Action Alternative of the Yucca Mountain EIS for its conclusions or analysis. Among other things, the environmental impacts in the Yucca Mountain EIS No-Action Alternative were deliberately underestimated by the DOE.

11.8. In case the NRC does not issue a generic Waste Confidence rule, the No-Action Alternative should not presume that sufficient information exists to resume site-by-site licensing decisions. It does not.

11.9. The No-Action Alternative as described in paragraph 11.6 above should be the preferred alternative.

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

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Dr. Arjun Makhijani
1 January 2013

12.0 References

10 CFR 51, 2012	U.S. Nuclear Regulatory Commission. *Code of Federal Regulations. Title 10 – Energy. Part 51 – Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.* 1-1-12 Edition. Washington, DC: Office of the Federal Register, National Archives and Records Administration; U.S. Government Printing Office, 2012. On the Web at http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol2/pdf/CFR-2012-title10-vol2-part51.pdf.
10 CFR 61, 2012	U.S. Nuclear Regulatory Commission. *Code of Federal Regulations. Title 10 – Energy: Chapter I Nuclear Regulatory Commission; Part 61 – Licensing Requirements For Land Disposal Of Radioactive Waste*. 1-1-12 Edition. Washington, DC: Office of the Federal Register, National Archives and Records Administration; U.S. Government Printing Office, 2012. On the Web at http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol2/pdf/CFR-2012-title10-vol2-part61.pdf.
40 CFR 191, 2011	U.S. Environmental Protection Agency. *Code of Federal Regulations. Title 40 – Protection of Environment. Chapter I – Environmental Protection Agency. Part 191 – Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*. 7-1-11 Edition. Washington, DC: Office of the Federal Register, National Archives and Records Administration; United States Government Printing Office, 2011. On the Web at http://www.gpo.gov/fdsys/pkg/CFR-2012-title40-vol26/pdf/CFR-2012-title40-vol26-part191.pdf. Accessed Dec. 10, 2012.
Borchardt 2012	R. W. Borchardt (Executive Director for Operations). Memorandum to: Chairman Macfarlane, Commissioner Svinicki, Commissioner Apostolakis, Commissioner Magwood, Commissioner Ostendorff. Subject: *Approach for Addressing Policy Issues Resulting from Court Decision to Vacate Waste Confidence Decision and Rule*. (COMSECY-12-0016) [Washington, DC: Nuclear Regulatory Commission], July 9, 2012. On the Web at http://pbadupws.nrc.gov/docs/ML1218/ML12180A424.pdf.
DOE 2002	U.S. Department of Energy. Office of Civilian Radioactive Waste Management. *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*. (DOE/EIS-0250) Washington, DC: DOE, OCRWM, February 2002. Links on the Web at http://energy.gov/nepa/downloads/eis-0250-final-environmental-impact-statement, including Vol. I, at http://energy.gov/sites/prod/files/EIS-0250-FEIS-01-2002_0.pdf. Vol. II, at http://energy.gov/sites/prod/files/EIS-0250-FEIS-02-2002.pdf.
DOE 2010	U.S. Department of Energy. Office of Nuclear Energy. *Next Generation Nuclear Plant: A Report to Congress*. [Washington, DC]: DOE, April 2010. On the Web at http://www.ne.doe.gov/pdfFiles/NGNP_ReporttoCongress_2010.pdf
DOE 1994	U.S. Department of Energy. *Spent Nuclear Fuel Discharges from U.S. Reactors 1992*. (SR/CNEAF/94-01) Washington, DC: DOE, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Survey Management Division, May 1994. On the Web at http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/25/070/25070038.pdf.

Einziger et al. 2003	Robert E. Einziger, Hanchung Tsai, Michael C. Billone, and Bruce A. Hilton. "Examination of Spent Pressurized Water Reactor Fuel Rods After 25 years in Dry Storage," *Nuclear Technology*, v.144 (November 2003): pp. 186-200. Links on the Web at http://www.new.ans.org/pubs/journals/nt/a_3439.
IAEA 2011	International Atomic Energy Agency. *Impact of high burnup uranium oxide and mixed uranium-plutonium oxide water reactor fuel on spent fuel management*. (IAEA Nuclear Energy Series No. NF-T-3.8) Vienna: IAEA, 2011. On the Web at http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1490_web.pdf.
Macfarlane 2012	Allison M. Macfarlane (Chairman, U.S. Nuclear Regulatory Commission). Letter to Diane Curran (Harmon, Curran, Spielberg & Eisenberg, L.L.P.), December 5, 2012. [Re: The scoping process for an environmental impact statement for the Waste Confidence Decision.]
Makhijani 2009	Arjun Makhijani. *Comments of the Institute for Energy and Environmental Research on the U.S. Nuclear Regulatory Commission's Proposed Waste Confidence Rule Update and Proposed Rule Regarding Environmental Impacts of Temporary Spent Fuel Storage*. Takoma Park, MD: Institute for Energy and Environmental Research, 6 February 2009. On the Web at http://ieer.org/resource/testimony/comments-nrcs-proposed-waste-confidence/, to http://ieer.org/wp/wp-content/uploads/2012/06/WasteConfidenceComments2009.pdf. [NRC accession number: ML090680888.]
NAS-NRC 2000	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. On the Web at http://www.nap.edu/catalog.php?record_id=9949.
NRC 2001	U.S. Nuclear Regulatory Commission. "10 CFR Part 72: [Docket No. PRM-72-4]: Prairie Island Coalition; Denial of Petition for Rulemaking." *Federal Register*, v. 66, no. 25 (February 6, 2001): pp. 9055-9058. On the Web at http://www.gpo.gov/fdsys/pkg/FR-2001-02-06/pdf/01-3025.pdf. "FR Doc No: 01-3025"
NRC 2008	U.S. Nuclear Regulatory Commission. "10 CFR Part 51: [Docket ID–2008–0482]: Waste Confidence Decision Update." *Federal Register*, v. 73, no. 197 (October 9, 2008): pp. 59551-59570. On the Web at http://www.gpo.gov/fdsys/pkg/FR-2008-10-09/pdf/E8-23381.pdf. "FR DOC # E8-23381" "Proposed Rules"
NRC 2010a	U.S. Nuclear Regulatory Commission. "10 CFR Part 51: [NRC–2008–0482]: Waste Confidence Decision Update." *Federal Register*, v. 75, no. 246 (December 23, 2010): pp. 81037-81076. On the Web at http://www.gpo.gov/fdsys/pkg/FR-2010-12-23/pdf/2010-31637.pdf. "FR DOC # 2010-31637" "Update and final revision of Waste Confidence Decision."

NRC 2010b	U.S. Nuclear Regulatory Commission. "10 CFR Part 51: [NRC–2008-0404]: Consideration of Environmental Impacts of Temporary Storage of Spent Fuel After Cessation of Reactor Operation." *Federal Register*, v. 75, no. 246 (December 23, 2010): pp. 81032-81037. On the Web at http://www.gpo.gov/fdsys/pkg/FR-2010-12-23/html/2010-31624.htm. "RIN 3150–AI47" "Final Rule."
NRC 2011	U.S. Nuclear Regulatory Commission. *Draft Report for Comment: Background and Preliminary Assumptions for an Environmental Impact Statement – Long-Term Waste Confidence Update*. Washington, DC: NRC, December 2011. On the Web at http://pbadupws.nrc.gov/docs/ML1134/ML11340A141.pdf.
NRC 2012a	U.S. Nuclear Regulatory Commission. *Draft Report for Comment: Identification and Prioritization of the Technical Information Needs Affecting Potential Regulation of Extended Storage and Transportation of Spent Nuclear Fuel*. Washington, DC: NRC, May 2012. On the Web at http://pbadupws.nrc.gov/docs/ML1205/ML120580143.pdf.
NRC 2012b	U.S. Nuclear Regulatory Commission. *Public Scoping Meeting for the Environmental Impact Statement to Support an Updated Waste Confidence Decision and Rule: November 14, 2012. 1:00 P.M.. Transcript of Proceedings. Public Meeting*. Washington, DC: NRC, November 2012. On the Web at http://pbadupws.nrc.gov/docs/ML1233/ML12331A347.pdf.
NRC 2012c	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]
NRC 2012d	U.S. Nuclear Regulatory Commission. "10 CFR Part 51: [NRC–2012–0246]: Consideration of Environmental Impacts of Temporary Storage of Spent Fuel After Cessation of Reactor Operation." *Federal Register*, v. 77, no. 207 (October 25, 2012): pp. 65137-65139. On the Web at http://www.gpo.gov/fdsys/pkg/FR-2012-10-25/pdf/2012-26295.pdf. "RIN 3150–AJ20" "Request for comments on the notice of intent to prepare and environmental impact statement and notice of public meetings." Scoping notice.
NWTRB 2010	United States Nuclear Waste Technical Review Board. *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel*. Arlington, VA: NWTRB, December 2010. On the Web at http://www.nwtrb.gov/reports/eds_rpt.pdf. "Prepared by Dr. Douglas B. Rigby, staff member, in support of the Board's analysis of issues associated with extended dry storage and transportation, an effort lead by Dr. Andrew C. Kadak, Board member."
Rivera et Meyer 1980	J. E. Rivera and J. E. Meyer. *Stainless Steel Clad for Light Water Reactor* Fuels. (Energy Laboratory Report No. MIT-EL 80-021) Cambridge: Massachusetts Institute of Technology, Energy Laboratory and Department of Nuclear Engineering, July 1980. On the Web at http://dspace.mit.edu/bitstream/handle/1721.1/60538/EL_TR_1980_021.pdf.

Thompson 2013	Gordon Thompson, *Declaration of Dr. Gordon Thompson Regarding the Scope of Proposed Waste Confidence Environmental Impact Statement*, Institute for Resource and Security Studies, Cambridge, Massachusetts, January 2, 2013.
U.S. Court of Appeals 2012	United States Court of Appeals. For The District Of Columbia Circuit. No. 11-1045. State of New York, et al., Petitioners v. Nuclear Regulatory Commission and United States of America, Respondents; State of New Jersey, et al., Intervenors. Consolidated with 11-1051, 11-1056, 11-1057. On Petitions for Review of Orders of the Nuclear Regulatory Commission Argued March 16, 2012 Decided June 8, 2012. On the Web at http://www.cadc.uscourts.gov/internet/opinions.nsf/57ACA94A8FFAD8AF85257A1700502AA4/$file/11-1045-1377720.pdf. Heading: "USCA Case #11-1045 Document #1377720 Filed: 06/08/2012"
Vietti-Cook 2012	Annette L. Vietti-Cook (Secretary). Memorandum to: R. W. Borchardt (Executive Director for Operations). Subject: *Staff Requirements – COMSECY-12-0016 – Approach For Addressing Policy Issues Resulting From Court Decision To Vacate Waste Confidence Decision And Rule*. [Washington, DC: Nuclear Regulatory Commission], September 6, 2012. On the Web at http://www.nrc.gov/reading-rm/doc-collections/commission/comm-secy/2012/2012-0016comsrm.pdf.

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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

***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)

Hower, G.L., and A. Makhijani, "Further Comparison of Spread-F and Backscatter Sounder Measurements," *Journal of Geophysical Research* 74 (1969): 3723.

Makhijani, A., and A.J. Lichtenberg, *An Assessment of Energy and Materials Utilization in the U.S.A.*, University of California Electronics Research Laboratory, Berkeley, 1971.

Logan, B. G., A.J. Lichtenberg, M. Lieberman, and A. Makhijani, "Multiple-Mirror Confinement of Plasmas," *Physical Review Letters* 28 (1972): 144-147.

Makhijani, A., and A.J. Lichtenberg, "Energy and Well-Being," *Environment* 14 (June 1972): 10-.

Makhijani, A., A.J. Lichtenberg, M. Lieberman, and B. Logan, "Plasma Confinement in Multiple Mirror Systems. I. Theory," *Physics of Fluids* 17 (1974): 12911301.

A Time to Choose: America's Energy Future, final report of the Ford Foundation Energy Policy Project, Ballinger, Cambridge, 1974. One of many co-authors.

Makhijani, A., and A. Poole, *Energy and Agriculture in the Third World*, Ballinger, Cambridge, 1975.

Makhijani, A., *Energy Policy for the Rural Third World*, International Institute for Environment and Development, London, 1976.

Kahn, E., M. Davidson, A. Makhijani, P. Caeser, and S. Berman, *Investment Planning in the Energy Sector*, Lawrence Berkeley Laboratory, Berkeley, 1976.

Makhijani, A., "Solar Energy for the Rural Third World," *Bulletin of the Atomic Scientists*, May 1977.

Makhijani, A., "Energy Policy for Rural India," *Economic and Political Weekly (Bombay)* 12 (1977).

Makhijani, A., *Some Questions of Method in the Tennessee Valley Authority Rate Study*, Report to the Tennessee Valley Authority, Chattanooga, 1978.

Makhijani, A., *The Economics and Sociology of Alternative Energy Sources*, Economic and Social Commission for Asia and the Pacific, 1979.

Makhijani, A., *Energy Use in the Post-Harvest Component of the Food Systems in Ivory Coast and Nicaragua*, Food and Agriculture Organization of the United Nations, Rome, 1982.

Makhijani, A., *Oil Prices and the Crises of Debt and Unemployment: Methodological and Structural Aspects*, International Labour Office of the United Nations, Final Draft Report, Geneva, April 1983.

Makhijani, A., and D. Albright, *The Irradiation of Personnel at Operation Crossroads*, International Radiation Research and Training Institute, Washington, D.C., 1983.

Makhijani, A., K.M. Tucker, with Appendix by D. White, *Heat, High Water, and Rock Instability at Hanford*, Health and Energy Institute, Washington, D.C., 1985.

Makhijani, A., and J. Kelly, *Target: Japan - The Decision to Bomb Hiroshima and Nagasaki*, July 1985, a report published as a book in Japanese under the title, *Why Japan?*, Kyoikusha, Tokyo, 1985.

Makhijani, A., *Experimental Irradiation of Air Force Personnel During Operation Redwing - 1956*, Environmental Policy Institute, Washington, D.C., 1985.

Makhijani, A., and R.S. Browne, "Restructuring the International Monetary System," *World Policy Journal* (Winter 1985-86).

Makhijani, A., R. Alvarez, and B. Blackwelder, *Deadly Crop in the Tank Farm: An Assessment of Management of High-Level Radioactive Wastes in the Savannah River Plant Tank Farm*, Environmental Policy Institute, Washington, D.C., 1986.

Makhijani, A., "Relative Wages and Productivity in International Competition," *College Industry Conference Proceedings*, American Society for Engineering Education, Washington, D.C., 1987.

Makhijani, A., *An Assessment of the Energy Recovery Aspect of the Proposed Mass Burn Facility at Preston, Connecticut*, Institute for Energy and Environmental Research, Takoma Park, 1987.

Makhijani, A., R. Alvarez, and B. Blackwelder, *Evading the Deadly Issues: Corporate Mismanagement of America's Nuclear Weapons Production*, Environmental Policy Institute, Washington, D.C., 1987.

Franke, B. and A. Makhijani, *Avoidable Death: A Review of the Selection and Characterization of a Radioactive Waste Repository in West Germany,* Health & Energy Institute, Washington, DC; Institute for Energy and Environmental Research, Takoma Park, November 1987.

Makhijani, A., *Release Estimates of Radioactive and Non-Radioactive Materials to the Environment by the Feed Materials Production Center, 1951-85*, Institute for Energy and Environmental Research, Takoma Park, 1988.

Alvarez, R., and A. Makhijani, "The Hidden Nuclear Legacy," *Technology Review* 91 (1988): 42-51.

Makhijani, A., Annie Makhijani, and A. Bickel, *Saving Our Skins: Technical Potential and Policies for the Elimination of Ozone-Depleting Chlorine Compounds*, Environmental Policy Institute and Institute for Energy and Environmental Research, Takoma Park, 1988.

Makhijani, A., Annie Makhijani, and A. Bickel, *Reducing Ozone-Depleting Chlorine and Bromine Accumulations in the Stratosphere: A Critique of the U.S. Environmental Protection Agency's Analysis and Recommendations*, Institute for Energy and Environmental Research and Environmental Policy Institute/Friends of the Earth, Takoma Park, 1989.

Makhijani, A., and B. Franke, *Addendum to Release Estimates of Radioactive and Non-Radioactive Materials to the Environment by the Feed Materials Production Center, 1951-85*, Institute for Energy and Environmental Research, Takoma Park, 1989.

Makhijani, A., *Global Warming and Ozone Depletion: An Action Program for States*, Institute for Energy and Environmental Research, Takoma Park, 1989.

Makhijani, A., *Managing Municipal Solid Wastes in Montgomery County*, Prepared for the Sugarloaf Citizens Association, Institute for Energy and Environmental Research, Takoma Park, 1990.

Saleska, S., and A. Makhijani, *To Reprocess or Not to Reprocess: The Purex Question - A Preliminary Assessment of Alternatives for the Management of N-Reactor Irradiated Fuel at the U.S. Department of Energy's Hanford Nuclear Weapons Production Facility*, Institute for Energy and Environmental Research, Takoma Park, 1990.

Makhijani, A., "Common Security is Far Off," *Bulletin of the Atomic Scientists*, May 1990.

Makhijani, A., *Draft Power in South Asian Agriculture: Analysis of the Problem and Suggestions for Policy*, prepared for the Office of Technology Assessment, Institute for Energy and Environmental Research, Takoma Park, 1990.

Mehta, P.S., S.J. Mehta, A.S. Mehta, and A. Makhijani, "Bhopal Tragedy's Health Effects: A Review of Methyl Isocyanate Toxicity," *JAMA* 264 (December 5, 1990): 2781-2781,.

Special Commission of International Physicians for the Prevention of Nuclear War and the Institute for Energy and Environmental Research, *Radioactive Heaven and Earth: The Health and Environmental Effects of Nuclear Weapons Testing In, On, and Above the Earth*, Apex Press, New York, 1991. One of many co-authors.

Makhijani, A., and S. Saleska, *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, New York, 1992.

Makhijani, A., *From Global Capitalism to Economic Justice: An Inquiry into the Elimination of Systemic Poverty, Violence and Environmental Destruction in the World Economy*, Apex Press, New York, 1992.

Special Commission of International Physicians for the Prevention of Nuclear War and the Institute for Energy and Environmental Research, *Plutonium: Deadly Gold of the Nuclear Age*, International Physicians Press, Cambridge, MA, 1992. One of several co-authors.

Makhijani, A., "Energy Enters Guilty Plea," *Bulletin of the Atomic Scientists*, March/April 1994.

Makhijani, A., "Open the Files," *Bulletin of the Atomic Scientists*, Jan./Feb. 1995.

Makhijani, A., " 'Always' the Target?" *Bulletin of the Atomic Scientists*, May/June 1995.

Makhijani, A., and Annie Makhijani, *Fissile Materials in a Glass, Darkly: Technical and Policy Aspects of the Disposition of Plutonium and Highly Enriched Uranium*, IEER Press, Takoma Park, 1995.

Makhijani, A., and K. Gurney, *Mending the Ozone Hole: Science, Technology, and Policy*, MIT Press, Cambridge, MA, 1995.

Makhijani, A., H. Hu, K. Yih, eds., *Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and the Health and Environmental Effects*, MIT Press, Cambridge, MA, 1995.

Zerriffi, H., and A. Makhijani, *The Nuclear Safety Smokescreen: Warhead Safety and Reliability and the Science Based Stockpile Stewardship Program*, Institute for Energy and Environmental Research, Takoma Park, May 1996.

Zerriffi, H., and A. Makhijani, "The Stewardship Smokescreen," *Bulletin of the Atomic Scientists*, September/October 1996.

Makhijani, A., *Energy Efficiency Investments as a Source of Foreign Exchange*, prepared for the International Energy Agency Conference in Chelyabinsk, Russia, 24-26 September 1996.

Makhijani, A., "India's Options," *Bulletin of the Atomic Scientists*, March/April 1997.

Ortmeyer, P. and A. Makhijani, "Worse than We Knew," *Bulletin of the Atomic Scientists*, November/December 1997.

Fioravanti, M., and A. Makhijani, *Containing the Cold War Mess: Restructuring the Environmental Management of the U.S. Nuclear Weapons Complex*, Institute for Energy and Environmental Research, Takoma Park, October 1997.

Principal author of three chapters in Schwartz, S., ed., *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940*, Brookings Institution, Washington, D.C., 1998.

Franke, B., and A. Makhijani, *Radiation Exposures in the Vicinity of the Uranium Facility in Apollo, Pennsylvania*, Institute for Energy and Environmental Research, Takoma Park, February 2, 1998.

Fioravanti, M., and A. Makhijani, *Supplement to Containing the Cold War Mess - IEER's Response to the Department of Energy's Review*, Institute for Energy and Environmental Research, Takoma Park, March 1998.

Makhijani, A., "A Legacy Lost," *Bulletin of the Atomic Scientists*, July/August 1998.

Makhijani, A., and Hisham Zerriffi, *Dangerous Thermonuclear Quest: The Potential of Explosive Fusion Research for the Development of Pure Fusion Weapons*, Institute for Energy and Environmental Research, Takoma Park, July 1998.

Makhijani, A., and Scott Saleska, *The Nuclear Power Deception - U.S. Nuclear Mythology from Electricity "Too Cheap to Meter" to "Inherently Safe" Reactors*, Apex Press, New York, 1999.

Makhijani, A., "Stepping Back from the Nuclear Cliff," *The Progressive* 63, no. 8 (August 1999), Makhijani, A., Bernd Franke, and Hisham Zerriffi, *Preliminary Partial Dose Estimates from the Processing of Nuclear Materials at Three Plants during the 1940s and 1950s*, Institute for Energy and Environmental Research, Takoma Park, September 2000. (Prepared under contract to the newspaper *USA Today*.)

Makhijani, A., and Bernd Franke, *Final Report of the Institute for Energy and Environmental Research on the Second Clean Air Act Audit of Los Alamos National Laboratory by the Independent Technical Audit Team*, Institute for Energy and Environmental Research, Takoma Park, December 13, 2000.

Makhijani, A., *Plutonium End Game: Managing Global Stocks of Separated Weapons-Usable Commercial and Surplus Nuclear Weapons Plutonium*, Institute for Energy and Environmental Research, Takoma Park, January 2001.

Makhijani, A., Hisham Zerriffi, and Annie Makhijani, "Magical Thinking: Another Go at Transmutation," *Bulletin of the Atomic Scientists*, March/April 2001.

Makhijani, A., *Ecology and Genetics: An Essay on the Nature of Life and the Problem of Genetic Engineering*. New York: Apex Press, 2001.

Makhijani, A., "Burden of Proof," *Bulletin of the Atomic Scientists*, July/August 2001.

Makhijani, A., "Reflections on September 11, 2001," in Kamla Bhasin, Smitu Kothari, and Bindia Thapar, eds., *Voices of Sanity: Reaching Out for Peace*, Lokayan, New Delhi, 2001, pp. 59-64.

Makhijani, A., and Michele Boyd, *Poison in the Vadose Zone: An examination of the threats to the Snake River Plain aquifer from the Idaho National Engineering and Environmental Laboratory*, Institute for Energy and Environmental Research, Takoma Park, October 2001.

Makhijani, A., *Securing the Energy Future of the United States: Securing the Energy Future of the United States: Oil, Nuclear, and Electricity Vulnerabilities and a Post-September 11, 2001 Roadmap for Action*, Institute for Energy and Environmental Research, Takoma Park, November 2001.

Makhijani, A., and Sriram Gopal, *Setting Cleanup Standards to Protect Future Generations: The Scientific Basis of Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats*, Institute for Energy and Environmental Research, Takoma Park, December 2001.

Makhijani, A., "Some Factors in Assessing the Response to September 11, 2001," *Medicine and Global Survival*, International Physicians for the Prevention of Nuclear War, Cambridge, Mass., February 2002.

Makhijani, Annie, Linda Gunter, and A. Makhijani, *Cogema: Above the Law?: Concerns about the French Parent Company of a U.S. Corporation Set to Process Plutonium in South Carolina*.

A report prepared by Institute for Energy and Environmental Research and Safe Energy Communication Council. Takoma Park, MD, May 7, 2002.

Deller, N., A. Makhijani, and J. Burroughs, eds., *Rule of Power or Rule of Law? An Assessment of U.S. Policies and Actions Regarding Security-Related Treaties*, Apex Press, New York, 2003.

Makhijani, A., "Nuclear targeting: The first 60 years," *Bulletin of the Atomic Scientists*, May/June 2003.

Makhijani, A., "Strontium," *Chemical & Engineering News*, September 8, 2003.

Makhijani, A., and Nicole Deller, *NATO and Nuclear Disarmament: An Analysis of the Obligations of the NATO Allies of the United States under the Nuclear Non-Proliferation Treaty and the Comprehensive Test Ban Treaty*, Institute for Energy and Environmental Research, Takoma Park, Maryland, October 2003.

Makhijani, A., *Manifesto for Global Democracy: Two Essays on Imperialism and the Struggle for Freedom*, Apex Press, New York, 2004.

Makhijani, A., "Atomic Myths, Radioactive Realities: Why nuclear power is a poor way to meet energy needs," *Journal of Land, Resources, & Environmental Law* 24, no. 1 (2004): 61-72. Adapted from an oral presentation given on April 18, 2003, at the Eighth Annual Wallace Stegner Center Symposium titled "Nuclear West: Legacy and Future," held at the University of Utah S.J. Quinney College of Law."

Makhijani, A., and Michele Boyd, *Nuclear Dumps by the Riverside: Threats to the Savannah River from Radioactive Contamination at the Savannah River Site*, Institute for Energy and Environmental Research, Takoma Park, Maryland, March 2004.

Makhijani, A., and Brice Smith, *The Role of E.I. du Pont de Nemours and Company (Du Pont) and the General Electric Company in Plutonium Production and the Associated I-131 Emissions from the Hanford Works*, Institute for Energy and Environmental Research, Takoma Park. Maryland, March 30, 2004.

Makhijani, A., Peter Bickel, Aiyou Chen, and Brice Smith, *Cash Crop on the Wind Farm: A New Mexico Case Study of the Cost, Price, and Value of Wind-Generated Electricity*, Institute for Energy and Environmental Research, Takoma Park, Maryland, April 2004.

Makhijani, A., Lois Chalmers, and Brice Smith, *Uranium Enrichment: Just Plain Facts to Fuel an Informed Debate on Nuclear Proliferation and Nuclear Power*, Institute for Energy and Environmental Research, Takoma Park, Maryland, October 15, 2004.

Makhijani, A., and Brice Smith, *Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County New Mexico by LES*, Institute for Energy and Environmental Research, Takoma Park, Maryland, November 24, 2004.

Makhijani, A., project director, *Examen critique du programme de recherche de l'ANDRA pour déterminer l'aptitude du site de Bure au confinement géologique des déchets à haute activité et à vie longue: Rapport final*, prepared for the Comité Local d'Information et de Suivi du Laboratoire de Bure (CLIS); coordinator: Annie Makhijani; authors: Detlef Appel, Jaak Daemen, George Danko,Yuri Dublyansky, Rod Ewing, Gerhard Jentzsch, Horst Letz, Arjun Makhijani, Institute for Energy and Environmental Research, Takoma Park, Maryland, December 2004.

Institute for Energy and Environmental Research, *Lower Bound for Cesium-137 Releases from the Sodium Burn Pit at the Santa Susana Field Laboratory*, IEER, Takoma Park, Maryland, January 13, 2005. (Authored by A. Makhijani and Brice Smith.)

Institute for Energy and Environmental Research, *Iodine-131 Releases from the July 1959 Accident at the Atomics International Sodium Reactor Experiment*, IEER, Takoma Park, Maryland, January 13, 2005. (Authored by A. Makhijani and Brice Smith.)

Makhijani, A., and Brice Smith. *Update to Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County New Mexico by LES*. Institute for Energy and Environmental Research, Takoma Park, Maryland, July 5, 2005.

Makhijani, A., "A Readiness to Harm: The Health Effects of Nuclear Weapons Complexes," *Arms Control Today* 35 (July/August 2005).

Makhijani, A., *Bad to the Bone: Analysis of the Federal Maximum Contaminant Levels for Plutonium-239 and Other Alpha-Emitting Transuranic Radionuclides in Drinking Water*, Institute for Energy and Environmental Research, Takoma Park, Maryland, August 2005.

Makhijani, A., and Brice Smith, *Dangerous Discrepancies: Missing Weapons Plutonium in Los Alamos National Laboratory Waste Accounts*, Institute for Energy and Environmental Research, Takoma Park, Maryland, April 21, 2006.

Makhijani, Annie, and A. Makhijani, *Low-Carbon Diet without Nukes in France: An Energy Technology and Policy Case Study on Simultaneous Reduction of Climate Change and Proliferation Risks*, Institute for Energy and Environmental Research, Takoma Park, Maryland, May 4, 2006.

Makhijani, Annie, and A. Makhijani. *Shifting Radioactivity Risks: A Case Study of the K-65 Silos and Silo 3 Remediation and Waste Management at the Fernald Nuclear Weapons Site*, Institute for Energy and Environmental Research, Takoma Park, Maryland, August 2006.

Smith, Brice, and A. Makhijani, "Nuclear is Not the Way," *Wilson Quarterly*.30 (Autumn 2006): 64.

Makhijani, A., Brice Smith, and Michael C. Thorne, *Science for the Vulnerable: Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk*, Institute for Energy and Environmental Research, Takoma Park, Maryland, October 19, 2006.

Makhijani, A., *Carbon-Free and Nuclear Free: A Roadmap for U.S. Energy Policy*, IEER Press, Takoma Park, Maryland; RDR Books, Muskegon, Michigan, 2007.

Makhijani, A., *Assessing Nuclear Plant Capital Costs for the Two Proposed NRG Reactors at the South Texas Project Site*, Institute for Energy and Environmental Research, Takoma Park, Maryland, March 24, 2008.

Makhijani, A., "Nuclear isn't necessary," *Nature Reports Climate Change* 2 (October 2008): 132-134. "Commentary"

Makhijani, A., *Energy Efficiency Potential: San Antonio's Bright Energy Future,* Institute for Energy and Environmental Research, Takoma Park, Maryland, October 9, 2008.

Makhijani, A., *The Use of Reference Man in Radiation Protection Standards and Guidance with Recommendations for Change,* Institute for Energy and Environmental Research, Takoma Park, Maryland, December 2008.

Makhijani, A., *Comments of the Institute for Energy and Environmental Research on the U.S. Nuclear Regulatory Commission's Proposed Waste Confidence Rule Update and Proposed Rule Regarding Environmental Impacts of Temporary Spent Fuel Storage*, Institute for Energy and Environmental Research, Takoma Park, Maryland, February 6, 2009.

Makhijani, A., *Technical and Economic Feasibility of a Carbon-Free and Nuclear-Free Energy System in the United States*, Institute for Energy and Environmental Research, Takoma Park, Maryland, March 4, 2009.

Fundación Ideas para el Progreso*, A New Energy Model For Spain: Recommendations for a Sustainable Future* (originally: *Un nuevo modelo energético para España: Recomendaciones para un futuro sostenible*), by the Working Group of Foundation Ideas for Progress on Energy and Climate Change, Fundación Ideas , Madrid, May 20, 2009. Arjun Makhijani contributed Section 2.2. The cost of nuclear energy and the problem of waste.

IEER Comments on the Nuclear Regulatory Commission's Rulemaking Regarding the "Safe Disposal of Unique Waste Streams Including Significant Quantities of Depleted Uranium," Institute for Energy and Environmental Research, Takoma Park, Maryland, October 30, 2009.

Makhijani, A., "The Never-Ending Story: Nuclear Fallout in the Marshall Islands, a book review," *Nonproliferation Review* 17, no. 1 (March 2010):197-204.

Makhijani, A., "Detailed Comments on *Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* (*TC & WM EIS*) (DOE/EIS-0391), EIS October 2009," March 18, 2010, appears as Attachment 3 IN Harry Smiskin (Yakama Tribal Council). Letter dated March 19, 2010, transmitting the comments of the Confederated Tribes and Bands of the Yakama Nation on the *Draft Tank Closure and Waste Management Environmental Impact Statement* (Draft TC & WM EIS) for the Hanford Site, Richland, Washington (DOE/EIS-0391-D) to David A. Brockman (Richland Operations Office,

U.S. Department of Energy) and Mary Beth Burandt (Office of River Protection, U.S. Department of Energy).

Makhijani, A., *The Mythology and Messy Reality of Nuclear Fuel Reprocessing,* Institute for Energy and Environmental Research, Takoma Park, Maryland, April 8, 2010.
Makhijani, A.," Civil Liability for Nuclear Claims Bill, 2010: Is Life Cheap in India?" *The Hindu*. June 21, 2010

Farmer, J. Doyne, and A. Makhijani, "A US nuclear future? Counterpoint: Not wanted, not needed," *Nature* 467 (23 September 2010): 391-393. "Comment."

Makhijani, A., *eUtah: A Renewable Energy Roadmap*, HEAL Utah, Salt Lake City, December 14, 2010.

Richardson, Bill, with Gay Dillingham, Charles Streeper, and A. Makhijani, "Universal Transparency: A Goal for the U.S. at the 2012 Nuclear Security Summit," *Arms Control Today* 41 (January/February 2011): 8-13.

Makhijani, A., OPINION: Spent nuclear fuel pools vulnerable to terrorist attacks: *Kyodo News*, March 21, 2011. In Japanese and English.

Makhijani, A., project director, *Examen Critique du Programme de l'Andra sur les Recherches Effectuées dans le Laboratoire Souterrain de Bure et sur la Zone de Transposition Pour Définir une ZIRA: Rapport Final*, prepared for the Comité Local d'Information et de Suivi du Laboratoire de Bure (CLIS); coordinator: Annie Makhijani; authors: Jaak Daemen, George Danko, Gerhard Jentzsch, Elena Kalinina, Arjun Makhijani, et Krishan Wahi. Institute for Energy and Environmental Research, Takoma Park, Maryland, 9 mars 2011, avec corrections 20 avril 2011.

Makhijani, A., *IEER's Comments on Unique Waste Streams Rulemaking (10 CFR Part 61) - including Depleted Uranium Disposal*. Institute for Energy and Environmental Research, Takoma Park, Maryland, June 18, 2011. Addressed to the Nuclear Regulatory Commission.

Makhijani, A. "Comments of the Institute for Energy and Environmental Research on the Department of Energy's *Draft Environmental Impact Statement for the Disposal of Greater-Than-Class C (GTCC) Low-Level Radioactive Waste and GTCC-Like Waste* (DOE/EIS-0375-D), published in February 2011." (9 June 2011). Included as Attachment 3 to the Yakama Nation Comments on DOE's Greater-Than-Class C Waste Draft EIS (DOE/EIS-0375-D), June 27, 2011.

Makhijani, A., *Institute for Energy and Environmental Research (IEER) Comments on Docket ID NRC–2010–0267: NRC "Draft Regulatory Basis for a Potential Rulemaking on Spent Nuclear Fuel Reprocessing Facilities."* Institute for Energy and Environmental Research, Takoma Park, Maryland, 7 July 2011.

Makhijani, A., "IEER's Preliminary review of the NRC's July 12, 2011, Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident. U.S. Nuclear Regulatory Commission, July 12, 2011"

Prepared for Friends of the Earth. Institute for Energy and Environmental Research, Takoma Park, Maryland, July 19, 2011.

Makhijani, A., Comments on the July 29, 2011, *Draft Report to the Secretary of Energy*, of the Blue Ribbon Commission on America's Nuclear Future (BRC) Prepared by the Institute for Energy and Environmental Research (IEER) on behalf of the Yakama Nation, 30 September 2011. Conveyed to the Blue Ribbon Commission on October 11, 2011.

Makhijani, A., *Comments of the Institute for Energy and Environmental Research on the Nuclear Regulatory Commission's Draft Policy Statement on Volume Reduction and Low-Level Radioactive Waste Management (76 FR 50500 (August 15, 2011))*. Institute for Energy and Environmental Research, Takoma Park, Maryland, October 14, 2011.

Makhijani, A., and Yves Marignac, *Sûreté Nucléaire en France Post-Fukushima : Analyse critique des Évaluations complémentaires de sûreté (ECS) menées sur les installations nucléaires françaises après Fukushima.* Institute for Energy and Environmental Research, Takoma Park, Maryland, and WISE-Paris, Paris, février 2012.

Makhijani, A., and Yves Marignac. "In Perspective: France's Post-Fukushima Safety Assessment — Is It Enough?," *Nuclear Intelligence Weekly* VI (9) (March 2, 2012): 12.

Makhijani, A., Christina Mills, and M. V. Ramana, *Renewable Minnesota: A technical and economic analysis of a 100% renewable energy-based electricity sector for Minnesota*. Institute for Energy and Environmental Research, Takoma Park, Maryland, March 13, 2012.

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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

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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 assist in the preparation of comments invited by the US Nuclear Regulatory Commission (NRC).[1] The NRC has invited comments on the scope of an environmental impact statement (EIS) that the NRC proposes to prepare, which is referred to hereafter as the NRC's "proposed EIS".[2] That EIS would support a rulemaking by the NRC to update the NRC's Waste Confidence Decision and Rule. In this declaration I set forth some recommendations on the scope of the proposed EIS. These recommendations address 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 should be addressed in the proposed EIS.

(I-3) The issues discussed in this declaration are outlined in Section III, below. These issues all pertain to the concept of radiological risk, which is defined in Section IV, below. In brief, in this declaration the term "radiological risk" refers to the potential for harm to humans as a result of unplanned exposure to ionizing radiation.

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[1] These organizations include: Beyond Nuclear; Blue Ridge Environmental Defense League; Citizens Allied for Safe Energy; Ecology Party of Florida; Friends of the Earth; Missouri Coalition for the Environment; Nevada Nuclear Waste Task Force; NC WARN; Nuclear Information and Resource Service; Nuclear Watch South; Public Citizen; Riverkeeper; San Luis Obispo Mothers for Peace; SEED Coalition; and Southern Alliance for Clean Energy.
[2] NRC, 2012.

(I-4) The NRC's invitation to submit comments makes the following statement about scenarios to be considered in the proposed EIS:[3]

> "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."

(I-5) The latter part of that statement by the NRC envisions storage of spent fuel for an unspecified period. In that context, it should be noted that the NRC previously embarked on a related EIS, and published a draft document setting forth preliminary assumptions that would apply to that EIS.[4] That document is referred to hereafter as the NRC's "preliminary-assumptions document". The preliminary-assumptions document called for a time horizon of about 2250 in the EIS then under discussion.[5] That document also assumed that a repository would ultimately become available.[6]

(I-6) From the perspective of the radiological risk posed by temporary storage of spent fuel, a time horizon of about 2250 has some logic. A major determinant of the risk, especially in terms of atmospheric release, is the inventory of Cesium-137, which has a half-life of about 30 years.[7] Between 2012 and 2250, a given inventory of Cesium-137 would shrink to a value of about 0.004 (0.4 percent) of its initial value. At that point, the radiological risk posed by storing spent fuel would not disappear, but would be entering a different phase. Moreover, the NRC's preliminary-assumptions document represents a body of work by the NRC staff, and reflects some public input. Accordingly, I recommend as follows:

> **Recommendation #1:** The NRC's preliminary-assumptions document should be a point of departure for determining the scope of the proposed EIS, especially in regard to storage after the end of the 21st century.

(I-7) Spent fuel can more precisely be described as spent nuclear fuel (SNF). I typically use that term hereafter. Also, the NRC's preliminary-assumptions document has introduced the possibility that some SNF discharged from NRC-licensed reactors will be reprocessed in the future.[8] If that outcome were to occur, reprocessing would generate high-level waste (HLW) that would contain most of the radioactivity present in the SNF that is reprocessed.[9] Accordingly, I recommend as follows:

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[3] NRC, 2012, page 65138.
[4] NRC, 2011.
[5] NRC, 2011, Section 7.
[6] NRC, 2011, Section 8.
[7] The inventory of Cesium-137 is an indicator of biological hazard and decay heat production; both properties are determinants of radiological risk.
[8] NRC, 2011, Section 8.
[9] Here, "radioactivity" refers to the inventory of radio-isotopes, measured in Bq.

> **Recommendation #2:** The proposed EIS should not only address the storage of SNF, but also the potential storage of HLW from reprocessing of SNF.

(I-8) It does not follow from my Recommendation #2 that I recommend the future reprocessing of SNF discharged from NRC-licensed reactors, or that I view the future introduction of such reprocessing as likely. Indeed, as discussed in paragraph VI-3, below, trends in the nuclear-power industry over the past two decades suggest that the most likely outcome for that industry over the next few decades is general decline in its activities. Such a future would be inconsistent with reprocessing.

(I-9) The NRC's statement quoted in paragraph I-4, above, refers to "temporary spent fuel storage **after cessation of reactor operation**" [emphasis added]. That statement is imprecise, and could be seriously misleading in regard to the radiological risk posed by storage of SNF. At all contemporary US commercial reactors, SNF assemblies are discharged only when the reactor is shut down. Thereafter, the SNF assemblies may be stored adjacent to an operating reactor from which they were discharged, adjacent to another operating reactor, or at a location not adjacent to an operating reactor. As discussed in Section VIII, below, the radiological risk could be substantially greater if SNF is stored adjacent to an operating reactor. Accordingly, I recommend as follows:

> **Recommendation #3:** The proposed EIS should consider the radiological risk posed by storage of SNF from the moment of its discharge from a reactor.

(I-10) This declaration has the following narrative sections:

I. Introduction
II. My Professional Qualifications
III. Issues Discussed in this Declaration
IV. Radiological Risk
V. The Future Risk Environment
VI. Scenarios to be Considered in the Proposed EIS
VII. SNF and HLW Storage Modes and Dynamics to be Considered in the Proposed EIS
VIII. Phenomena Relevant to Radioactive Release from SNF or HLW
IX. Assessing Likelihood and Impacts of Radiological Incidents
X. Summary of Recommendations

(I-11) In addition to the above-named narrative sections, this declaration has two appendices that are an integral part of the declaration. Appendix A is a bibliography. Documents cited in the narrative or in Appendix B are listed in that bibliography unless otherwise identified. Appendix B contains tables and figures that support the narrative.

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.

(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 self-sustaining, exothermic oxidation reactions of fuel cladding in a high-density SNF pool if water is lost from the pool. For simplicity, that event can be referred to as a "pool fire". In examining the potential for a pool fire, I identified partial loss of water 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 SNF was not an acceptable option at Gorleben.[11] As a direct result, policy throughout

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[10] Beyea et al, 1979.
[11] Albrecht, 1979.

Germany 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.[12] Also, I co-authored a journal article, on SNF radiological risk, that received considerable attention from relevant stakeholders.[13] The findings in that article were generally confirmed by a subsequent report by the National Research Council.[14] 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]

(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] The time horizon used in my report was, by CORWM's specification, 300 years.

III. Issues Discussed in this Declaration

(III-1) The primary purpose of this declaration is to set forth recommendations regarding the scope of the proposed EIS with respect to the environmental impacts of long-term, temporary storage of SNF or related HLW. My declaration is complementary to the declaration of Dr. Arjun Makhijani, which addresses some SNF storage issues and also some issues of SNF disposal.[17]

(III-2) In this declaration I focus on environmental impacts that are associated with radiological risk, which is defined in Section IV, below. In addressing radiological risk, I focus on the potential for unplanned release of radioactive material, especially atmospheric release. Within that focus, I consider two categories of initiating event – conventional accidents, and attacks.

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[12] See, for example: Thompson, 2009.
[13] Alvarez et al, 2003.
[14] National Research Council, 2006.
[15] Thompson, 2008a.
[16] Thompson, 2005.
[17] Makhijani, 2013.

(III-3) Analysts who examine the radiological risk associated with potential attacks affecting nuclear facilities have a double duty. First, they owe the public an accurate assessment of the risk. Second, they should refrain from publishing information that could directly assist a potential attacker. This declaration satisfies both requirements. It does not purport to provide a comprehensive assessment of radiological risk. Instead, it offers recommendations for such an assessment. From that perspective the 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-4) The NRC's preliminary-assumptions document called for a time horizon of about 2250 when considering the environmental impacts of long-term, temporary storage of SNF or HLW. Given such a distant time horizon, a risk assessor should consider the potential for substantial change in the risk environment. In Section V, I outline a process for considering such change.

(III-5) Most stakeholders would agree that the proposed EIS should consider a range of scenarios for the future, and a range of alternative options for storing SNF or HLW. Moreover, I understand that considering these matters is a legal requirement for an EIS. Accordingly, I offer recommendations regarding scenarios and alternative options. I also offer recommendations on improving the state of knowledge about the radiological risk posed by storing SNF or HLW.

IV. 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, risk can be managed. Indeed, as shown in Table IV-1, management of risk could be one of three major pillars of a framework of principles for the design and appraisal of infrastructure projects in the 21st century. Facilities for long-term, temporary storage of SNF or HLW would be appropriate projects for employment of that framework.

(IV-2) Table IV-2 shows some categories of risk that could be posed by a commercial nuclear facility. Radiological risk is defined 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 unplanned release, especially 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) The effects of an unplanned release of radioactive material could be among the most severe impacts that arise from storing SNF or HLW. Thus, assessing radiological risk should be a major function of the proposed EIS. Accordingly, I recommend as follows:

> **Recommendation #4:** 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.

(IV-4) Defining radiological risk as "the potential for harm" does not 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. That approach is consistent with my general definition of "risk" as the potential for an unplanned, undesired outcome. The NRC has articulated a similar definition.[18]

(IV-5) In the nuclear industry and elsewhere, one often encounters a more limited definition, in which risk is the arithmetic product of a numerical indicator of harmful impact and a numerical indicator of the impact's probability.[19] That definition is hereafter designated as the "arithmetic" definition of risk. The arithmetic definition can be seriously misleading in two respects. First, the full spectrum of impact and/or probability may not be susceptible to numerical estimation, and numerical estimates may be incomplete or highly uncertain. Second, many subscribers to the arithmetic definition argue that equal levels of the numerically-estimated risk 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.

(IV-6) Quantitative analysis is essential to science, engineering, and other fields. Yet, the limitations of quantitative analysis should be recognized. Analysts should be especially careful to avoid the intellectual trap of ignoring issues that are difficult to quantify. Many practitioners of radiological risk assessment fall into that trap. Thus, important risk factors are ignored. Examples include: (i) acts of malice or insanity; and (ii) gross errors in design, construction, and operation of facilities. Risk assessments for nuclear facilities routinely ignore these and other factors that may be major determinants of risk.[20]

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[18] The NRC Glossary defines risk as: "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." (See: http://www.nrc.gov/reading-rm/basic-ref/glossary/risk.html, accessed on 16 February 2012.)

[19] Often, the arithmetic product will be calculated for each of a range of impact scenarios, and these products will be summed across the scenarios.

[20] For example, there is evidence that a major risk factor underlying the 1986 Chernobyl reactor accident was endemic secrecy in the USSR. (See: Shlyakhter and Wilson, 1992.) Also, there is evidence that a major risk factor underlying the 2011 accident at the Fukushima #1 reactor site was collusion among government, the regulators, and the licensee (TEPCO). (See: Diet, 2012, page 16.) Radiological-risk

(IV-7) A nuclear facility typically has the potential to experience unplanned releases of radioactive material across a spectrum ranging from small releases to large releases. Risk analysts who subscribe to the arithmetic definition often conclude that small releases are more probable. With their arithmetic approach, it then appears that large releases with low probability are equivalent to small releases with high probability. Often, these analysts leap to the assumption that the apparent equivalence is "scientific". Thus, they argue, equal levels of the numerically-estimated risk should be equally acceptable to citizens. In fact, the assumption of equivalence lacks a scientific basis. It is a subjective statement that reflects the values and interests of this group of analysts. From the perspective of a citizen, the potential for a large release may be much less acceptable than the potential for a small release, regardless of probability. That perspective could have a solid, rational basis, because a large release could have effects that are qualitatively different from the effects of a small release. Moreover, a prudent citizen will be skeptical of the probability findings generated by arithmetic risk analysts, given the propensity of these analysts to ignore important risk factors.

(IV-8) Radiological risk assessment requires the identification of potential events that could initiate a radiological incident. One category of initiating events, which I categorize as "conventional accidents", encompasses events such as random failure of equipment, random human error, or natural forces such as earthquakes. This category of events has been extensively studied in the context of commercial nuclear facilities.

(IV-9) The NRC's preliminary-assumptions document called for consideration of another category of potential initiating events under the rubric of "terrorism". In discussing such events the document stated:[21]

> "The staff plans to consider the environmental impacts of terrorism related to storage and transportation at a generic level. The terrorism consideration will be developed using available information in agency records and other available information for current facilities, package technologies, and transportation infrastructures; current technologies and reasonably foreseeable technologies that are being explored in depth; mitigation measures; and security arrangements that have a bearing on likely environmental consequences."

(IV-10) I welcome the NRC's willingness to consider initiating events that are beyond the category of conventional accidents. However, I find the above-quoted NRC statement on terrorism to be unsatisfactory. For example, it does not define terrorism or explain why this phenomenon should be considered to the exclusion of other potential events that involve violence.

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studies performed by the nuclear industry and its regulators do not consider secrecy or collusion as risk factors.

[21] NRC, 2011, Section 8.1(9).

(IV-11) Events involving violence could be significant for the radiological risk posed by storing SNF or HLW. My view is that such events should be categorized as "attacks", with the understanding that an attack could adversely affect stored SNF or HLW either directly or indirectly. Accordingly, I recommend as follows:

> **Recommendation #5:** The proposed EIS should assess the radiological risk arising from a range of conventional accidents or attacks that could affect stored SNF or HLW.

(IV-12) Table IV-3 shows that the NRC has publicly examined potential attacks on stored SNF. In that instance, the potential, hypothesized attacks were "sabotage events" at an SNF storage pool.

(IV-13) As discussed in paragraph III-5, above, there is a general expectation and, I understand, a legal requirement that the proposed EIS should consider alternative options and their respective impacts. Accordingly, given that the effects of an unplanned release of radioactive material could be among the most severe impacts that arise from storing SNF or HLW, I recommend as follows:

> **Recommendation #6:** The comparative radiological risk posed by a range of alternative options for storing SNF or HLW should be assessed in the proposed EIS as a major indicator of the comparative impacts of these alternatives.

V. The Future Risk Environment

(V-1) As discussed in paragraph I-4, above, the NRC currently envisions that the proposed EIS will consider scenarios including:

- temporary storage of SNF until a repository is made available in either the middle of the 21st century or at the end of the 21st century
- temporary storage of SNF for an unspecified period if no repository is made available by the end of the 21st century

(V-2) The NRC's preliminary-assumptions document called for consideration of temporary storage of SNF within a time horizon of about 2250. Accordingly, in this declaration I assume that the "unspecified period" mentioned in the second bullet of paragraph V-1 would extend until about 2250.

(V-3) As discussed in Section IV, above, assessment of radiological risk should be one of the major features of the proposed EIS. There is a considerable body of experience with radiological risk assessment. In this instance, however, there are unusual challenges in risk assessment because of the extended time frame. Thus, before attempting to assess the radiological risk posed by storage of SNF or HLW over a period of decades or centuries, a risk assessor should seek to understand the risk environment throughout that period. 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. Therefore, a credible risk assessment would systematically examine the potential for substantial change, over time, in the risk environment.

(V-4) There have been many serious efforts to forecast the future risk environment or factors that could influence that environment. Such efforts find, unsurprisingly, that uncertainty grows as the time horizon of the forecast becomes more distant. Three examples of forecasting are illustrative:

- The World Economic Forum (WEF) has now published seven editions of its "Global Risks" report. The seventh edition, published in 2012, examines fifty global risks across five categories. A 10-year time horizon is employed. Risks were assessed by surveying 469 experts and industry leaders. Five "centers of gravity" of risk are identified: (i) chronic fiscal imbalances; (ii) greenhouse gas emissions; (iii) global governance failure; (iv) unsustainable population growth; and (v) critical systems failure.[22]

- The US National Intelligence Council (NIC) has now published five editions of its "Global Trends" report. The fifth edition, published in December 2012, has a time horizon of 2030.[23] Findings in that report include the statement:[24]

> "Extrapolations of the megatrends would alone point to a changed world by 2030 – but the world could be transformed in radically different ways. We believe that six key ***game-changers*** – questions regarding the global economy, governance, conflict, regional instability, technology, and the role of the United States – will largely determine what kind of transformed world we will inhabit in 2030."

- The Stockholm Environment Institute (SEI) convened its Global Scenario Group in 1995. The Group's work led to SEI's "Great Transition" report of 2002.[25] The time horizon in that report varied by scenario, extending to 2065 in some cases. The report identified six global scenarios in three categories: (i) conventional worlds; (ii) barbarization; and (iii) great transitions. These scenarios are described further in Table V-1.

(V-5) The forecasting efforts mentioned in the preceding paragraph, and numerous other studies, have identified human abuse of natural resources as a factor that could adversely

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[22] WEF, 2012.
[23] NIC, 2012.
[24] NIC, 2012, page iii.
[25] Raskin et al, 2002.

affect human welfare over the coming decades. For example, a group of authors examining the "safe operating space for humanity" has said:[26]

> "Human activities increasingly influence the Earth's climate (International Panel on Climate Change (IPPC) 2007a) and ecosystems (Millennium Ecosystem Assessment (MEA) 2005a). The Earth has entered a new epoch, the Anthropocene, where humans constitute the dominant driver of change to the Earth System (Crutzen 2002, Steffen et al. 2007). The exponential growth of human activities is raising concern that further pressure on the Earth System could destabilize critical biophysical systems and trigger abrupt or irreversible environmental changes that would be deleterious or even catastrophic for human well-being. This is a profound dilemma because the predominant paradigm of social and economic development remains largely oblivious to the risk of human-induced environmental disasters at continental to planetary scales (Stern 2007)."

(V-6) Societal response to the threats mentioned in the preceding quotation is inhibited by a number of factors, including a widespread lack of recognition of the rapidity of action that is needed to prevent adverse outcomes. For example, government leaders meeting in Copenhagen in 2009 committed their countries to holding the human-caused increase in average global temperature below 2°C. Yet, although accumulating scientific knowledge indicates that a 2°C increase may be dangerously high, current trends in greenhouse gas emissions make it unlikely that the increase can be held below 2°C.[27] Correcting those trends to achieve a 2°C limit would, according to analysis published in November 2012 by Pricewaterhouse Coopers, require an unprecedented reduction in global carbon intensity (CO_2 emissions per unit of economic product) averaging 5.1% per year throughout the period from the present until 2050.[28] There is no international agreement or plan to achieve such reduction.

(V-7) Adverse outcomes for human welfare, as a result of our abuse of natural resources, could include direct effects, such as reduced agricultural yields and increased incidence of infectious diseases. These direct effects could be accompanied and amplified by indirect effects, with the potential for a descending spiral in the human condition. Many analysts have noted that indirect effects could include an increase in violent conflict. For example, the Defense Science Board has examined the implications of climate change for national and international security, and has stated:[29]

> "Climate change is likely to have the greatest impact on security through its indirect effects on conflict and vulnerability."

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[26] Rockstrom et al, 2009.
[27] Anderson and Bows, 2011.
[28] PwC, 2012.
[29] Defense Science Board, 2011, page xi.

(V-8) The NRC envisions storage of SNF until about 2100 if a repository becomes available, or until about 2250 if no repository is available by the end of the 21st century. Both time horizons are considerably more distant than the time horizons of the forecasts outlined in paragraph V-4, above. Those forecasts acknowledge substantial uncertainty in their projections. One could reasonably expect that the NRC would acknowledge a much greater degree of uncertainty, in view of the comparatively distant time horizons it envisions. As discussed below, the NRC's preliminary-assumptions document did not meet that expectation. The proposed EIS should rectify that deficiency.

(V-9) The NRC's preliminary-assumptions document postulated that the risk environment throughout the period ending in 2250 will be little changed from what it is now. Indeed, the document specifically stated that "the EIS will minimize speculation about future conditions".[30] Consistent with that position, the document proposed a range of status quo assumptions. For example, nuclear fission power would continue providing about 20 percent of US electricity production. The SNF generated from that activity would have properties similar to the SNF generated by the present generation of light-water reactors. The NRC or an equivalent governmental entity would provide regulatory oversight that is at least as stringent as present requirements. The responsible entities would continue to fund the storage of SNF, "regardless of cost".[31]

(V-10) The NRC's preliminary-assumptions document acknowledged that a public commenter requested the NRC to "include in the EIS a scenario that accounts for a collapse of society and loss of government institutions, with a resulting lack of control over, and knowledge about, nuclear plants and radioactive waste". The document refused to meet that request, offering the following argument as justification:[32]

> "The request to include a societal-collapse scenario would require an analysis of the impacts of storage under a highly speculative scenario in which societal institutions, knowledge, and controls no longer exist. However, as described above, the trend in modern society is toward more awareness and control over issues that pose a risk to humans and their environment. The staff concludes that a loss of societal structures and the associated knowledge base is not reasonably foreseeable and, in fact, is highly unlikely to occur within the 200-year timeframe to be considered in the EIS. The staff's view, therefore, is that any of the impacts associated with this scenario are also not reasonably foreseeable."

(V-11) The NRC's argument in the preceding quotation fails on at least three grounds, discussed here and in the following two paragraphs. First, the NRC considers only a status-quo scenario and a scenario involving complete collapse of organized society, before excluding the latter scenario. By limiting its view in that manner, the NRC has failed to understand the range of possible societal conditions. Any serious forecast of

[30] NRC, 2011, Section 8.1.
[31] NRC, 2011, Section 8.1(6).
[32] NRC, 2011, Section 8.1(6).

societal developments over the period ending in 2250 – or in 2100 – would postulate a broad range of possible scenarios.

(V-12) Second, the NRC claims to see a contemporary societal trend "toward more awareness and control over issues that pose a risk to humans and their environment". If that trend were real, it would have limited relevance across the period ending in 2250, but would be more significant across the period ending in 2100. Regrettably, no such trend can be seen in the contemporary United States with any consistency. Improvements in natural-resource management were made in the 20th century, but much of that momentum has been lost. For example, despite the clear and urgent need for rapid reduction of greenhouse-gas emissions, present US policies will not yield that reduction. The Energy Information Administration's latest reference-case forecast is that US energy-related emissions of carbon dioxide will rise continually from 2016 to 2040.[33] Also, the NRC itself is enabling the continued accumulation of SNF without the existence of a repository into which that SNF can be placed, and has indicated a willingness to enable further accumulation until at least 2250.[34] Such a policy places a growing burden on future generations without a commensurate benefit, and is the antithesis of sustainable development. These and other examples show that the contemporary societal trend cited by the NRC is not real.

(V-13) The third ground on which the NRC's argument fails is that it ignores a human history that includes conflict and the degradation of institutions. Looking forward from 2012 to 2250 is analogous to looking forward from 1774 to 2012. Any informed person knows that there have been numerous, major changes in human affairs within the present territory of the USA since 1774. Just from the perspective of large-scale violent conflict, US history has witnessed a Revolutionary War, a Civil War, two World Wars, a Cold War that came close to nuclear-weapon exchange during the Cuban Missile Crisis, and many other wars. With the exception of the Revolutionary War, these precise events could not have been predicted in 1774 although they were, to some degree, foreseeable. Such occurrences demonstrate that it is unreasonable to assume that society and its institutions will remain stable over an extended future period.

(V-14) The NRC's preliminary-assumptions document attempted to argue that its exclusive focus on a status quo scenario represented the only "reasonably foreseeable" outcome until 2250. That is the reverse of the truth. Limiting analysis to a status quo scenario across such a time period is speculative in the extreme. The only way to consider reasonably foreseeable outcomes is to articulate a broad range of possible future scenarios, while acknowledging the uncertainty that inevitably accompanies such an exercise. The uncertainty within a time horizon of 2100 would be large, and within a time horizon of 2250 it would be substantially larger.

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[33] EIA, 2012, Figure 13.

[34] The NRC's preliminary-assumptions document assumed that "spent nuclear fuel and high-level waste **ultimately** [emphasis added] will be transported to a geologic repository for disposal and that at least one repository will need to be constructed". (See: NRC, 2011, Section 8.2.)

(V-15) Drawing from the preceding paragraphs in Section V and other sources with which I am familiar, I recommend in paragraphs V-16 and V-17 a process whereby the proposed EIS could be informed by a forecast of the risk environment during the time period covered by the EIS. Across that period, the EIS should assess risks in all relevant categories, including radiological risk. Those assessments should be done for all the scenarios, and all the SNF and HLW storage options, that are considered in the EIS. The risk environment could vary across scenarios, but would typically not vary across storage options. Characteristics of the risk environment could affect both the likelihood and the magnitude of adverse outcomes.

(V-16) The risk environment can be characterized by a set of indicators that represent an array of natural, technical, and societal factors. At any given time and place, the risk environment is temporarily static. As time and place vary, the risk environment becomes dynamic. Accordingly, I recommend as follows:

> **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.

(V-17) Dynamic aspects of the potential risk environment that are particularly relevant to radiological risk could include:

- <u>Influence of Natural Factors</u>: Global climate change could increase: (i) sea level; (ii) the incidence of high winds and associated surges in coastal water level; (iii) the incidence of drought; and (iv) the incidence of river-basin flooding.

- <u>Influence of Technical Factors</u>: Technological advances could: (i) increase the capabilities and decrease the costs of instruments that could be used to attack SNF or HLW storage facilities; and (ii) provide new design options for protecting stored SNF or HLW against conventional accidents or attacks.

- <u>Influence of Global Societal Factors</u>: Failure to adequately address natural-resource limits and other global challenges could: (i) increase the incidence of violent conflict involving States and non-State actors; (ii) impoverish large numbers of people; (iii) degrade national and international systems of governance; and (iv) degrade the technological capabilities of societies.

- <u>Influence of Societal Factors within US Territory</u>: Global societal factors, as discussed above, could influence the risk environment within US territory either directly or indirectly; indirect impacts could include an increased potential for attack on US assets by non-State actors or States.

VI. Scenarios to be Considered in the Proposed EIS

(VI-1) As shown in Section V, above, if the proposed EIS is to be credible then it must consider a broad range of possible scenarios for the future. Here, in Section VI, I outline the types of scenario that should be considered in order to credibly assess radiological risk.

(VI-2) The future role of nuclear power is one of the issues that should be reflected in the choice of scenarios. As discussed in paragraph V-9, above, the NRC's preliminary-assumptions document postulated that the status quo for nuclear power will persist through all scenarios until 2250, one exception being the possible introduction of reprocessing. From the perspective of 2012, introduction of commercial reprocessing in the USA would be a major policy step. Across the period from 2012 to 2250, however, that step would be only one of numerous possible changes in US energy infrastructure. Scenarios identified in the NRC's preliminary-assumptions document were:[35]

- Scenario 1 – Extended onsite storage at reactor sites and offsite independent spent fuel storage installations
- Scenario 2 – Interim onsite storage and shipment to regional storage facilities
- Scenario 3 – Interim onsite storage and shipment to one centralized storage facility
- Scenario 4 – Interim onsite storage and shipment to at least one reprocessing facility

(VI-3) Trends in the nuclear-power industry over the past two decades suggest that the most likely outcome for that industry over the next few decades is not the status quo, but decline.[36] For example, in the early 1990s the nuclear industry supplied 17 percent of the world's electricity while in 2011 that fraction had fallen to 11 percent. The industry's annual, worldwide production of electricity peaked in 2006 at 2,660 TWh and fell to 2,518 TWh in 2011. The mean age of the world's fleet of operating reactors is now 27 years, and is increasing. The same general picture holds in the USA, where the last completion of a new reactor was in 1996.

(VI-4) A two-decade trend prior to 2012 does not ordain any particular future between 2012 and 2250, but is more significant for the period between 2012 and 2100. Across either time frame, it is clear that reasonably foreseeable outcomes for the US nuclear industry include shrinkage in the number of operating reactors, potentially leading to shutdown of all reactors by the middle of the 21st century. An important implication is that the industry's revenue would decline as reactors close. Payment for the management of the SNF remaining from reactor operation could initially come from funds set aside during the years of operation. Over time, those funds could be depleted, at which point

[35] NRC, 2011, Section 8.2.
[36] Schneider et al, 2012.

the most likely source of payment would be the general funds of the US government. Also, shrinkage of the US reactor fleet would inevitably reduce national capabilities in nuclear engineering.

(VI-5) From the two preceding paragraphs, it is clear that scenarios in the proposed EIS should cover outcomes in which the nuclear-power industry largely disappears, leaving behind a hazardous residue of SNF and HLW. Management of that residue could be a charge on the general public, who would receive no commensurate benefit. Society's remaining capabilities in nuclear engineering could be severely limited. These conditions could apply even if the general society at that time is prosperous and technologically competent. Also, as discussed in Section V, above, reasonably foreseeable factors could lead to prosperity, technological competence, and the quality of governance being at lower levels than in 2012.

(VI-6) Conversely, scenarios in the proposed EIS should also cover outcomes in which the nuclear-power industry employs new technology or expands the scale of its operations. As discussed in paragraphs VI-3 and VI-4, above, such outcomes would be inconsistent with current trends. However, they are as reasonably foreseeable as is a status quo scenario for the industry.

(VI-7) One potential new technology that is relevant to radiological risk is the use of ceramic fuel cladding as a replacement for the zirconium alloy (zircaloy) fuel cladding that is now used in light-water reactors. In situations where the fuel overheats, ceramic cladding may behave better than zircaloy cladding. Experience and analysis show that zircaloy cladding can readily undergo exothermic reaction with air or steam, and a steam-zircaloy reaction can yield a copious amount of hydrogen. These phenomena can greatly exacerbate the severity of a fuel-overheating incident. Currently, efforts to develop ceramic cladding appear to be focused on a "triplex" silicon carbide cladding. The developers hope to begin a prototype test program – in which complete fuel assemblies made with the triplex cladding are placed in commercial reactors – by about 2020.[37]

(VI-8) As mentioned in paragraph VI-2, above, the NRC's preliminary-assumptions document identified a scenario in which SNF is reprocessed. The technology to be employed for reprocessing was not discussed but, given that document's preference for the status quo, would presumably be the prevailing current technology (i.e., PUREX).

(VI-9) Consistent with paragraph VI-6, above, scenarios in the proposed EIS should cover a range of outcomes in which the nuclear-power industry expands the scale of its operations and/or employs technology that is "new" by comparison with the prevailing technology now used in light-water reactors. Potential new technology could include, in addition to ceramic fuel cladding and current-technology reprocessing:

[37] Yueh et al, 2010.

- Mixed-oxide (MOX) fuel
- Burning of light-water SNF in CANDU-type reactors (i.e., the DUPIC cycle)
- Reactors fueled by TRISO particles embedded in pebbles or prismatic blocks
- Sodium-cooled, fast-neutron breeder reactors
- Electrometallurgical pyroprocessing of SNF
- Accelerator-driven subcritical reactors
- Fusion reactors
- Fusion-fission hybrid reactors

(VI-10) Paragraphs VI-2 through VI-9 outline how reasonably foreseeable future roles of nuclear power should be reflected in the proposed EIS. To summarize, I recommend as follows:

> **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 21^{st} century; (ii) expansion in the number of operating reactors; and (iii) introduction of new technology.

(VI-11) I pursue a related matter in Section VII, below. That matter is the potential variation, over time, in the inventories and modes of storage of SNF and HLW. In Section VII, I recommend that storage scenarios should be articulated to express a dynamic view of the inventory of stored SNF and HLW.

(VI-12) Other issues are also important in choosing scenarios. Notably, the scenarios should reflect the full range of potential variation of the risk environment, as discussed in Section V, above. Thus, I recommend as follows:

> **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.

(VI-13) The variation mentioned in Recommendation #9 could significantly influence radiological risk. For example, an impoverished society with degraded technological capability and governance might be unable or unwilling to maintain an SNF or HLW storage facility and the associated arrangements for security and emergency response. In that situation, the probability and consequences of a conventional accident or attack could increase.

(VI-14) As a corollary to Recommendation #9, the scenarios considered in the proposed EIS should cover a broad range of situations in which States and non-State actors are involved in violent conflict. During such situations, stored SNF or HLW could be attacked directly or could experience indirect effects of violent conflict. A range of possible attacks is reasonably foreseeable.

(VI-15) Table VI-1 outlines the types of attack that could occur at an SNF storage facility, and the atmospheric releases of radioactive material that could ensue. This table assumes that the stored SNF has zircaloy cladding. The table would apply to high-density pool storage of SNF, or to storage of SNF in dry casks, but the event details would vary across those two cases. The table could also apply to dry-cask transportation of SNF. A somewhat similar table could be prepared for storage of HLW, with details varying according to the mode of storage.

(VI-16) A notable feature of Table VI-1 is that the atmospheric release of volatile radioactive species, including Cesium-137, would not necessarily scale linearly with the apparent violence of the attack. The apparent violence would decrease progressively as one moved from a Type 1 attack to a Type 4 attack. Yet, the release of volatile species from a Type 4 attack could exceed the release from a Type 3 attack or even a Type 2 attack. The reason is that a successful Type 4 attack would exploit the propensity of zircaloy cladding to undergo exothermic reaction. In the case of high-density pool storage of SNF, a Type 4 attacker might rely on self-ignition of the zircaloy, but in the case of dry-cask storage the attacker might use an incendiary device to ignite the zircaloy.

(VI-17) Table VI-1 shows some of the instruments that might be used to attack an SNF storage facility. The instruments that are mentioned have been available since World War II or, in some cases, much earlier. Attack scenarios that are considered in the proposed EIS should consider the use of a range of possible instruments and modes of attack. That range should include all relevant instruments and modes of attack that are now available to States or non-State actors.

(VI-18) The shaped charge can illustrate some of the instruments of attack that are currently available. Table VI-2 outlines the status and potential applications of shaped-charge technology. Table VI-3 and Figures VI-1 through VI-3 provide supporting information. It is clear that an appropriate shaped charge could penetrate the structure of any commercial reactor or SNF storage facility in the USA. The capability to design, build, and use a shaped charge is widely distributed around the world. Many of the non-State actors that have engaged in violent conflict in recent decades could have deployed that capability, and some have done so (e.g., Iraqi insurgents).

(VI-19) Some potential attacks on nuclear facilities would involve the use of general-aviation aircraft. Figure VI-4 illustrates the fact that general-aviation aircraft have been used as instruments of attack. In the context of the proposed EIS, reasonably foreseeable events include attacks in which general-aviation aircraft are equipped with explosive charges, potentially including shaped charges.

(VI-20) Paragraphs VI-14 through VI-19 outline how reasonably foreseeable acts of violence affecting stored SNF or HLW should be considered in the proposed EIS. To summarize, I recommend as follows:

> **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. SNF and HLW Storage Modes and Dynamics to be Considered in the Proposed EIS

(VII-1) The NRC's preliminary-assumptions document envisioned the long-term temporary storage of SNF and related HLW. Subsequently, in the context of the proposed EIS, the NRC introduced the possibility that a repository may affect the need for storage. As discussed in paragraph I-4, above, the NRC envisions the possibility that storage will continue "**until** [emphasis added] a repository is made available". The implication is that the repository would absorb the entire stored inventory of SNF and HLW immediately upon becoming "available". That outcome is impossible. In fact, transfer of stored SNF and HLW would occur over a period of decades.

(VII-2) Table VII-1 shows the estimated duration of phases of implementation of the Yucca Mountain repository. For the case in which the repository would receive 105,000 MTHM of commercial SNF, one sees that the Construction phase would occupy 5 years. Thereafter, emplacement of SNF would occupy an additional 38-51 years. (The Development and Emplacement phases would occur in parallel.) It is notable that legislation limited the amount of SNF that could be placed in Yucca Mountain to 63,000 MTHM, and that the Blue Ribbon Commission published a projection that 133,000 MTHM of SNF will be accumulated in the USA by 2050.[38] The same projection indicates that an increasing fraction of the SNF inventory will be in dry storage.

(VII-3) Thus, a range of reasonably foreseeable situations could unfold over time. For example, the national inventory of stored SNF could rise over several decades, then fall over several more decades while emplacement in a repository is occurring, then resume growing when the repository is full. During that process, there could be significant shifts of SNF from one storage mode to another.

(VII-4) It is clear that, if the proposed EIS is to be credible, it must examine a range of possible trends in SNF and HLW storage over time, throughout the period covered by the EIS. This matter is significant from the perspective of radiological risk, as discussed below. Accordingly, I recommend as follows:

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[38] BRC, 2012, Figure 15.

Recommendation #11: The proposed EIS should take a dynamic view of the potential inventories and modes of storage of SNF and HLW, by considering a range of storage scenarios.

(VII-5) Taking a "dynamic view" would mean that scenarios of the type discussed in Section VI, above, would be accompanied by storage scenarios that account for at least the following factors and their variations over time:

- Discharge of SNF from reactors
- Initial mode of storage of SNF (e.g., high-density pool storage, or low-density pool storage)
- Reprocessing of SNF
- Initial mode of storage of HLW (e.g., liquid in tanks, or vitrified canisters in vaults or dry casks)
- Transfer of SNF or HLW from one storage mode to another (e.g., transfer of SNF from high-density pool storage to dry-cask storage)
- Movement of SNF or HLW from one site to another
- Emplacement of SNF or HLW in a repository

(VII-6) The radiological risk posed by a particular facility for storing SNF or HLW could vary in response to at least five major factors, as follows:

- The threat environment at the facility could change over time.
- The mass of SNF or HLW stored at the facility could change over time.
- The modes of storage could vary in the radiological risk that they pose, for a given mass of SNF or HLW.
- The radiological risk posed by a given mode of storage (e.g., a high-density SNF storage pool) could vary according to the operational status of an adjacent facility (e.g., a reactor).
- The radiological risk posed by a given mass of SNF or HLW tends to decline with age, other factors being equal, because: (i) its radioactive decay heat production declines over time, resulting in a decreased propensity to overheat and release radioactive material to the atmosphere; and (ii) the inventory of radioactive material that is available for release also declines

(VII-7) From paragraph VII-6 it is clear that each storage scenario of the type discussed in paragraph VII-5 would have its own profile of radiological risk over time.

(VII-8) In paragraph VII-6, above, I note that: (i) modes of storage could vary in the radiological risk that they pose, for a given mass of SNF or HLW; and (ii) the radiological risk posed by a given mode of storage (e.g., a high-density SNF storage pool) could vary according to the operational status of an adjacent facility (e.g., a reactor). These observations support a more general point, which is addressed in my Recommendation #6, namely that the comparative radiological risk posed by a range of alternative options for storing SNF or HLW should be assessed in the proposed EIS as a major indicator of the comparative impacts of these alternatives. Accordingly, I recommend as follows:

> **Recommendation #12:** 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 SNF or HLW.

(VII-9) The comparative radiological risk posed by alternative options for storing SNF or HLW is determined by a number of factors. One factor that can be a significant determinant of comparative risk, other factors being equal, is the extent to which the storage facility is placed below ground level. In illustration, Holtec has developed a design for an SNF dry-cask storage module that is said to be more robust against attack than conventional modules. The module in question is the HI-STORM 100U module, which would employ the same internal canister (MPC) as is used in the conventional Holtec modules. For most of its height, the 100U module would be below ground level. Holtec has described the robustness of the 100U module as follows:[39]

> "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."

(VII-10) In considering the storage of SNF or HLW below ground level, it should be noted that there is considerable discussion about the roles of reversibility and retrievability in the design of repositories for radioactive waste.[40] Indeed, the Yucca Mountain repository was nominally designed for retrievability during the Emplacement and Monitoring phases that are shown in Table VII-1. Reversibility and retrievability at a repository are issues relevant to discussion about the extent to which nuclear power could be compatible with sustainable development. In the context of this declaration, it is notable that retrievable emplacement of SNF or HLW in a repository, deep underground, would be a form of storage that could pose lower radiological risk than would storage at the surface. Accordingly, I recommend as follows:

> **Recommendation #13:** In assessing the comparative radiological risk posed by alternative options for storing SNF or HLW, the proposed EIS should regard retrievable emplacement in a repository as a mode of storage.

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[39] Holtec, 2007.
[40] Nuclear Energy Agency, 2011.

(VII-11) In paragraph II-4, above, I mention the concept of a "pool fire". That term refers to the occurrence of self-sustaining, exothermic oxidation reactions of fuel cladding in a high-density SNF pool if water is lost from the pool. More precisely, a pool fire would involve the following sequence of events:

- loss of water from the pool due to leakage, boiling away, siphoning, or other mechanism
- failure to provide water makeup or cooling
- uncovering of SNF assemblies
- heat-up of some SNF assemblies to the ignition point of zircaloy, followed by combustion of these assemblies in steam and/or air
- a hydrogen explosion (not inevitable, but likely) that damages the building surrounding the pool
- release of radioactive material from affected SNF assemblies to the atmosphere
- propagation of combustion to other SNF assemblies

(VII-12) A pool-fire event sequence would unfold over a timeframe ranging from a few hours to a number of days. During this timeframe, there might, in principle, be opportunities for personnel to halt or mitigate the event sequence through actions such as plugging holes in a pool, or adding water. However, addition of water after zircaloy ignites could be counter-productive, because the water could feed combustion. Circumstances accompanying the pool-fire event sequence, such as a core-damage event sequence at an adjacent reactor, could preclude mitigating actions. This matter is discussed in Section VIII, below.

(VII-13) The NRC concedes that a pool fire could occur, but argues that its probability is very low.[41] Nevertheless, the NRC acknowledges this event in its planning for emergencies. For example, a workbook used to train personnel in use of NRC's dose-projection code RASCAL contains an exercise in which trainees are asked to calculate offsite radiation doses in the event of a pool fire. The exercise is introduced with the following description of the event:[42]

> "The plant staff are calling you from San Onofre, Unit 2 because there has been an earthquake in the vicinity. The spent fuel pool has lost much of its water due to a large crack possibly flowing into a sink hole. Due to a malfunctioning pump, it has not been possible to provide enough water to make up for the loss. The water dropped to the top of the fuel at 8:49 A.M., and appears likely to continue dropping. Estimates are that the fuel will be fully uncovered by 11:00 A.M. The pool has high density racking and contains one batch of fuel that was unloaded

[41] For example, in a 2008 decision the NRC stated: "Thus, the **very low probability** [emphasis added] of an SFP zirconium fire would result in an SFP risk level less than that for a reactor accident." (See: NRC, 2008, page 46212.)
[42] Athey et al, 2007, page 116.

> from the reactor only 2 weeks earlier. (A batch is defined as one-third of a core) Another batch was unloaded about a year before that, and 8 batches have been in the pool for longer than 2 years. The spent fuel building has been severely damaged and is in many places directly open to the atmosphere."

(VII-14) One notable feature of pool fires is that the potential for their occurrence derives almost entirely from the practice of employing high-density racks in SNF pools. That practice is now almost universal at US pools. If the high-density racks were replaced with low-density racks, SNF would not spontaneously ignite across a broad range of water-loss scenarios. The nuclear industry is reluctant to make the change to low-density racks, primarily because of the cost involved. Another notable feature of pool fires is that a pool fire could release a large inventory of radioactive material, especially Cesium-137, creating substantial radiological impact.

(VII-15) SNF stored in a dry cask could, in principle, experience an event analogous to a pool fire. I term that potential event a "cask fire". Occurrence of a cask fire would require that three conditions are satisfied. First, a circulating pathway between SNF and the atmosphere must exist, so that air can reach the SNF and combustion products (and Cesium-137) can reach the atmosphere. Second, circulation of fluid through this pathway must be driven by natural convection. Third, the temperature of the cladding of a portion of the SNF in the cask must be raised to the ignition point, so that a self-sustaining reaction can begin.

(VII-16) A pool fire could be initiated by a conventional accident or by an attack. By contrast, a cask fire could be initiated by an attack, but its initiation by a conventional accident is comparatively unlikely. This matter is addressed further in Section VIII, below. A cask fire could release a substantial fraction of the volatile radioactive material, such as Cesium-137, in the cask. Thus, a cask fire could create substantial radiological impact.

(VII-17) In light of the discussion in paragraphs VII-11 through VII-16, above, I recommend as follows:

> **Recommendation #14:** In assessing the comparative radiological risk posed by alternative options for storing SNF or HLW, the proposed EIS should give special attention to the potential for radioactive release from stored SNF as a result of a pool fire or a cask fire.

(VII-18) My Recommendation #12 is that 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 SNF or HLW. Two SNF storage scenarios could be particularly useful to illustrate the options available, and their comparative radiological risk. These SNF storage scenarios would be: (i) an Extended Status Quo scenario; and (ii) a Nuclear Power Rundown with SNF Risk Minimization scenario.

(VII-19) The Extended Status Quo storage scenario would involve:

- Production of SNF continues at about the present level
- Newly-discharged SNF is placed in high-density pools adjacent to reactors
- Excess SNF is placed in dry casks on reactor sites
- This situation continues for some number of centuries

(VII-20) The Nuclear Power Rundown with SNF Risk Minimization storage scenario would involve:

- The present reactors shut down at the ends of their license periods or earlier, and no new reactors commence operating
- Newly-discharged SNF is placed in low-density pools adjacent to reactors
- Excess SNF is placed in dry casks on reactor sites, with additional protection (e.g., the HI-STORM 100U system, or placement of casks within berms, robust buildings, or tunnels)
- A repository begins receiving SNF as soon as possible

(VII-21) To summarize the discussion in paragraphs VII-18 through VII-20, above, I recommend as follows:

> **Recommendation #15:** The SNF storage scenarios to be considered in the proposed EIS should include: (i) an Extended Status Quo scenario; (ii) a Nuclear Power Rundown with SNF Risk Minimization scenario; and (iii) a range of other scenarios.

VIII. Phenomena Relevant to Radioactive Release from SNF or HLW

(VIII-1) My Recommendation #14 indicates that the proposed EIS should give special attention to the potential for radioactive release from stored SNF as a result of a pool fire or a cask fire. To date, the phenomena associated with a pool fire or a cask fire have not been adequately examined. I address that matter in the following paragraphs. Section VIII closes with some brief observations on phenomena relevant to radioactive release from HLW.

(VIII-2) As stated in paragraph II-4, above, I publicly identified the potential for a pool fire in 1979, and the Lower Saxony government accepted my findings. Independently, a group at Sandia Laboratories identified the same potential in a report prepared for the NRC.[43] In light of knowledge that has accumulated since 1979, the Sandia report generally stands up well, provided that one reads the report in its entirety. However, the report's introduction contains an erroneous statement that complete drainage of an SNF pool is the most severe situation in the context of a pool fire. The body of the report

[43] Benjamin et al, 1979.

clearly shows that partial drainage can be a more severe case, as I had previously recognized. Unfortunately, NRC continued, until October 2000, to employ the erroneous assumption that complete drainage is the most severe case.

(VIII-3) After receiving the Sandia report, the NRC conducted and sponsored a number of analyses related to pool fires. Those analyses were published over a period of about two decades. I identified and critiqued that body of work in a February 2009 report, reaching the following conclusion:[44]

> "NRC has conducted some analyses related to the radiological risk described in conclusion C2. [That conclusion addressed both pool fires and cask fires.] The analyses that have been published, taken together, provide an incomplete and inaccurate assessment of the risk. None of the published analyses meets the standards of an EIS prepared under NEPA. NRC has issued statements about the radiological risk associated with malice-induced accidents affecting spent fuel, but has neither published any technical analysis of that risk, nor published any citation to a secret analysis that could meet the standards of an EIS prepared under NEPA."

(VIII-4) After September 2001, the NRC ceased publishing analysis on pool fires, but claims to have done some secret studies. To my knowledge, the NRC has not published any significant analysis on pool fires or cask fires since February 2009. Thus, my conclusion of February 2009, as quoted in paragraph VIII-3, remains valid.

(VIII-5) The US Government Accountability Office (GAO) confirms that the NRC has, indeed, done some secret studies on pool fires. However, according to the GAO, the NRC has lost track of those studies. An August 2012 GAO report states:[45]

> "Because a decision on a permanent means of disposing of spent fuel may not be made for years, NRC officials and others may need to make interim decisions, which could be informed by past studies on stored spent fuel. In response to GAO requests, however, NRC could not easily identify, locate, or access studies it had conducted or commissioned because it does not have an agencywide mechanism to ensure that it can identify and locate such classified studies."

(VIII-6) I identified a similar problem in my February 2009 report, which I discuss in paragraph VIII-3, above. In that report, I examined statements, in two official NRC documents published in 2008, regarding secret studies allegedly conducted or sponsored by the NRC in order to improve technical understanding of pool fires. I concluded:[46]

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[44] Thompson 2009, Section 11, Conclusion C3.
[45] GAO, 2012, Highlights.
[46] Thompson, 2009, Section 5.2, pp 24-25.

> "To summarize, the Draft Update, issued in October 2008, mentions one set of secret studies, while the rulemaking petition decision, issued in August 2008, mentions a different set of secret studies. This inconsistency represents, at a minimum, carelessness and a lack of respect for the public."

(VIII-7) The experiences outlined in paragraphs VIII-5 and VIII-6 illustrate the corrosive, counterproductive effects of an entrenched culture of secrecy. Such a culture is not compatible with a clear-headed, science-based approach to the understanding of radiological risk. Entrenched secrecy perpetuates dogma, stifles dissent, encourages conflicts of interest, promotes laziness, and can create a false sense of security. Indeed, secrecy can significantly increase radiological risk. For example, there is evidence that a major risk factor underlying the 1986 Chernobyl reactor accident was endemic secrecy in the USSR.[47]

(VIII-8) There is no justification for secrecy about the phenomena associated with potential pool fires. A pool fire could be initiated by either a conventional accident or an attack. In either case, the phenomena associated with the fire itself would be similar. Effective management of the radiological risk of a potential pool fire, in the context of conventional accidents, demands open, transparent consideration of all associated phenomena. The resulting publication of information would not significantly assist an entity that contemplates an attack on an SNF pool. A capable entity in that category would already possess, or could readily obtain, the information needed to plan an attack. The NRC itself has published sabotage scenarios, as shown in Table IV-3, that could, with modest adaptation, lead to an unstoppable pool fire with severe offsite impacts. In any event, if the NRC determines in future that an attack-initiated pool fire is a significant threat, the mitigation of that threat could be simple. The NRC could order its licensees to re-equip their SNF pools with low-density racks, which could be accomplished comparatively quickly.

(VIII-9) In light of the discussion in paragraphs VIII-2 through VIII-8, above, I recommend as follows:

> **Recommendation #16:** In assessing the potential for radioactive release from stored SNF 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.

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[47] Shlyakhter and Wilson, 1992.

(VIII-10) My Recommendation #16 addresses phenomena associated with a pool fire, rather than the pre-conditions and initiating events that could cause a pool fire to commence. To date, these matters have not been adequately examined. I address them in the following paragraphs.

(VIII-11) As mentioned in paragraph VII-12, above, a pool-fire event sequence would unfold over a timeframe ranging from a few hours to a number of days. During this timeframe, there might, in principle, be opportunities for personnel to halt or mitigate the event sequence. For a particular event sequence, the timeframe, and the existence of potential opportunities to halt or mitigate the sequence, would reflect factors including: (i) the facility design; (ii) the age and disposition of SNF in the pool; and (iii) the nature of the initiating event, which could be a conventional accident or an attack.

(VIII-12) Although potential opportunities to halt or mitigate a pool-fire event sequence might exist in principle, circumstances accompanying the sequence could prevent personnel from exploiting those opportunities. One category of such circumstances would be the degradation of site conditions caused by an incident at an adjacent facility. For example, that incident could block cooling and water makeup to the pool, and access by personnel to restore those services could be precluded by phenomena such as high radiation fields, fires, explosions, damage to equipment and structures, and release of high-temperature steam and gases. That situation is not speculative, because it occurred at the Fukushima #1 site in 2011. Figure VIII-1 shows Unit 4 at that site during the 2011 accident. A concrete pumping truck is shown, spraying water into the SNF pool. Prior to the arrival of that truck, unsuccessful attempts had been made over a number of days to add water to SNF pools at the site, employing fire trucks, police riot control vehicles, and bags of water suspended from helicopters. Yet, despite this vivid illustration of the threat, the NRC has never published a credible analysis of the potential for degraded-site conditions to enable or exacerbate a pool fire.

(VIII-13) In light of the discussion in paragraphs VIII-11 and VIII-12, above, I recommend as follows:

> **Recommendation #17:** 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).

(VIII-14) In paragraph VII-15, above, I outline the conditions that must be satisfied for a cask fire to occur. In paragraph VII-16, I note that an attack could satisfy those conditions. The NRC has not yet conceded that an attack could initiate a cask fire. However, the NRC has been reliably informed that a reasonably foreseeable attack could penetrate a cask, damage SNF inside the cask, and cause a release of radioactive material to the atmosphere. That point has been established by a body of empirical work whose findings have been openly published. For example, consider a 2008 Sandia report on tests related to potential sabotage of an SNF storage or transport cask. The report states:[48]

> "In some plausible, intentional sabotage scenarios, such as an attack employing a high energy density device (HEDD), i.e., explosive armor-piercing weapons, it is possible that a cask could be penetrated. Then, a small percentage of aerosolized particles produced within from disrupted fuel rod and pellet materials could be released as a radiological inhalation source hazard. If released to the environment in a significant quantity, the spent fuel respirable particles have the potential to cause radiological consequences."

(VIII-15) From the preceding paragraph, it is clear that attack-induced penetration of an SNF cask, leading to atmospheric release, is a reasonably foreseeable event. With a few additional steps, attackers could initiate a cask fire. I addressed that matter in a 2008 declaration, being careful to avoid disclosing information that could directly assist an attacker.[49] I conclude that an attack-induced cask fire is a reasonably foreseeable event.

(VIII-16) My position on the foreseeability of an attack-induced cask fire differs from the public position of the NRC. The difference boils down to a question: Could attackers who are capable of penetrating an SNF cask take the additional steps needed to initiate a cask fire? That question could be addressed 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.

(VIII-17) Figure VIII-2 shows that the NRC has sponsored a test burn of an SNF assembly. The findings from that test could improve understanding of both pool fires and cask fires. Accordingly, those findings should be published. Findings from similar tests should also be published.

(VIII-18) In light of the discussion in paragraphs VIII-14 through VIII-17, above, I recommend as follows:

> **Recommendation #18:** In assessing the potential for radioactive release from stored SNF as a result of a cask fire, the proposed EIS could rely on a body of analytic and empirical investigation that is not fully published, provided that the NRC has engaged an independent Red Team to determine through representative

[48] Molecke et al, 2008, Section 1, page 9.
[49] Thompson, 2008b, Section V.

tests whether a cask fire can be initiated and, if so, what release of radioactive material would be likely to occur.

(VIII-19) The preceding paragraphs in Section VIII have addressed phenomena associated with a pool fire or a cask fire. That focus of attention is consistent with my Recommendation #14. However, as stated in my Recommendation #2, the proposed EIS should address the potential storage of HLW as well as SNF. Thus, the proposed EIS should be supported by a thorough examination of phenomena relevant to radioactive release from HLW. I have studied such phenomena in several contexts. One such context is the storage of HLW in liquid form at the Sellafield site in the UK.[50]

IX. Assessing Likelihood and Impacts of Radiological Incidents

(IX-1) My Recommendation #4 is that assessment of radiological risk should be a major function of the proposed EIS. Such assessment will require estimation of the likelihood and the impacts of potential radiological incidents. I address these matters in the following paragraphs.

(IX-2) An analyst who seeks to estimate the likelihood of potential radiological incidents can employ various sources of information and various analytic tools. One of those tools is the art of probabilistic risk assessment (PRA). The high point of PRA practice in the nuclear-power sector to date was the NRC's NUREG-1150 study, which examined the radiological risk posed by five US nuclear power plants, in the context of conventional accidents.[51]

(IX-3) PRA techniques, if judiciously applied, could contribute to an assessment of the likelihood of radiological incidents involving stored SNF or HLW. However, as discussed in paragraph IV-6, above, the limitations of PRA techniques should be recognized.[52] Accordingly, I recommend as follows:

> **Recommendation #19:** 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.

(IX-4) An analyst who seeks to estimate the impacts of potential radiological incidents should consider a range of impacts. In the context of incidents involving atmospheric release, I recommend as follows:

> **Recommendation #20:** 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

[50] Thompson, 1998.
[51] NRC, 1990.
[52] For additional information on the limitations of PRA, see: Hirsch et al, 1989.

to total exposure; (v) abandonment of assets; (vi) cleanup costs; (vii) direct and indirect economic impacts; and (viii) social impacts.

(IX-5) In paragraphs (IV-5) through (IV-7), above, I describe the "arithmetic" definition of risk and show how that definition can be seriously misleading. Nevertheless, the NRC is prone to using the arithmetic definition in official documents. Here is an example:[53]

> "Risk is defined as the probability of the occurrence of a given event multiplied by the consequences of that event."

(IX-6) The quoted statement is inconsistent with the NRC's Glossary, as footnoted in my paragraph (IV-4), above. Moreover, the quoted statement is inconsistent with its own footnote, which refers to an ASME standard. In light of these inconsistencies and my finding that the arithmetic definition can be seriously misleading, I recommend as follows:

> **Recommendation #21:** In considering radiological risk, the proposed EIS should repudiate the arithmetic definition of risk.

(IX-7) Radiological risk is one category of potential impacts from storage of SNF or HLW. A related category is the set of implications of storage options for national security. I address that matter in Table IX-1, with a focus on the threat of attack by non-State actors. That table shows how robust and inherently-safer design of infrastructure facilities, such as facilities for storing SNF or HLW, could contribute to a national strategy of protective deterrence. Accordingly, I recommend as follows:

> **Recommendation #22:** In assessing the overall impacts of storing SNF or HLW, the proposed EIS should consider the implications of alternative storage options for a national strategy of protective deterrence.

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[53] NRC, 2008, page 46207.

X. Summary of Recommendations

(X-1) Numbered recommendations regarding the scope of the proposed EIS are set forth within Sections I through IX of this declaration. Here, the recommendations are repeated, grouped by the sections where they are set forth. Each recommendation should be read within the context of the narrative that surrounds it. The recommendations are:

SECTION I

Recommendation #1: The NRC's preliminary-assumptions document should be a point of departure for determining the scope of the proposed EIS, especially in regard to storage after the end of the 21st century.

Recommendation #2: The proposed EIS should not only address the storage of SNF, but also the potential storage of HLW from reprocessing of SNF.

Recommendation #3: The proposed EIS should consider the radiological risk posed by storage of SNF from the moment of its discharge from a reactor.

SECTION IV

Recommendation #4: 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.

Recommendation #5: The proposed EIS should assess the radiological risk arising from a range of conventional accidents or attacks that could affect stored SNF or HLW.

Recommendation #6: The comparative radiological risk posed by a range of alternative options for storing SNF or HLW should be assessed in the proposed EIS as a major indicator of the comparative impacts of these alternatives.

SECTION V

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.

SECTION VI

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.

SECTION VII

Recommendation #11: The proposed EIS should take a dynamic view of the potential inventories and modes of storage of SNF and HLW, by considering a range of storage scenarios.

Recommendation #12: 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 SNF or HLW.

Recommendation #13: In assessing the comparative radiological risk posed by alternative options for storing SNF or HLW, the proposed EIS should regard retrievable emplacement in a repository as a mode of storage.

Recommendation #14: In assessing the comparative radiological risk posed by alternative options for storing SNF or HLW, the proposed EIS should give special attention to the potential for radioactive release from stored SNF as a result of a pool fire or a cask fire.

Recommendation #15: The SNF storage scenarios to be considered in the proposed EIS should include: (i) an Extended Status Quo scenario; (ii) a Nuclear Power Rundown with SNF Risk Minimization scenario; and (iii) a range of other scenarios.

SECTION VIII

Recommendation #16: In assessing the potential for radioactive release from stored SNF 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.

Recommendation #17: 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).

Recommendation #18: In assessing the potential for radioactive release from stored SNF as a result of a cask fire, the proposed EIS could rely on a body of analytic and empirical investigation 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.

SECTION IX

Recommendation #19: 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.

Recommendation #20: 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.

Recommendation #21: In considering radiological risk, the proposed EIS should repudiate the arithmetic definition of risk.

Recommendation #22: In assessing the overall impacts of storing SNF or HLW, the proposed EIS should consider the implications of alternative storage options for a national strategy of protective deterrence.

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I declare, under penalty of perjury, that the facts set forth in the foregoing narrative, and in the two 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 2 January 2013.

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Gordon R. Thompson

APPENDIX A: Bibliography

(Albrecht, 1979)
Ernst Albrecht, Minister-President of Lower Saxony, "Declaration of the state government of Lower Saxony concerning the proposed nuclear fuel center at Gorleben" (English translation), May 1979.

(Alvarez et al, 2003)
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.

(Anderson and Bows, 2011)
Kevin Anderson and Alice Bows, "Beyond 'dangerous' climate change: emission scenarios for a new world", *Philosophical Transactions of the Royal Society A*, Volume 369, 2011, pp 20-44.

(Army, 1967)
Department of the Army, *Explosives and Demolitions, FM 5-25* (Washington, DC: Department of the Army, May 1967).

(Athey et al, 2007)
G. F. Athey, S. A. McGuire, and J. V. Ramsdell, Jr., *RASCAL 3.0.5 Workbook, NUREG-1889* (Washington, DC: US Nuclear Regulatory Commission, September 2007).

(Benjamin et al, 1979)
Allan S. Benjamin and three other authors, *Spent Fuel Heatup Following Loss of Water During Storage, NUREG/CR-0649* (Washington, DC: US Nuclear Regulatory Commission, March 1979).

(Beyea et al, 1979)
Jan Beyea, Yves Lenoir, Gene Rochlin, and Gordon Thompson (group chair), "Potential Accidents and Their Effects," Chapter 3 in *Report of the Gorleben International Review*, March 1979. (This chapter was prepared in English and translated into German for submission to the Lower Saxony State Government.)

(BRC, 2012)
Blue Ribbon Commission on America's Nuclear Future, *Report to the Secretary of Energy* (Washington, DC: US Department of Energy, January 2012).

(Brick, 2010)
Michael Brick, "Man Crashes Plane Into Texas IRS Office", *The New York Times*, 18 February 2010.

(Defense Science Board, 2011)
Defense Science Board, *Report of the Defense Science Board Task Force on Trends and Implications of Climate Change on National and International Security* (Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, October 2011).

(Diet, 2012)
National Diet of Japan, *The official report of The Fukushima Nuclear Accident Independent Investigation Commission, Executive summary* (Tokyo: National Diet of Japan, 2012).

(DOE, 2002)
US Department of Energy, *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada, DOE/EIS-0250F* (Washington, DC: DOE, February 2002).

(EIA, 2012)
US Energy Information Administration, *AEO2013 Early Release Overview* (Washington, DC: EIA, 5 December 2012). Accessed on 6 December 2012 at:
http://www.eia.gov/forecasts/aeo/er/early_introduction.cfm

(GAO, 2012)
US Government Accountability Office, *Spent Nuclear Fuel: Accumulating Quantities at Commercial Reactors Present Storage and Other Challenges, GAO-12-797* (Washington, DC: GAO, August 2012).

(Hirsch et al, 1989)
H. Hirsch and three other authors, *IAEA Safety Targets and Probabilistic Risk Assessment* (Hannover, Germany: Gesellschaft fur Okologische Forschung und Beratung, August 1989).

(Holtec, 2007)
Holtec International, "The HI-STORM 100 Storage System", accessed at http://www.holtecinternational.com/hstorm100.html on 17 June 2007.

(Makhijani, 2013)
Arjun Makhijani (Institute for Energy and Environmental Research), "Declaration of Dr. Arjun Makhijani Regarding the Scope of Proposed Waste Confidence Environmental Impact Statement", 1 January 2013.

(Molecke et al, 2008)
Martin A. Molecke and nine other authors, *Spent Fuel Sabotage Test Program, Characterization of Aerosol Dispersal: Interim Final Report, SAND2007-8070* (Albuquerque, New Mexico: Sandia National Laboratories, January 2008).

(National Research Council, 2006)
National Research Council Committee on the Safety and Security of Commercial Spent Nuclear Fuel Storage (a committee of the Council's Board on Radioactive Waste Management), *Safety and Security of Commercial Spent Nuclear Fuel Storage: Public Report* (Washington, DC: National Academies Press, 2006).

(NIC, 2012)
US National Intelligence Council, *Global Trends 2030: Alternative Worlds* (Washington, DC: Office of the Director of National Intelligence, December 2012).

(NRC, 2012)
US Nuclear Regulatory Commission, "Consideration of Environmental Impacts of Temporary Storage of Spent Fuel After Cessation of Reactor Operation", *Federal Register*, Volume 77, Number 207, 25 October 2012, pp 65137-65139.

(NRC, 2011)
US Nuclear Regulatory Commission, *Draft Report for Comment: Background and Preliminary Assumptions for an Environmental Impact Statement – Long-Term Waste Confidence Update* (Washington, DC: NRC, December 2011).

(NRC, 2008)
US Nuclear Regulatory Commission, "10 CFR Part 51, The Attorney General of Commonwealth of Massachusetts, The Attorney General of California; Denial of Petitions for Rulemaking", *Federal Register*, Volume 73, Number 154, 8 August 2008, pp 46204-46213.

(NRC, 1990)
US Nuclear Regulatory Commission, *Severe Accident Risks: An Assessment for Five US Nuclear Power Plants, NUREG-1150* (Washington, DC: Nuclear Regulatory Commission, December 1990).

(NRC, 1979)
US Nuclear Regulatory Commission, *Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel, NUREG-0575* (Washington, DC: Nuclear Regulatory Commission, August 1979).

(Nuclear Energy Agency, 2011)
Nuclear Energy Agency, *Reversibility and Retrievability (R&R) for the Deep Disposal of High-level Radioactive Waste and Spent Fuel* (Paris: OECD, December 2011).

(Nuclear Energy Agency, 2000)
Nuclear Energy Agency, *Nuclear Energy in a Sustainable Development Perspective* (Paris: OECD, 2000).

(PwC, 2012)
Pricewaterhouse Coopers LLP, *Too late for two degrees?: Low carbon economy index 2012* (London: Pricewaterhouse Coopers LLP, November 2012).

(Raskin et al, 2002)
Paul Raskin and six other authors, *Great Transition: The Promise and Lure of the Times Ahead* (Boston, Massachusetts: Stockholm Environment Institute, 2002).

(Raytheon, 2008)
Raytheon Company, "Raytheon Unveils New Record-Breaking Bunker Busting Technology", 12 March 2008, accessed on 7 March 2012 at: http://www.raytheon.com/newsroom/feature/bb_03-10/

(Rockstrom et al, 2009)
Johan Rockstrom and twenty-eight other authors, "Planetary Boundaries: Exploring the Safe Operating Space for Humanity", *Ecology and Society*, Volume 14, Number 2, Article 32, 2009. Accessed on 1 November 2012 at: http://www.ecologyandsociety.org/vol14/iss2/art32/

(Schneider et al, 2012)
Mycle Schneider and Antony Froggatt with Julie Hazemann, *World Nuclear Industry Status Report 2012* (Paris: Mycle Schneider Consulting, July 2012).

(Shlyakhter and Wilson, 1992)
Alexander Shlyakhter and Richard Wilson, "Chernobyl: the inevitable results of secrecy", *Public Understanding of Science*, Volume 1, July 1992, pp 251-259.

(Thompson, 2009)
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).

(Thompson, 2008a)
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.

(Thompson, 2008b)
Gordon R. Thompson, "Declaration of Dr. Gordon R. Thompson on Behalf of San Luis Obispo Mothers for Peace in Support of Contention 2 Regarding the Construction and Operation of the Diablo Canyon Independent Spent Fuel Storage Installation", 14 April 2008.

(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).

(Thompson, 1998)
Gordon Thompson, *High Level Radioactive Liquid Waste at Sellafield: Risks, Alternative Options and Lessons for Policy* (Cambridge, Massachusetts: Institute for Resource and Security Studies, June 1998).

(Warwick, 2008)
Graham Warwick, "VIDEO: Raytheon tests bunker-busting tandem warhead", *Flightglobal*, 26 February 2008, accessed on 7 March 2012 from: http://www.flightglobal.com/news/articles/video-raytheon-tests-bunker-busting-tandem-warhead-221842/

(WCED, 1987)
World Commission on Environment and Development, *Our Common Future* (Oxford, UK: Oxford University Press, 1987).

(Weber, 2011)
Michael Weber (US Nuclear Regulatory Commission), "Ensuring Spent Fuel Pool Safety", viewgraphs for display at American Nuclear Society meeting, 28 June 2011.

(WEF, 2012)
World Economic Forum, *Global Risks 2012* (Geneva: WEF, 2012).

(Yueh et al, 2010)
Ken Yueh, David Carpenter, and Herbert Feinroth, "Clad in clay", *Nuclear Engineering International*, 8 March 2010.

APPENDIX B: Tables and Figures

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Table IV-1
A Possible Framework of Sustainable-Development Principles for Design and Appraisal of Infrastructure Projects

Objective	Design Approach Dictated by Objective
#1. Build and preserve assets	Design for preservation and enhancement of: • Human capital • Natural capital • Engineered capital
#2. Create options for the future	Design for: • Reversibility • Resilience • Adaptability • Flexibility
#3. Manage risk	Prepare for unusual events by: • Identifying and characterizing potential events • Designing infrastructure to ride out events or to fail consistent with objectives #1 and #2 • Planning for emergency response

Notes:
(a) This particular framework of principles is attributable to Gordon R. Thompson. Each principle in the framework has been widely discussed by many authors and has, to some extent, been applied to the design of infrastructure. (See, for example: Nuclear Energy Agency, 2000.) However, at present there is no generally accepted framework that integrates these principles.
(b) This framework reflects the definition of sustainable development that was set forth by the World Commission on Environment and Development in 1987, as follows (WCED, 1987, beginning of Chapter 2):

> <u>"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."</u>

(c) Infrastructure should serve a societal purpose. A particular societal purpose could be served by a variety of configurations of infrastructure. A framework such as the one set forth here could be used to appraise the comparative sustainability of proposed configurations, across a range of options.
(d) Logically, the principles used to appraise an infrastructure project should be identical to the principles used to design the project.

Table IV-2
Some Categories of Risk Posed by a Commercial Nuclear Facility

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 conventional 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 IV-3
Potential Sabotage Events at an SNF Storage Pool, as Postulated in the NRC's August 1979 Generic EIS 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 V-1
Future World Scenarios Identified by the Stockholm Environment Institute

Scenario	Characteristics
Conventional Worlds	
Market Forces	Competitive, open, and integrated global markets drive world development. Social and environmental concerns are secondary.
Policy Reform	Comprehensive and coordinated government action is initiated for poverty reduction and environmental sustainability.
Barbarization	
Breakdown	Conflict and crises spiral out of control and institutions collapse.
Fortress World	This scenario features an authoritarian response to the threat of breakdown, as the world divides into a kind of global apartheid with the elite in interconnected, protected enclaves and an impoverished majority outside.
Great Transitions	
Eco-Communalism	This is a vision of bio-regionalism, localism, face-to-face democracy and economic autarky. While this scenario is popular among some environmental and anarchistic subcultures, it is difficult to visualize a plausible path, from the globalizing trends of today to eco-communalism, that does not pass through some form of barbarization.
New Sustainability Paradigm	This scenario changes the character of global civilization rather than retreating into localism. It validates global solidarity, cultural cross-fertilization and economic connectedness while seeking a liberatory, humanistic, and ecological transition.

Source: Raskin et al, 2002

Table VI-1
Potential Types of Attack on an SNF 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-2
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-3
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 VII-1
Estimated Duration of Phases of Implementation of the Yucca Mountain Repository

Phase of Repository Implementation		Duration of Phase (years)	
		If Yucca Mountain total inventory of commercial spent fuel = 63,000 MTHM	If Yucca Mountain total inventory of commercial spent fuel = 105,000 MTHM
Construction phase		5	5
Operation and monitoring phases	Development	22	36
	Emplacement	24-50	38-51
	Monitoring	76-300	62-300
Closure phase		10-17	12-23

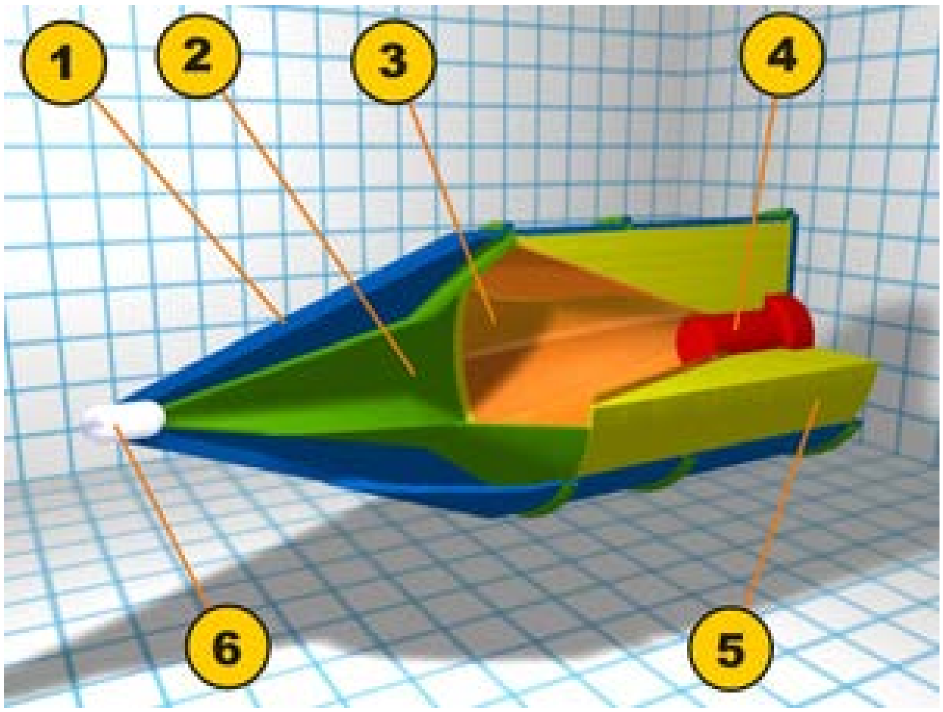
Notes:
(a) These estimates are from: DOE, 2002, Volume I, pages 8-8 and 2-18.
(b) The Development and Emplacement phases would begin on the same date. Other phases would be sequential.
(c) The Construction phase would begin with issuance of construction authorization, and end with issuance of a license to receive and dispose of radioactive waste.

Table IX-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".

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

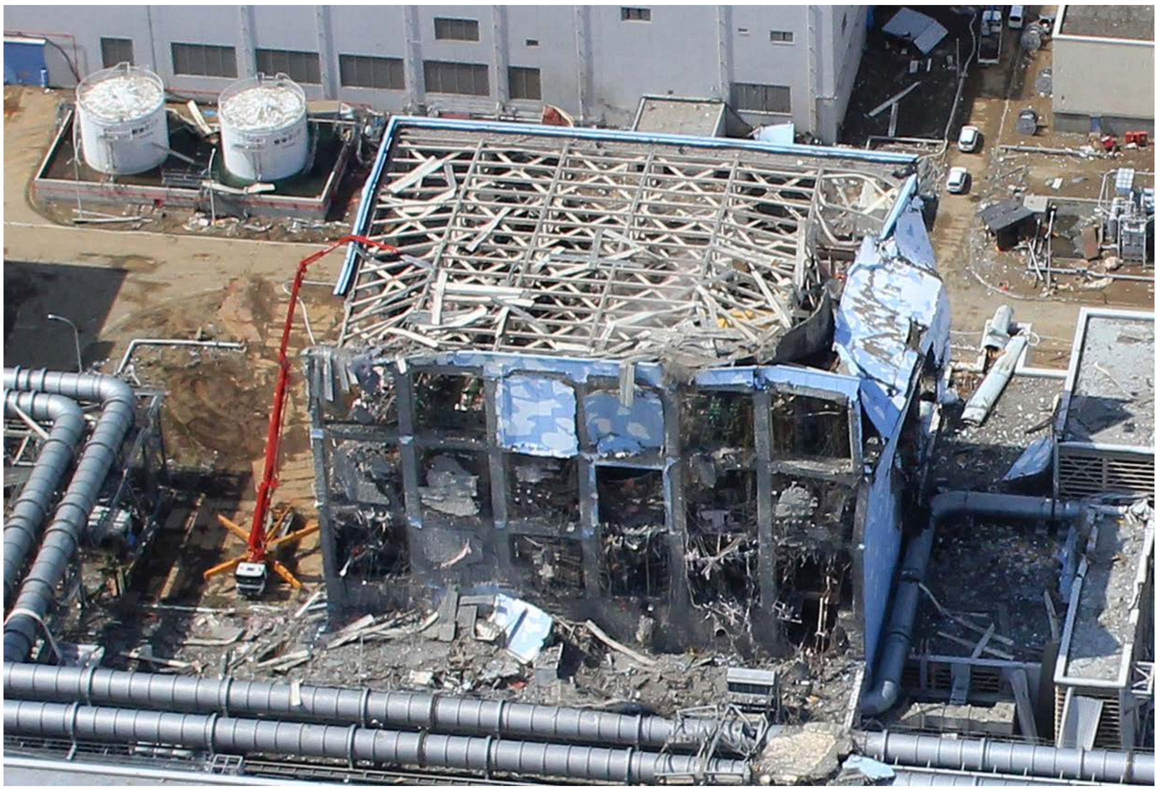
After Test (viewed from the attacked face)

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
Outcome of Test Burn of a BWR Fuel Assembly

Notes:
(a) This figure is from: Weber, 2011.
(b) The figure shows the outcome of a test to investigate the burning of SNF. An inactive 9x9 BWR fuel assembly with zircaloy-2 cladding was burned in air. The assembly was at reactor scale although not all rods were full length. The assembly was electrically heated (via 74 electric heater rods) at a rate of 5 kW.
(c) The fuel assembly was surrounded by thermal insulation – the white material in the photograph.
(d) This test did not attempt to simulate the release of Cesium or other materials from the damaged fuel.

DECLARATION OF PHILLIP MUSEGAAS REGARDING THE SCOPE OF THE PROPOSED WASTE CONFIDENCE ENVIRONMENTAL IMPACT STATEMENT

Under penalty of perjury, I, Phillip Musegaas, Esq., declare as follows:

Statement of Qualifications

1. I am the Hudson River Program Director for Riverkeeper, Inc. ("Riverkeeper"). I have been employed by Riverkeeper since August 2005. Riverkeeper is a 501(c)(3) 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.

2. Through my work at Riverkeeper, I have been involved with various legal and policy matters involving the Indian Point nuclear power plant. Generally, since its inception in 1966, Riverkeeper has used litigation, science, advocacy, and public education to raise and address concerns relating to Indian Point, which is located on the eastern bank of the Hudson River in Buchanan, NY. Riverkeeper is headquartered in Ossining, New York, approximately 10 miles from the Indian Point facility, and has numerous members that reside within at least fifty (50) miles of the plant. Since the terrorist attacks of September 11th, Riverkeeper has become increasingly concerned with the environmental, safety, and security issues presented by the large amount of irradiated ("spent") fuel stored onsite at the Indian Point facility. Indian Point Energy Center currently stores over 1,500 tons of spent fuel onsite, either in densely packed pools or in dry casks. This is one of the largest quantities of high level radioactive waste in the northeast. Moreover, the owner and operator of the plant, Entergy Nuclear Indian Point Unit 2, L.L.C. and Entergy Nuclear Indian Point Unit 3, L.L.C. ("Entergy") have applied for a twenty year license extension, which, if granted would result in an approximate 1,000 tons of additional spent fuel being produced and stored onsite, perhaps indefinitely.

The spent fuel pools ("SFPs") storing nuclear waste at Indian Point are vulnerable to environmental degradation and safety/security risks. The Indian Point SFPs have a documented history of leaking radioactive water to the environment. Around 2005, the owners of Indian Point "discovered" that SFP leaks, which began in the 1990s, were still occurring and had resulted in extensive contamination plumes in the groundwater beneath the site. Since this time, Riverkeeper has been actively involved in raising site-specific concerns about the environmental and safety implications of the SFP leakage at Indian Point, as well as more general concerns about the radiological leakage and contamination issues facing nuclear plants across the country and the inadequacy of the Nuclear Regulatory Commission's ("NRC") legal and regulatory framework for addressing such issues. This work, which I have been directly involved in while at Riverkeeper, includes the following:

- Riverkeeper successfully intervened in the Indian Point license renewal proceeding before the NRC, which was initiated in April 2007, and raised an adjudicable issue relating to the sufficiency of the environmental analysis afforded to the "newly discovered" SFP leaks and groundwater contamination occurring at Indian Point. This contention was proffered and accepted for adjudication pursuant to the National

Attachment 3
January 2, 2013

Environmental Policy Act ("NEPA"). While this contention ultimately (and recently) was subject to a settlement, Riverkeeper spent five years preparing to adjudicate this issue, reviewing thousands of Entergy and NRC documents related to the SFP leaks and groundwater contamination at Indian Point, and obtaining expert analyses pertaining to the likelihood of ongoing and future SFP leaks and the environmental consequences of SFP leaks at Indian Point.[1]

- As an intervenor, Riverkeeper raised a legal claim in New York State administrative permit proceedings relating to whether radiological leaks and groundwater contamination at Indian Point result in violations of relevant state requirements and standards. These proceedings are currently pending before the New York State Department of Environmental Conservation ("NYSDEC") and concern Entergy's application for a Water Quality Certification under Section 401 of the Clean Water Act, which was filed in April 2009 in connection with Entergy's Federal License Renewal Application to the NRC. In this proceeding, Riverkeeper once again invested a significant amount of time and obtained expert analyses pertaining to the relevant issues. This issue resulted in adjudicatory hearings and a voluminous record relating to the SFP leaks at Indian Point, the environmental impacts of the leaks to the groundwater and the Hudson River, the inadequacy of Entergy's programs for managing the aging of buried plant components and the likely future radiological leaks from such components, and the applicability of state water quality related standards to radiological leakage and contamination issues, as memorialized in Riverkeeper's post-hearing briefings on the issue.[2]

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[1] *See* 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 29-37, *available at* ADAMS Accession No. ML12335A617 (hereinafter "Riverkeeper Statement of Position Regarding SFP Leaks Contention"); Prefiled Direct Testimony of Arnold Gundersen Regarding Consolidated Contention RK-EC-3/CW-EC-1 (Spent Fuel Pool Leaks) (December 21, 2011), *available at* ADAMS Accession No. ML12340A811; Prefiled Written Testimony of Gillian Stewart on Consolidated Contention RK-EC-3/CW-EC-1 - Spent Fuel Pool Leaks (December 22, 2011), *available at*, ADAMS Accession No. ML12335A586.

[2] In the Matter of a Renewal and Modification of a State Pollutant Discharge Elimination System ("SPDES") Permit Pursuant to Article 17 of the Environmental Conservation Law And Title 6 of the Official Compilation of Codes, Rules and Regulations of the State of New York parts 704 and 750 *et seq.* by Entergy Nuclear Indian Point 2, LLC and Entergy Nuclear Indian Point 3, LLC, Permittee, DEC # 3-5522-00011/00004, SPDES # NY-0004472, and In the Matter of the Application by Entergy Nuclear Indian Point 2, LLC and Entergy Nuclear Indian Point 3, LLC, for a Certificate Pursuant to §401 of the Federal Clean Water Act, DEC # 3-5522-00011/00030, DEC # 3-5522-00011/00031, Post-Hearing Closing Brief of Intervenors Riverkeeper, Natural Resources Defense Council, and Scenic Hudson Regarding Issue for Adjudication No. 3 – Radiological Materials (April 27, 2012), *available at*, http://www.riverkeeper.org/wp-content/uploads/2012/12/2012.04.27.Indian-Point-401-SPDES-Proceedings-Riverkeeper-Closing-Brief-Radiological.pdf; In the Matter of a Renewal and Modification of a State Pollutant Discharge Elimination System ("SPDES") Permit Pursuant to Article 17 of the Environmental Conservation Law And Title 6 of the Official Compilation of Codes, Rules and Regulations of the State of New York parts 704 and 750 *et seq.* by Entergy Nuclear Indian Point 2, LLC and Entergy Nuclear Indian Point 3, LLC, Permittee, DEC # 3-5522-00011/00004, SPDES # NY-0004472, and In the Matter of the Application by Entergy Nuclear Indian Point 2, LLC and Entergy Nuclear Indian Point 3, LLC, for a Certificate Pursuant to §401 of the Federal Clean Water Act, DEC # 3-5522-00011/00030, DEC # 3-5522-00011/00031, Post-Hearing Closing Reply Brief of Intervenors Riverkeeper, Natural Resources Defense Council, and Scenic Hudson Regarding Issue for Adjudication No. 3 – Radiological Materials (October 5, 2012), *available at*, http://www.riverkeeper.org/wp-content/uploads/2012/12/2012.10.05.Indian-Point-401-SPDES-Proceedings-Riverkeeper-Closing-Reply-Brief-Radiological.pdf. There has yet to be a final decision relating to this issue, as the State proceedings to which it is a part of remain ongoing.

- Riverkeeper has been a national stakeholder in NRC task force activities related to radiological leakage and environmental contamination issues occurring at nuclear plants across the country. In particular, in March 2010, NRC convened a team of agency staffers to evaluate actions taken in response to recent incidents of radiological leakage and determine what future actions are necessary.[3] Riverkeeper submitted various sets of comments to inform that iterative process,[4] and I have appeared as a panel member at multiple NRC task-force related meetings and workshops to discuss relevant concerns and recommendations.[5]

- Riverkeeper was consulted and provided feedback to the U.S. Government Accountability Office ("GAO") in relation to GAO's study of leaking underground piping systems at nuclear power plants. GAO's study resulted in the publication of a final report in June 2011.[6]

In addition to the extensive work Riverkeeper has done relating to radiological leakage and contamination issues, Riverkeeper has also been an engaged stakeholder in NRC's waste confidence related proceedings. Due to the high level of concern related to SFP leaks, and the safety and security implications of "temporary" nuclear waste storage at reactor sites, Riverkeeper has been an active voice in NRC proceedings on such matters. In 2009, Riverkeeper submitted comments on NRC's initial proposed "update" to the Waste Confidence Decision and Temporary Storage Rule.[7] Riverkeeper was also a party to the Federal appeal of the NRC's final rule concerning this "update," the outcome of which necessitates the instant EIS process. In addition, Riverkeeper has raised safety issues related to SFP storage and waste-confidence related issues in the Indian Point license renewal proceeding. Riverkeeper initially raised a contention relating to the risk of SFP fires and the inadequacy of Entergy's severe accident mitigation alternatives analysis.[8] This contention was supported by multiple expert analyses.[9] Riverkeeper has also raised a contention relating to the need for site-specific review

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[3] Memorandum to B.S. Mallett (Deputy Executive Director for Reactor and Preparedness Programs), C.A. Casto (Deputy Regional Administrator, Region IV), from R.W. Borchardt (Executive Director for Operations), Subject: Groundwater Contamination Task Force (March 5, 2010), ADAMS Accession No. ML100640188.

[4] *See, e.g.*, Riverkeeper Comments For Senior Management Review of NRC Groundwater Task Force Report, Docket ID NRC-2010-0302 (November 1, 2010), ADAMS Accession No. ML103120555.

[5] *See, e.g.*, Riverkeeper, Inc., Spent Fuel Pool Leaks and Groundwater Contamination at Indian Point, Nuclear Regulatory Commission Public Meeting (April 20, 2010), ADAMS Accession No. ML101320360.

[6] U.S. GAO Report to Congressional Requesters, GAO-11-563, Oversight of Underground Piping Systems Commensurate with Risk, but Proactive Measures Could Help Address Future Leaks (June 2011), *available at*, http://www.gao.gov/assets/320/319322.pdf (hereinafter "June 2011 GAO Report").

[7] Riverkeeper Comments on the Nuclear Regulatory Commission's Waste Confidence Decision Update and Proposed Rule regarding the Consideration of Environmental Impacts of Temporary Storage of Spent Fuel After Cessation of Reactor Operation (February 6, 2009), ADAMS Accession No. ML090410728.

[8] Riverkeeper, Inc.'s Request for Hearing and Petition to Intervene in the License Renewal Proceedings for the Indian Point Nuclear Power Plant (November 30, 2007), at 54-74, ADAMS Accession No. ML073410093.

[9] *See id.* at Contention EC-2 Exhibits (Gordon R. Thompson, *Risk-Related Impacts from Continued Operation of The Indian Point Nuclear Power Plants* (November 28, 2007); Edwin S. Lyman, *A Critique of the Radiological Consequence Assessment Conducted in Support of the Indian Point Severe Accident Mitigation Alternatives Analysis* (November 2007); Edwin S. Lyman, *Chernobyl on the Hudson? The Health and Economic Consequences of a Terrorist Attack at the Indian Point Nuclear Plant* (September 2004)).

of on-site nuclear waste storage during post-operations timeframes in light of the Federal Circuit Court's vacature of the NRC's Waste Confidence Decision.[10]

As a long-time advocate on environmental and safety issues associated with the ever-increasing inventories of spent fuel at Indian Point, I have extensive experience with the relevant issues.

Lastly, I note that as an environmental advocacy organization, Riverkeeper has been and will continue to be an active public stakeholder in NEPA-related processes, including commenting on the appropriate scope of environmental reviews, as well as environmental impact statements.

3. In *New York v. NRC*, 681 F.3d 471, 481 (D.C. Cir. 2012), the court concluded, among other things, that the Commission's analysis of SFP leaks in the stricken Waste Confidence Decision was insufficient. The Court chastised the Commission for relying only on statements about health impacts of past SFP leaks. In particular, the Court explained that (1) such impacts are not the only type that must be assessed, and (2) that a "proper analysis of the risks would necessarily look *forward* to examine the effects of the additional time in storage, as well as examining past leaks."[11] The Court further instructed that NRC cannot rely on existing recommendations for improvements to SFPs that NRC may have addressed or will address at some point; the Court emphasized that an existing monitoring or regulatory compliance program is not sufficient to demonstrate that significant environmental impacts will not occur during extended on-site pool storage period.[12]

In light of these directives, my declaration will address the proper scope of the proposed waste confidence environmental impact statement (the "EIS") as it relates only to assessing impacts of spent fuel pool ("SFP") leaks occurring after the expiration of a plant's operating license. Specifically, my declaration will explain that the EIS must analyze, in depth: (1) the probability of future leaks from SFPs; (2) the consequences of future leaks from SFPs; (3) the cumulative impacts of future leaks from SFPs and non-SFP systems, structures, and components; (4) measures that may mitigate the impacts of SFP leaks; and (5) the impact of decommissioning on SFP leaks.

EIS Must Analyze the *Probability* of Future Leaks from Spent Fuel Pools

4. The NRC's EIS must analyze in-depth the probability that densely packed SFPs at reactor sites will leak toxic radionuclides to the environment following the cessation of plant operations.

a. Even before plants' operating licenses have expired, SPF leaks have occurred across the country.

In light of evidence of already leaking SFPs around the country, which calls into question the current and future integrity of aging SFP structures at nuclear power plants, the NRC must

[10] State of New York, Riverkeeper, Inc., and Hudson River Sloop Clearwater's Joint Contention NYS-39/RK-EC-9/CW-EC-10 Concerning the On-Site Storage of Nuclear Waste at Indian Point (July 8, 2012), ADAMS Accession No. ML12190A002.
[11] *New York v. NRC*, 681 F.3d 471, 481 (D.C. Cir. 2012) (emphasis in original).
[12] *Id.*

conduct an in-depth and site-specific analysis in its EIS of SFP leaks to discern the extent and degree to which SFPs will leak in the future. Indeed, the NRC's previous assertion that "pool storage is a benign environment . . . that does not lead to significant degradation" and that "degradation mechanisms are well understood,"[13] has been called into question by occurrences at multiple sites where SFP structures have leaked (and in some cases, continue to leak) radioactive water into the subsurface.

For example, operators of Indian Point Entergy Center,[14] Brookhaven National Laboratories, Seabrook Station, Point Beach Nuclear Plant, and Salem Nuclear Generating Station have discovered radioactive leaks from SFPs or associated structures.[15] SFPs leaks occurring during the reactors' *initial* licensing terms raise a significant concern that the structural integrity of the SFPs may be compromised in timeframes much shorter than those contemplated in the scenarios proposed for the EIS. Indeed, NRC has implied that improved maintenance of SFPs is needed, notwithstanding the possibility of long-term onsite waste storage.[16] Notably, SFPs located at the existing fleet of U.S. nuclear power plants that have been in use for upwards of, or over, 40 years[17] face a typical "bathtub curve,"[18] i.e., ever-increasing aging issues and a stronger potential for leaks as they continue to operate. The instances of SFP leakage and related reactor operating experience indicate that future leaks of radioactive water from SFPs at currently operating reactors across the country are reasonably likely to occur during the "temporary" storage time period following permanent cessation of operations.

b. *<u>The EIS must analyze in-depth the probability of future SFP leaks in light of the established practices that challenge and prevent full and timely detection of such leaks.</u>*

The need for a detailed analysis of the probability of future SFP leaks is underscored by the marked inability of plant licensees to fully detect current, let alone future, SFP degradation and SFP leaks. The NRC has acknowledged and explained that "[s]ystems or structures can experience undetected radioactive leaks over a prolonged period of time" and that "[s]ystems or structures that are buried or that are in contact with soil, such as SFPs . . . are particularly susceptible to *undetected* leakage."[19] One particular challenge facing SFPs is that the high

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[13] *See, e.g.*, Waste Confidence Decision Update, NRC–2008–0482, 75 Fed. Reg. 81037, 81069 (Dec. 23, 2010).
[14] Radioactive water leaks from the Indian Point Unit 2 SFP remain active and will continue to occur into the indefinite future. For a full explanation of the past and ongoing problem of Indian Point Unit 2 SFP leaks, see Riverkeeper Statement of Position Regarding SFP Leaks Contention, *supra* Note 1.
[15] *See* Liquid Radioactive Release Lessons Learned Task Force Final Report, September 1, 2006, at 3-10, *available at*, ADAMS Accession No. ML062650312 (hereinafter "NRC 2006 Radioactive Release Lessons Learned Report").
[16] *Id.* at 26.
[17] The current fleet of U.S. nuclear reactors began operating decades ago and the majority of reactors have already received extended operating licenses and have, thus, been operating for over 40 years now; most of the remaining reactors are approaching the end of their initial 40 year operating licenses and are currently seeking or will soon seek extended operating licenses. *See generally* http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html (last visited December 13, 2012).
[18] A "bathtub curve" is defined as "the phenomenon that the fraction of products failing in a given timespan is usually high early in the lifecycle, low in the middle, and rising strongly towards the end. When plotted as a curve, this looks like the profile of a bathtub." WordIQ.com, Bathtub curve – Definition, http://www.wordiq.com/definition/Bathtub_curve (last visited Dec. 13, 2012).
[19] *See* NRC 2006 Radioactive Release Lessons Learned Report at 26, *supra* Note 15 (emphasis added).

density of spent nuclear fuel they contain has made it impossible to conduct complete physical inspections of the pools that would detect ongoing leaks and degraded conditions that could lead to future leaks. For example, at Indian Point, approximately 40% of the Indian Point 2 SFP liner, which has a history of leakage, has never been inspected as a result of the densely packed spent fuel that makes large portions of the pool inaccessible for inspection; the plant owner has no plans to complete any comprehensive inspections of the degraded SFP liner.[20] Indeed, it is unlikely that nuclear power plant licensees with sites that have a history of SFP leakage, let alone those with currently non-leaking SFPs, will voluntarily undertake periodic SFP inspections, or other proactive, preventative measures to timely avoid or stop future SFP leaks, in the absence of regulatory requirements that would mandate such inspections and a process for safely moving spent fuel in order to conduct them.

In addition, existing "tell tale" leak detection systems at some SFPs are not designed to detect slow, long term leaks that could result in extensive environmental contamination over time. In fact, the Indian Point 2 SFP was not built with a leak detection system at all.[21]

Such circumstances are exacerbated by the fact that, as NRC has explained, "SFP performance deficiencies are not specifically addressed in the NRC inspection program significance determination process."[22] Moreover, NRC has allowed nuclear power plant operators to rely upon a *voluntary* initiative to address accidental radiological leaks, which relies entirely upon voluntary monitoring of groundwater in order to detect radiological leaks from SFPs, as well as all other plant systems, structures, or components.[23] NRC's ongoing refusal to incorporate *mandatory* groundwater testing requirements into its regulations[24] is problematic and increases the likelihood that radiological SFP leaks may occur undetected. In any event, sole reliance on after-the-fact groundwater monitoring all-but ensures that some SFP leaks that do occur will not be discovered until after radioactive water has leached into the environment, groundwater, or surface waters.[25] Based on the foregoing, it is, and will continue to be, difficult for licensees to predict and detect degradation of SFPs and future radiological leaks that occur as a result of such

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[20] *See* Riverkeeper Statement of Position Regarding SFP Leaks Contention, *supra* Note 1; U.S. Nuclear Regulatory Commission, Safety Evaluation Report Related to the License Renewal of Indian Point Nuclear Generating Unit Nos. 2 and 3, Docket Nos. 50-247 and 50-286 (November 2009), at 3-134, 3-139, *accessible at*, http://www.nrc.gov/reading-rm/adams/web-based.html, NRC ADAMS Accession No. ML093170671.
[21] Entergy, Problem Development Sheet – Groundwater (NRC Official Hearing Exhibit, Entergy Nuclear Operations, Inc. (Indian Point Nuclear Generating Units 2 and 3), ASLBP #: 07-858-03-LR-BD01, Docket #: 05000247, 05000286, Exhibit # RIV000074-00-BD01), *available at*, ADAMS Accession No. ML12335A601.
[22] NRC 2006 Radioactive Release Lessons Learned Report at 26, *supra* Note 15; *see* also *Regulatory Roulette: The NRC's Inconsistent Oversight of Radioactive Releases from Nuclear Power Plants,* Dave Lochbaum, Union of Concerned Scientists, September 2010, available at http://www.ucsusa.org/assets/documents/nuclear_power/nuclear-power-radioactive-releases.pdf (last accessed December 21, 2012).
[23] *See* 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 (hereinafter "SECY-11-0019").
[24] *See* NRC 2006 Radioactive Release Lessons Learned Report at iii, 33, *supra* Note 15; SECY-11-0019 at 3, *supra* Note 23.
[25] For example, evidence gleaned in the context of the Indian Point license renewal proceeding reveals numerous instances of radiological leaks that were detected by an "established" groundwater monitoring system months or years after initial radiological leakage began, and demonstrates the inadequacy of such monitoring. *See, e.g.*, Riverkeeper Statement of Position Regarding SFP Leaks Contention at 34, 36, *supra* Note 1.

degradation. The difficulties present in detecting SFP leaks makes a comprehensive assessment of the likelihood of such future leaks critically important: the EIS must fully analyze the probability of future SFP leaks in light of the established lack of regulatory requirements and industry practices that make full and timely detection of such leaks extremely unlikely. Given the regulatory history, this lack of requirements will ostensibly continue during the time period following permanent cessation of operations.

c. *The EIS must analyze in-depth and consider the likelihood of SPF leaks and releases resulting from human error.*

In addition to SFP leaks resulting from pool degradation and unforeseen structural problems, consideration of the extent to which SFPs will leak in the future must also fully take into account the likelihood of leaks and releases resulting from human error in operations relating to on-site nuclear waste. Numerous such radiological releases have already occurred.[26] Such instances have involved plant personnel not properly following procedures, not adequately monitoring, and not properly operating plant equipment.[27] Increased on-site storage of spent fuel in pools for many years after the expiration of the plant's licenses[28] patently increases the opportunity for human error resulting in unauthorized releases from SFPs. Such circumstances must be appropriately and adequately accounted for in the context of determining the probability of future SFP leaks.

d. *In analyzing SPF leaks, the EIS must take into account site-specific factors.*

Notably, determining the probability of future SFP leaks necessitates a consideration of site-specific factors. To begin with, special consideration must be afforded to SFPs that have already leaked. With respect to any known incidents of SFP 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 SFPs. For example, at Indian Point, the history of SFP leakage, (including the facts that the Unit 2 SFP is still actively leaking), makes it reasonably likely that the Unit 2 SFP will continue to leak in the future.

In addition, other site-specific factors must be considered in order to assess the probability of future SFP leaks at nuclear power plants. These include the impact of natural disasters (i.e., earthquakes, hurricanes, floods, etc.) on the integrity of SFPs, and the probability that any such events may create or exacerbate existing SFP degradation and leaks. Such impacts must take into account current information regarding seismicity in regions where nuclear power plants are located,[29] as well as the most current scientific knowledge regarding sea level rise and other

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[26] NRC 2006 Radioactive Release Lessons Learned Report at 34, *supra* Note 15.
[27] *Id.*
[28] For the appropriate time frame NRC should use in evaluating the impacts of long-term onsite storage of spent nuclear fuel, *see generally*, Makhijani Declaration at Sections 3 and 4 and Thompson Declaration at Sections V and VI.
[29] 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 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

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.[30] 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.[31]

e. *Conclusion: NRC must undertake a comprehensive, in-depth assessment, with due consideration of site-specific factors, of the probability of SFP leaks during post-operation on-site storage of spent nuclear fuel.*

In sum, NRC must undertake a comprehensive assessment, with due consideration of site-specific factors, of the probability of SFP leaks during post-operation on-site storage of spent nuclear fuel.[32] In accordance with the Court of Appeal's decision, NRC must speak fully to "whether and how future leaks might occur."[33] NRC cannot simply rely on the findings or outcomes of its groundwater task force initiative relating to alleged "improvements" to SFPs or otherwise. For example, a monitoring and regulatory compliance program is *not* "a buffer against pool degradation," and NRC cannot conclude that "leaks will not occur because the NRC is 'on duty.'"[34] Any alleged assurances from NRC regarding the low likelihood of future SFP leaks or assurances that the eventuality of such leaks is "under control," are not substitutes for the full analysis that is required, as detailed above.

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.

[30] *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).

[31] For additional information regarding the necessity of site-specific review, *see*, Makhijani Declaration at Section 9.

[32] For the appropriate time frame NRC should use in evaluating the impacts of long-term onsite storage of spent nuclear fuel, *see generally*, Makhijani Declaration at Sections 3 and 4 and Thompson Declaration at Sections V and VI.

[33] *New York v. NRC*, 681 F.3d 471, 481 (D.C. Cir. 2012).

[34] *Id.*

EIS Must Analyze In-Depth the *Consequences* of Future Leaks from Spent Fuel Pools

5. The EIS must analyze the full range of potential consequences stemming from the probability that densely packed SFPs at reactor sites will leak toxic radionuclides to the environment after the cessation of plant operations.

As an initial matter, NRC's previous "approach" relating to assessing the impact of accidental radiological leaks from nuclear power plants cannot be relied upon or deferred to in lieu of the required full analysis.[35] In the past, NRC presumptively categorized inadvertent radiological leaks as "low risk" events that had no public health and safety significance.[36] Thus, the inquiry has historically focused upon whether or not such radioactive releases "stay below NRC dose limits."[37] This is an inappropriate baseline from which to analyze all relevant consequences of future SFP leaks. To begin with, as the Court of Appeals explained, "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 environment impact during the extended storage period."[38] Indeed, "near-term health effects are not the only type of environmental impacts."[39] Moreover, the Court made eminently clear that NRC cannot make assumptions regarding the significance and impact of future SFP leaks based on conclusions about the harm of past leaks.[40] That is, NRC cannot simply assume and conclude that all contamination resulting from future incidents of SFP leakage will only present a low risk to public health and safety, and thereby, end the inquiry.

Instead, there are numerous considerations that must be taken into account in the EIS to determine all potential environmental impacts of future SFP leaks, including, but not limited to, the following:

a. Consequences of Radiological SFP Leaks to Groundwater Resources

The EIS must analyze in-depth the extent to which future SFP leaks will result in the contamination of groundwater resources, including groundwater that directly underlies reactor sites. In order to evaluate the significance of any groundwater contamination resulting from future SFP leaks, the EIS must properly frame and categorize the significance of contamination that may occur. In particular, NRC should not only assess potential groundwater contamination

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[35] *See generally id.*

[36] *See* SECY-11-0019 at Enclosure 2, page 5, *supra* Note 23 ("leaks have been of low significance with respect to public health and safety and the environment."); U.S. NRC Groundwater Task Force Final Report, June 2010, ADAMS Accession No. ML101680435, at 5 ("The low risk to public health and safety from these incidents . . . ."); Notice of Public Meeting, *Evaluation of the Groundwater Task Force Report, Public Meeting,* Nuclear Regulatory Commission, NRC-2010--0302, 75 Fed. Reg. 57987, 57989 (Sept. 23, 2010) (categorizing radioactive water leaks from nuclear power plants as "low risk, high public interest/confidence" events).

[37] *See* SECY-11-0019 at Enclosure 2, page 5, *supra* Note 23 ("Historically, the focus of the NRC's regulatory requirements has been to ensure that radioactive releases—including unintended leaks and spills—stay below NRC dose limits and design objectives, within the effluent limits that are approved for the plant.").

[38] *New York v. NRC*, 681 F.3d 471, 481 (D.C. Cir. 2012).

[39] *Id.*

[40] *Id.* ("the harm from past leaks—without more—tells us very little about . . . the harm such leaks might portend"; "we cannot reconcile a finding that past leaks have been harmless with a conclusion that future leaks at all sites will be harmless as well"; "That past leaks have not been harmful with respect to groundwater does not speak to . . . what the effects of those [future] leaks might be.").

in terms of NRC human dose exposure limits and potential impacts to public health. Rather, in order to determine the severity and significance of groundwater contamination, NRC must also take into account broader considerations, including, but not necessarily limited to, the following:

- NRC must consider whether and the extent to which radiological groundwater contamination results in violations of applicable state water quality standards adopted pursuant to the Clean Water Act ("CWA") or state environmental protection laws. This includes designated best usages of state groundwaters,[41] and any other established groundwater standards.

- NRC must consider the degree to which radiological groundwater contamination "threatens a violation of Federal, State, or local law or requirements."[42]

- NRC must consider the toxicity and characteristics of the radionuclides present in the groundwater, given the fact that future SFP leaks will result in ongoing groundwater impacts. That is, the EIS should assess how long-lived and persistent the radionuclides involved will be, and typical characteristics of differing radionuclides that may leak from SFPs. For example, the EIS must recognize and consider the relative half-lives of relevant radionuclides (for example, strontium-90 has a half-life of about 30 years and, thus, any plumes containing strontium may persist for upwards or over 300 years),[43] and the behavior of different radionuclides in the environment (for example, strontium-90 and cesium-137 adsorb to solid structures and partition in and out of groundwater and can therefore result in persistent and unpredictable legacy contamination).[44]

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[41] 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.

[42] 40 C.F.R. § 1508.27(b); 10 C.F.R. § 51.71(d).

[43] *See, e.g.*, U.S. EPA, Strontium, http://www.epa.gov/rpdweb00/radionuclides/strontium.html (last visited December 17, 2012).

[44] In the Matter of: Entergy Nuclear Indian Point 2, LLC, and Entergy Indian Point 3, LLC, For a State Pollution Discharge Elimination System Permit Renewal and Modification, DEC No.: 3-5522-00011/00004, SPDES No.: NY-0004472; Entergy Nuclear Indian Point 2, LLC, Entergy Nuclear Indian Point 3, LLC, and Entergy Nuclear Operations, Inc. Joint Application for CWA § 401 Water Quality Certification, DEC App. Nos. 3-5522-00011/00030 (IP2), 3-5522-00105/00031, Transcript ("Tr.") of Arbitration before Daniel P. O'Connell, ALJ, Maria E. Villa, ALJ, Reporter: Alan H. Brock, RDR, CRR, Farmer Arsenault Brock LLC (January 23, 2012, pages 3895-4125), at 3973:20-22 (Entergy Witness Barvenik Cross by Riverkeeper), Tr. 3975:5-11, 22-23, 3976:1-3, 7-12 (Entergy Witness Barvenik Cross by Riverkeeper) (Entergy witness explaining that partitioning relates to when radionuclides collect on the surface of "solid surfaces . . . natural or anthropogenic," such as "concrete foundations" or "the surface of pipes."). *See also* GeoEnvironmental, Inc. Hydrogeologic Site Investigation Report, Indian Point Energy Center (January 7, 2008), at 113 (Report commissioned by Entergy and explaining that, "[f]rom a contaminant plume perspective, these historic releases [those from the Unit 1 SFPs] still represent an ongoing legacy source of strontium in the groundwater to the south side of Unit 1. This is because strontium partitions from the water phase and adsorbs to solid materials, including subsurface soil and bedrock. The strontium previously adsorbed to these subsurface materials then partitions back to and continues to contaminate the groundwater over time, even after the storm drain releases have been terminated").

- NRC must consider the degree to which levels of radionuclides in any designated drinking water source exceed U.S. Environmental Protection Agency ("EPA") Maximum Contaminant Levels ("MCLs").[45] NRC should also consider EPA MCL standards even when groundwater is not used or designated for potable purposes because these standards constitute a recognized, highly conservative benchmark to assess the degree and severity of radioactive contamination. Indeed, NRC and plant owners who have commented upon groundwater contamination resulting from accidental radiological leaks have commonly cited to EPA MCLs in their analyses of such leaks to put the degree of leakage and contamination in context.[46]

- NRC must 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 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;
    - how external circumstances, including severe weather events and earthquakes, may affect the behavior, fate, and effect of radiological contamination plumes resulting from future SFP leaks. New information about local effects of such external circumstances, as discussed above, must be fully evaluated on a site-specific basis; and
    - the potential size of any groundwater contamination plumes. The EIS must give due consideration to the fact that future SFP leaks may occur for long periods of time undetected, and that such leaks will not be discovered until after they have caused measureable and sizeable impacts to the groundwater; this is as a result of the marked inability of licensees/ operators to detect future leaks and their reliance on *voluntary*, and not mandatory, groundwater monitoring, as discussed above.

- NRC must consider the degree to which radiological groundwater contamination is "likely to be highly controversial."[47] Radioactive contamination of any degree is

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[45] EPA's MCLs have been established for radionuclides in drinking water. EPA regulations implementing the Safe Drinking Water Act provide that "[t]he average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water must not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year (mrem/year)." 40 C.F.R. § 141.66(d). This dose converts to a maximum limit of radionuclides in water in terms of picocuries per liter (pCi/l), for particular radionuclides. *See* 40 C.F.R. § 141.66(d) (Table A); *See also* U.S. EPA, Radionuclides in Drinking Water: A Small Entity Compliance Guide (February 2002), *available at*, http://www.epa.gov/ogwdw/radionuclides/pdfs/guide_radionuclides_smallsystems_compliance.pdf, at 13.

[46] *See e.g.*, Indian Point Nuclear Generating Unit 2 – NRC Special Inspection Report No. 05000247/2005011, March 16, 2006 at 3, A1-3, A1-7, ADAMS Accession No. ML12335A615.

[47] 40 C.F.R. § 1508.27(b); 10 C.F.R. § 51.71(d).

inherently controversial and more so when it is occurring unseen and undetected for long periods of time, which may be the case in relation to future SFP leaks. Notably, inaccurate portrayals of the degree of groundwater contamination (i.e., presumptive categorization of contamination as "low-risk") is misleading, degrades public confidence, inhibits the public's ability to fully understand the relevant issues, and serves to exacerbate public concern and fear.

In sum, NRC must undertake an in-depth review of potential impacts of future SFP leaks on groundwater resources. NRC cannot presumptively or summarily determine that future levels of radiological groundwater contamination will be "low" and end the inquiry by portraying any such contamination as having "negligible" public health impacts. Such conclusions remain unsupported in light of the dearth of analysis concerning future SFP leaks, and entirely ignore the full range of relevant considerations relating to the potential impacts and significance of radiological groundwater contamination.

b. Consequences of Radiological SFP Leaks to Surface Water Resources

The EIS must fully consider the extent to which future SFP leaks will result in the contamination of surface water resources. Once again, the NRC must properly frame and evaluate the significance of any contamination affecting nearby surface water resources. That is, NRC cannot limit its analysis to determining only whether contamination will comply with NRC-calculated dose exposure limits. A broader array of considerations is necessary to determine the full range of potential impacts to surface waters that may occur as a result of SFP leaks during post-operation onsite storage. These considerations include, but are not limited to, the following:

- NRC must fully analyze the extent to which future SFP leaks will contaminate surface waters and the potential impact of such contamination on the aquatic ecology of such waters. The EIS must consider the length of time surface waters will be contaminated by, and thus, aquatic ecology exposed to, radiological contamination (again with due consideration for the fact that SFP leaks may occur for long periods of time undetected, as discussed above) 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.[48] Rather, NRC must fully evaluate the potential future impacts to aquatic organisms from SFP leaks.

- NRC must consider the degree to which radiological contamination of surface waters "threatens a violation of Federal, State, or local law or requirements."[49] In particular,

[48] *New York v. NRC*, 681 F.3d 471, 481 (D.C. Cir. 2012).
[49] 40 C.F.R. § 1508.27(b); 10 C.F.R. § 51.71(d).

the EIS must consider whether and the extent to which radiological contamination of surface waters results in violations of applicable state water quality standards adopted pursuant to the CWA or state environmental protection laws. This includes any prohibitions and limitations on the discharge of radiological materials to State surface waters,[50] designated best usages of surface waters, and other established surface water standards. For example, it is common for designated best usages established pursuant to the CWA to include recreational activities such as swimming, fishing, boating, etc.[51] 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.[52]

- NRC must fully analyze the potential impact of future SFP leaks on existing or reasonably foreseeable drinking water sources stemming from surface water resources.[53] In this regard, NRC should consider whether future leaks may result in violations of EPA MCLs, as discussed above. NRC should also examine the potential long-term impacts from low-level exposure to SFP leaks, in light of the conclusions of the Biological Effects of Ionizing Radiation VII report.[54]

- NRC must consider site-specific factors as they bear upon the likely impacts of radiological contamination resulting from future SFP leaks on surface waters, including:

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[50] 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).

[51] For example, 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 substance 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.

[52] 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.

[53] For example, the upstream portions of the Hudson River, a surface water estuary that flows both ways and is adjacent to the Indian Point nuclear power plant, is already a source of drinking water to local residents. In addition, a current proposal for an additional drinking water intake from the Hudson River exists in which a desalination plant would be sited on the banks of the Hudson River within 3 miles of the Indian Point facility. *See* generally, Haverstraw Water Supply Project, http://haverstrawwatersupplyproject.com/index.php/ (last visited December 13, 2012).

[54] 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 (concluding that every exposure to radiation, regardless of how small, and no matter what pathway, produces a corresponding increase in the likelihood of cancer; 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).

- 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. This is necessarily a site-specific factor, as surface waterways adjacent to nuclear plants, and the ecologies contained therein, vary;
- the relevant status of the aquatic ecology in a given waterway in the absence of additional impacts due to nuclear power plant SFP leaks. That is, due consideration must be afforded to existing circumstances present in affected waterways, such as stressed fish populations[55];
- the degree to which already existing radiological contamination of surface waters resulting from prior SFP leaks may affect the level and degree of exposure to future SFP leaks;
- how external circumstances, including severe weather events and earthquakes, may affect the behavior, fate, and effect of radiological contamination in surface waters resulting from future SFP leaks. New information about local effects of such external circumstances, as discussed above, must be fully evaluated on a site-specific basis.

In sum, NRC must undertake an encompassing, in-depth review of potential impacts of future SFP leaks on surface water resources. As with prospective groundwater impacts, NRC cannot summarily conclude that future impacts on surface waters will be "low" and end the inquiry by portraying any such contamination as having "negligible" public health impacts. Once again, such conclusions remain unclear in light of the dearth of analysis concerning future SFP leaks, and entirely ignore the full range of relevant considerations relating to the potential impacts and significance of radiological surface water contamination.

c. *Long-Term Public Health Consequences of Radiological SFP Leaks to the Offsite Environment*

In addition to a full assessment of environmental impacts of future SFP leaks on groundwater and surface water resources, the NRC should also undertake a forward-looking, in-depth assessment of the potential total maximum radiological exposure to the public resulting from future SFP leaks. NRC has explained that it "lacks regulatory guidance for monitoring and evaluating both the immediate and *long-term* offsite dose or environmental impact of [] inadvertent releases."[56] Similarly, the Court of Appeals chastised the NRC for failing to look ahead and undertake any assessment of "the effect of the *additional* time in [pool] storage"

[55] 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, 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.

[56] NRC 2006 Radioactive Release Lessons Learned Report at 13, *supra* Note 15 (emphasis added).

contemplated by the Waste Confidence rule, and potential *future* harm to the public.[57] Thus, NRC's EIS must include a comprehensive evaluation of the risks to public health posed by potential *future* SFP leaks and *long-term* exposure to such leaks. In this regard, NRC should examine the long-term impacts from low-level exposure to SFP leaks in light of the conclusions of the Biological Effects of Ionizing Radiation VII report.[58]

EIS Must Analyze In-Depth the Probability and Consequences of the *Cumulative* Environmental Impacts of SPF Leaks and Past, Present, and Future Radiological Leaks from non-SFP Systems, Structures, and Components

6. In order to accurately discern, and portray a realistic picture of, the probable impacts of future SFP leaks, NRC's EIS must consider cumulative environmental effects. 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*."[59] Indeed, a critical aspect of any environmental review conducted pursuant to NEPA is the consideration of "the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions."[60] This is because cumulative impacts "can result from individually minor but collectively significant actions taking place over a period of time."[61] 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.[62] In other words, the agency "cannot treat the identified environmental concern in a vacuum."[63]

In relation to SFP leaks, NRC must fully analyze the cumulative impacts resulting from past, present, and reasonably foreseeable future radiological leaks from non-SFP systems, structures, and components.[64] Such non-SFP leaking plant components at facilities around the country have

[57] *New York v. NRC*, 681 F.3d 471, 481 (D.C. Cir. 2012) (emphasis added).
[58] *See supra* Note 54.
[59] *New York v. NRC*, 681 F.3d 471, 481 (D.C. Cir. 2012) (first emphasis in original; second emphasis added).
[60] *See* 40 C.F.R. § 1508.7,10 C.F.R. §51.45(c); *see also* 10 C.F.R. § 51.75, 10 C.F.R. § 51.45.
[61] *See* 40 C.F.R. § 1508.7
[62] *See Grand Canyon Trust v. FAA*, 290 F.3d 339, 345-46 (D.C. Cir. 2002).
[63] *Id.* at 346.
[64] 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 "[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 EIS.

already contaminated on-site and off-site groundwater and public waterways.[65] As of June 2011, NRC reported that 42 of 65 reactor sites, i.e., 65%, have experienced problems with radiological leaks.[66] 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 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.[67]

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."[68] 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."[69] 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.[70] The NRC must consider and account for this in its EIS.

In addition, accidental spills and releases caused by human error have also resulted in releases of radioactivity to the environment at nuclear power plants.[71] Such incidents will likely continue to occur, and NRC must consider cumulative impacts that may result from such accidental spills and releases.

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[65] *See generally* NRC 2006 Radioactive Release Lessons Learned Report, *supra* Note 15; *see also* Riverkeeper Statement of Position Regarding SFP Leaks Contention at 41-43, *supra* Note 1 (describing various non-SFP component leaks that have occurred at Indian Point).

[66] *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).

[67] *See supra*, Note 18.

[68] June 2011 GAO Report at 22, *supra*, Note 6 (emphasis added).

[69] *Id.* at 1.

[70] 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 # 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).

[71] NRC 2006 Radioactive Release Lessons Learned Report at 34, *supra* Note 15; Riverkeeper Statement of Position Regarding SFP Leaks Contention at 42, 53, *supra* Note 1; 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).

In sum, it is reasonably foreseeable that non-SFP components will continue to contaminate the environment around U.S. nuclear power plants during periods of initial and/or extended operations, and during post-operation timeframes, and thereby result in cumulative impacts. Such other radiological leakage issues have already resulted in cumulative impacts.[72]

Thus, NRC must analyze the cumulative impacts of SFP and non-SFP leaks.[73] In its analysis, NRC should consider the potential impacts to groundwater resources, surface water resources, and public health, in the manner discussed in detail above.

EIS Must Analyze In-Depth All Relevant Measures to Mitigate Adverse Environmental Consequences of Future SFP Leaks and Resulting Contamination

7. The EIS must include a comprehensive assessment of all relevant measures that may mitigate adverse environmental consequences of future SFP leaks and any contamination of the environment resulting therefrom. Indeed, 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."[74] Without such a discussion, it is patent that the agency has failed to take the requisite "hard look" at the environmental consequences of a proposed action.[75] Regulations implementing NEPA are likewise instructive. In particular, federal regulations require that reviewing agencies consider and assess mitigation measures in an EIS.[76] These regulations define mitigation as:

> (a) Avoiding the impact altogether by not taking a certain action or parts of an action.

[72] For example, at Indian Point, SFP leaks have resulted in extensive contamination plumes that underlie the facility and leach to the Hudson River; numerous leaks from non-SFP structures and components have resulted in cumulative impact by contributing to the existing contamination and preventing the contamination plumes from abating. *See* Riverkeeper Statement of Position Regarding SFP Leaks Contention at 41-43, 53-54, *supra* Note 1; Riverkeeper and Hudson River Sloop Clearwater Revised Statement of Position Regarding Consolidated Contention RK-EC-3/CW-EC-1 (Spent Fuel Pool Leaks) (July 13, 2012), at 18-23, *available at* ADAMS Accession No. ML12195A343; GZA IPEC Quarter 2 Groundwater Report at pp.1-2, 1-3.

[73] Notably, the cumulative impact assessment described should, of course, also consider the cumulative impacts resulting from probable SFP leaks that may occur while reactors are still operating.

[74] *Robertson v. Methow Valley Citizens Council,* 490 U.S. 332, 351-52 (1989) (citations omitted) ("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 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.")

[75] *See id.*

[76] 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").

(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.[77]

Various feasible measures are available that would 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:

- *Immediate clean-up activities associated with groundwater contamination resulting from SFP leakage*. 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. A complete analysis will necessarily require consideration of site-specific factors. NRC must analyze the relative advantages and disadvantages of relevant clean-up measures, taking into account what may be known about the feasibility of given measures at particular reactor sites. 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 licensee's may have (or have not) already taken in response to previous radiological leakage and groundwater 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. To the best of my knowledge, NRC currently has no plans to impose any such mandatory requirements, but instead continues to rely on a purely voluntary industry program.[78] The benefits of mandatory monitoring are patent. Mandatory, as opposed to voluntary, monitoring can clearly assist in minimizing the impacts of potential future SFP leaks, and, therefore, must be fully considered in the EIS.

- *Preventative measures to proactively find SFP leaks before they occur and cause measureable environmental impacts*. As discussed above, the degree to which

[77] 40 C.F.R. §§ 1508.20.
[78] SECY-11-0019 at 3-4, *supra* Note 23.

licensees are currently committed to, or will be required to, inspect SFPs is unclear at best. NRC must assess the feasibility and efficacy of regular inspections of SFPs while plants continue to operate and 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 future 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, as discussed above, 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 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 analytes to ensure detection of particular radionuclides. Site-specific considerations will necessarily be relevant to NRC's assessment.

- *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. Indeed, an assessment of the significance of an environmental impact includes the degree to which it is highly controversial.[79] To the extent SFP leaks may be considered controversial,[80] 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.

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.[81] 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.

EIS Must Analyze In-Depth the Impact of Decommissioning Activities on SFP Leaks and Contamination that Occurs as a Result

8. NRC must assess the extent to which all of the matters discussed above, including the probability and environmental consequences of SFP 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

[79] 40 C.F.R. § 1508.27(b).
[80] For example, since leaks at Indian Point were "discovered," there has been a high level of public concern, which continues today. *See* NRC 2006 Radioactive Release Lessons Learned Report at ii, *supra* Note 15.
[81] *See Robertson v. Methow Valley Citizens Council,* 490 U.S. 332, 351-52 (1989).

decommissioning; and (3) the extent to which decommissioning actions are relevant to the consideration of potential mitigation measures.

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

Phillip Musegaas, Esq.
January 2, 2013

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

I. INTRODUCTION

As provided by the U.S. Nuclear Regulatory Commission's ("NRC's") press release of January 3, 2012, Blue Ridge Environmental Defense League ("BREDL"), the Institute for Energy and Environmental Research ("IEER"), Natural Resources Defense Council ("NRDC"), Riverkeeper, and Southern Alliance for Clean Energy ("SACE") hereby submit comments on the NRC's draft report, *Background and Preliminary Assumptions for an Environmental Impact Statement – Long-Term Waste Confidence Update* (December 2011) ("Draft Report"). The Draft Report should be withdrawn because the assumptions it proposes are inconsistent with the National Environmental Policy Act ("NEPA") and NRC regulations. In addition, by indicating that the NRC plans to prepare an EIS that discusses the environmental impacts of long-term SNF disposal without also discussing the impacts of SNF disposal in a repository and the impacts that may occur if SNF disposal is never achieved, the NRC unlawfully segments the environmental analysis for SNF disposal. Finally, the NRC's decision to issue the Draft Report without publishing a notice in the Federal Register is inconsistent with the NRC's open government policy and long-established practice.

II. DESCRIPTION OF COMMENTERS

BREDL, NRDC, Riverkeeper, and SACE are public interest environmental organizations whose members include neighbors of nuclear reactors, nuclear factories, and nuclear waste storage and disposal facilities. They submitted comments on the related Waste Confidence Decision ("WCD") and Waste Confidence Rule ("WCR") that were published in the Federal Register on December 23, 2010. 75 Fed. Reg. 81,032, 81,037. They are also parties to a lawsuit challenging the Waste Confidence Decision and Waste Confidence Rule in the D.C. Circuit, *State of New York v. NRC*, D.C. Cir. No. 11-1045 (consolidated with D.C. Cir. Nos. 11-1051, 11-1056, 11-1057.

IEER is a nonprofit organization that provides policymakers, journalists and the public with understandable and accurate scientific and technical information on energy and environmental issues. IEER commented on the WCD and WCR and also provided expert support for comments filed by BREDL, Riverkeeper, and SACE.

III. FACTUAL BACKGROUND

In the 2010 WCD, the NRC declared that it intends to "update" the WCD and WCR by analyzing, in an environmental impact statement ("EIS"), the effects of storing SNF from U.S. nuclear reactors for as long as 200 years. WCD, 75 Fed. Reg. at 81,040. On January 3, 2012, the NRC issued a press release regarding this proposal (PR No. 12-001) and attached the Draft Report for comment. According to the Press Release, the Draft Report:

> discusses several storage scenarios, including at nuclear power plants, regional or centralized storage sites or a combination of storage and reprocessing of spent fuel. A key assumption is that extended storage would be managed under a regulatory program similar to current regulation of spent fuel. To analyze the impacts associated with the scenarios, the staff will develop generic, composite sites for each scenario, and these sites will account of a range of characteristics of actual reactor and storage sites.

Id.

While the WCD and the Press Release state that the length of SNF storage time to be analyzed in the EIS is 200 years, the Draft Report itself states that the time period is 300 years: the new time period would be added on to the 100 years that SNF from the oldest reactors will have been in storage:

> The staff plans to develop the EIS to analyze impacts of storage from approximately the middle of this century for a period of 200 years. The staff selected mid-century as the starting point for the impacts analysis because it represents the time when some spent fuel will begin to reach the minimum storage periods accounted for in the current Waste Confidence rule (60 years after the expiration of licensed life). In other words, the oldest spent fuel will have been stored for about 100 years by the middle of the century. *The staff selected a 200-year span for the EIS because that is approximately when this oldest fuel will approach 300 years of storage.* The 200-year period is the timeframe being used by NRC and others in technical analyses to identify spent fuel aging issues.

Id. at 6 (emphasis added).

As part of the NRC's preliminary process for scoping for long-term SNF storage for periods up to 300 years, the Draft Report proposes a series of assumptions regarding the circumstances under which spent nuclear reactor fuel ("SNF") may be stored for an extended period of time that lasts as long as 300 years. These circumstances include the nature of future nuclear reactor operations, the length of time that active institutional controls and regulatory oversight will be maintained, and other aspects of SNF storage, transportation, and handling. The assumptions proposed by the NRC in the Draft Report will "define the scope of the EIS and preliminary scenarios for analysis." *Id.* at 9.

IV. DISCUSSION

A. NRC Should Publish the Draft Report in the Federal Register

As a preliminary matter, the NRC's process for seeking public input on the proposed assumptions for the EIS on long-term SNF disposal is inadequate. Given the enormous safety and environmental significance of the Draft Report's subject matter of long-term SNF storage and given its purpose and effect of defining the scope of the NRC's proposed EIS for long-term

SNF storage, the Draft Report should have been published for public comment in the Federal Register. The NRC's decision to use only a press release to notify the public of its proposed assumptions is inconsistent with its long-established practice of publishing even "preliminary" rulemaking notices. *See, e.g.*, Final Rule, Licensing Requirements for Land Disposal of Radioactive Wastes, 47 Fed. Reg. 57,446 (Dec. 27, 1982) (discussing previous publication of both a proposed rule and a "preliminary draft regulation"). The use of a press release to notify the public about the NRC's proposed assumptions is also inconsistent with the Commission's stated commitment to openness in decision-making. *See* NRC Strategic Plan for FY 2008-2013 at 16 (as part of NRC's commitment to "appropriately inform[] and involve[] stakeholders in the regulatory process," copies of "key documents and notifications" are "published in the Federal Register" in addition to being "made available electronically on the NRC Web site.") http://www.nrc.gov/public-involve/open/philosophy.html

The Draft Report clearly constitutes a "key document" with respect to the preparation of an EIS on long-term SNF storage impacts. Therefore, in order to ensure that the report reaches a broad enough audience, the NRC should withdraw the Draft Report and re-publish it for comment in the Federal Register.

B. The Scope of the EIS Should Include SNF Disposal in Addition to SNF Storage and Should be Integrated into Reactor Licensing Decisions.

By restricting the proposed scope of the EIS to the impacts of long-term SNF storage, the NRC segments the environmental analysis of nuclear reactor operation, in violation of NEPA. The NRC may not consider a segment of a project separately where it will result in the irreversible or irretrievable commitments to the remaining segment of a project. *United States Dept. of Energy, Project Management Corp., Tennessee Valley Authority* (Clinch River Breeder Reactor Plant), CLI-82-23, 16 NRC 412, 424 (1982). Here, the long-term above-ground storage is a risky response to the failure of the proposed Yucca Mt. project as a SNF repository and the lack of any other viable disposal options on the horizon. The NRC's proposal to store SNF for 200-300 years must be acknowledged as a measure of last resort to compensate for the federal government's failure to site a SNF repository, and the uncertainties and costs of the combined failure of repository siting and resort to long-term SNF must be integrated into the cost-benefit analyses for reactor licensing decisions.

C. The Draft Report's Key Assumption Regarding the Longevity of Institutional Controls is Inconsistent with NRC and EPA Regulations and Therefore is Impermissible.

One of the Draft Report's key assumptions is that active institutional controls over SNF storage will remain effective over a period of several hundred years. *Id.* at 11. The NRC proposes to assume, for instances, that "[l]ong-term storage and handling facilities will operate under a framework of aging management that is designed to monitor, detect, and mitigate significant aging impacts." *Id.* at 11. In addition, the NRC proposes to assume that:

> [t]he storage of spent fuel will remain under a regulatory program comparable to the current program. Regulatory oversight and maintenance of storage facilities and activities, such as spent fuel repackaging, will continue, as appropriate.

Id. at 11. Finally, the Draft Report proposes to assume that either licensees or the U.S. government "will provide sufficient resources and protection to ensure continued safe and secure storage." *Id.*

These assumptions regarding the long-term effectiveness of active institutional controls are contradicted by federal regulations governing the storage and disposal of radioactive waste. *See* 40 C.F.R. 191.14(d) (SNF, high-level waste and transuranic waste disposal) and 10 C.F.R. 61.59(b) (low level radioactive waste ("LLRW") disposal. These regulations were promulgated by the NRC and the U.S. Environmental Protection Agency ("EPA") after years of extensive study, mutual consultation, and gathering of public comments.

As a matter of law, these regulations establish a presumption that 100 years is the maximum length of time that institutional controls may be assumed to be effective. If the NRC wants to change that presumption and assume that institutional controls will be in effect for a period of 200-300 years, it must re-examine and update the extensive studies on which the NRC and EPA relied in establishing their regulations. As required by NEPA, it must also publish this analysis for comment by the public and by the EPA, with whom it cooperated in establishing the 100-year presumption.

D. In General, the NRC Proposes to Assume Many Important Facts That Should be the Subject of the EIS.

The proposed EIS for long-term SNF storage necessarily will involve a number of long-range predictions regarding a range of circumstances that will affect the feasibility, safety and environmental impacts of SNF storage hundreds of years from now. These circumstances include the number of nuclear reactors in operation, the size and vigor of the nuclear industry, the effectiveness of institutional controls by licensees, and even the continued existence of the NRC.

The NRC asserts that its assumptions are based on "present-day attributes, current scientific knowledge, and documented trends for potential growth in the use of nuclear power and spent fuel generation rates." Draft Report at 9. While it may be reasonable to forecast trends for twenty years, the NRC offers no basis – nor is any conceivable – for making 200 to 300-year forecasts and then assuming they are correct in an EIS. The irrationality of the NRC's approach is clear when one contemplates the violent and unpredicted events that occurred over the last 200-300 years in North America and that caused major upheavals in government, business and society: the Revolutionary War, the War of 1812, the Civil War, and the attacks of 2001 on U.S. facilities. The NRC simply has no basis to assume *any* of the facts that are asserted on pages 9 through 11.

V. CONCLUSION

For the foregoing reasons, -the NRC should withdraw the Draft Report and revise it to be consistent with NEPA and its regulations. Then the NRC should publish it for comment in the Federal Register and on its website.

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