

United States of America
Nuclear Regulatory Commission

Before the Atomic Safety and Licensing Board

In the Matter of)	
Progress Energy Florida, Inc.)	Docket Nos. 52-029-COL
(Levy County Nuclear Power Plant,)	and 52-030-COL
Units 1 and 2))	September 29, 2014

**ECOLOGY PARTY OF FLORIDA AND NUCLEAR INFORMATION
AND RESOURCE SERVICES' MOTION TO REOPEN THE RECORD**

I. INTRODUCTION

Pursuant to 10 C.F.R. § 2.326, the Ecology Party of Florida and Nuclear Information and Resource Service (“Petitioners”) hereby move to reopen the record in this proceeding to admit a new Contention challenging the failure of the Nuclear Regulatory Commission (“NRC”) to make predictive safety findings in this combined license proceeding regarding the disposal of nuclear waste.¹ Petitioners respectfully submit that reopening the record and admitting the new contention is necessary to ensure that the NRC fulfills its statutory obligation under the Atomic Energy Act (“AEA”) to protect public health and safety from the risks posed by irradiated reactor fuel generated during the reactor’s license term.

Several overlapping factors, set forth in three regulations, govern motions to reopen and admit new contentions. This motion and the accompanying Contention satisfy each of these factors. *See* 10 C.F.R. §§ 2.309(c), 2.323, and 2.326. This motion is supported by the expert declarations of Dr. Arjun Makhijani and Mark Cooper. It is also supported by the standing declarations of Emily Casey, David McSherry and December McSherry (the Ecology Party); and Amanda Hancock Anderson and W. Russell Anderson (NIRS).

¹ The Contention, entitled “Failure to Make Atomic Energy Act-Required Safety Findings Regarding Spent Fuel Disposal Feasibility and Capacity,” is attached and incorporated by reference.

II. JURISDICTION

Until issuance of its initial final decision, a Licensing Board has jurisdiction to reopen a proceeding. *See* 10 C.F.R. §§ 2.318(a), 2.713(a), 2.319(m), and 2.341; Metro. Edison Co. (Three Mile Island Nuclear Station, Unit 1), ALAB-699, 16 NRC 1324, 1326, 1327 (1982). After that, jurisdiction lies with the Commission.

III. THIS MOTION SATISFIES THE STANDARDS FOR REOPENING A CLOSED HEARING RECORD SET FORTH IN 10 C.F.R. § 2.326(a).

10 C.F.R. § 2.236(a) provides three criteria which must be satisfied for this motion to be granted:

- (1) The motion must be timely. However, an exceptionally grave issue may be considered in the discretion of the presiding officer even if untimely presented;
- (2) The motion must address a significant safety or environmental issue; and
- (3) The motion must demonstrate that a materially different result would be or would have been likely had the newly proffered evidence been considered initially.

Id. This motion and the accompanying contention satisfy all three criteria, as discussed below.

A. This Motion is Timely.

Pursuant to 10 C.F.R. § 2.323(a)(2), motions must be filed within “ten (10) days after the occurrence or circumstance from which the motion arises.” This motion to reopen is timely, having been filed ten (10) days from the date the NRC issued the Continued Storage of Spent Nuclear Fuel Rule (the “Continued Storage Rule”) and the supporting Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel (the “GEIS”). 79 Fed. Reg. 56,238-56,263 (Sept. 19, 2014); 79 Fed. Reg. 56,263-56,264 (Sept. 19, 2014).

B. This Motion and the Accompanying Contention Address a Significant Safety Issue.

This motion and the accompanying Contention raises the significant safety issue that the NRC has made no currently valid findings of confidence or reasonable assurance that the hundreds of tons of radioactive spent fuel that will be generated during any reactor's 40-year license term or subsequent relicensing term can be disposed of safely in a repository. The NRC must make these predictive safety findings in this combined license proceeding in order to fulfill its statutory obligation under the Atomic Energy Act ("AEA") to protect public health and safety from the risks posed by irradiated reactor fuel.² This motion and the accompanying Contention address significant issues associated with the storage and disposal of spent fuel.

C. This Motion and the Accompanying Contention Would Likely Produce a Materially Different Result in this Proceeding.

In the past, the NRC has made generic safety findings regarding the storage and disposal of spent fuel in its Waste Confidence Decision.³ The Continued Storage Rule does not make such safety findings. As explained more fully in the accompanying Contention, the NRC must therefore make new generic Waste Confidence findings or make those findings in every licensing or relicensing proceeding in order to fulfill its statutory obligation under the AEA. AEA Section 182, 42 U.S.C. § 2232; *Union of Concerned Scientists*.

² See Atomic Energy Act Section 182, 42 U.S.C. § 2232; *Union of Concerned Scientists v. NRC*, 824 F.2d 108 (D.C. Cir. 1987). Further, as the court held in *New York v. NRC*, the NRC must also support confidence and assurance findings on spent fuel storage and disposal with "an EIS or, in the alternative, an EA that concludes with a finding of no significant impact." 681 F. 3d 471, 478 (D.C. Circuit 2012). The GEIS does not address confidence and assurance findings on safety and environmental issues associated with spent fuel storage and disposal.

³ See, e.g., 1984 Waste Confidence Decision, 49 Fed. Reg. 34658, 34659-60; 1990 Waste Confidence Decision Review, 55 Fed. Reg. 38474, 38474-75; 2010 Waste Confidence Decision Update, 75 Fed. Reg. 81037, 81057-58.

If the Petitioners prevail on the Contention, the NRC will be required to either (1) conduct a new technical safety analysis of the feasibility of spent fuel disposal and the capacity of future repositories to accommodate the spent fuel that will be generated by reactors now under licensing and re-licensing review, or (2) deny the license. In addition, if the Petitioners prevail, it will result in preparation of an environmental impact statement (“EIS”) or environmental assessment (“EA”) of the environmental impacts of spent fuel disposal and reasonable alternatives for avoiding those impacts. As discussed in Section 6 of Dr. Makhijani’s declaration, the NRC currently has no such EIS or EA or any other relevant or up-to-date analysis on which it could rely. Finally, if the NRC fully assesses the safety risks and associated costs of spent fuel storage and disposal, its cost-benefit analysis may lead to the materially different decision not to issue a combined license in this proceeding. Declaration of Dr. Arjun Makhijani, § 7; Declaration of Mark Cooper (Attachment A), Paragraphs 4-5.

IV. THIS MOTION SATISFIES THE STANDARDS FOR REOPENING A CLOSED HEARING RECORD SET FORTH IN 10 C.F.R. § 2.326(b).

10 C.F.R. § 2.326(b) requires that a motion to reopen the record must be accompanied by affidavits that set forth the factual and/or technical bases for the movant’s claim that the criteria of Section 2.326(a) have been satisfied. The claims regarding satisfaction of 10 C.F.R. § 2.236(a) that are made in Section III above are supported by the declarations of Dr. Arjun Makhijani and Mark Cooper. Therefore this motion complies with 10 C.F.R. § 2.239(b).

V. THIS MOTION AND THE ACCOMPANYING CONTENTION SATISFY THE STANDARDS FOR CONTENTIONS FILED AFTER THE DEADLINE SET FORTH IN 10 C.F.R. §§ 2.326(d) AND 2.309(c).

10 C.F.R. § 2.326(d) provides that “[a] motion to reopen which relates to a contention not previously in controversy among the parties must also satisfy the § 2.309(c) requirements for new or amended contentions filed after the deadline in § 2.309(b).” This motion and the

accompanying new contention meet the requirements of 10 C.F.R. § 2.309(c), which calls for a showing that:

- (i) The information upon which the filing is based was not previously available;
- (ii) The information upon which the filing is based is materially different than information previously available; and
- (iii) The filing has been submitted in a timely fashion based on the availability of the subsequent information.

First, the information on which the contention is based -- i.e., the issuance of the Continued Storage Rule -- was not publicly available until September 19, 2014.

Second, the information in the Continued Storage Rule is materially different than previously available information because the Continued Storage Rule does not include the safety findings that were included in all the prior versions of the Waste Confidence Decision and on which the NRC previously relied for licensing of reactors. *See New York v. NRC*, 681 F.2d 471, 476-77 (D.C. Cir. 2012).

Third, the Contention is timely because it has been submitted within 30 days of September 19, 2014, the date the NRC issued the Continued Storage Rule and GEIS. *Shaw AREVA MOX Services* (Mixed Oxide Fuel Fabrication Facility), LBP-08-11, 67 NRC 460, 493 (2008) (“Many times, boards have selected 30 days as [the] specific presumptive time period” for timeliness of contentions filed after the initial deadline).

VI. CONSULTATION CERTIFICATION PURSUANT TO 10 C.F.R. § 2.323(B)

Petitioners certify that on September 26, 2014, we contacted counsel for the applicant and the NRC staff in an attempt to obtain their consent to the filing of the contention for which this motion is being filed. Counsel for the applicant stated that the applicant would oppose the admission of the contention. Counsel for the NRC staff stated that the Staff did not have enough

information to take a position and would respond to the contention when it is filed. While Petitioners did not explicitly consult with opposing counsel about the motion to reopen the record, Petitioners respectfully submit that it is reasonable to presume that they understood the record was closed and would need to be re-opened to admit the contention when they took their position on the contention.

VII. CONCLUSION

The issues Petitioners seek to raise in reopening this matter are material to the findings the NRC must make pursuant to the AEA before a combined license is issued. We therefore request that the record be reopened and the Contention be admitted.

Respectfully submitted,

(Electronically signed by)

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September 29, 2014

September 29, 2014

**DECLARATION OF MARK COOPER
IN SUPPORT OF MOTIONS TO REOPEN THE RECORD
OF NRC REACTOR LICENSING AND RE-LICENSING PROCEEDINGS**

Under penalty of perjury, I, Mark Cooper, declare as follows:

1. My name is Mark Cooper. I am a Senior Fellow for Economic Analysis at the Institute for Energy and the Environment at Vermont Law School. I am an expert in the field of economic and policy analysis with a focus on energy, technology, and communications issues.
2. On December 16, 2013, I prepared a declaration in this proceeding, which is attached and incorporated herein by reference. A copy of my curriculum vitae is attached to that declaration.
3. The purpose of my December 16, 2013 declaration was to evaluate whether the costs of nuclear waste management, including onsite spent nuclear reactor fuel storage and permanent disposal, are high enough to significantly affect the outcome of an analysis that compares the costs and benefits of nuclear reactors with other electricity sources.
4. The economic analysis I presented in my declaration continues to be valid and to represent my professional opinion on the matter. My analysis shows that the costs of managing spent nuclear fuel are likely to be quite large in absolute value, running to hundreds of billions of dollars (in constant 2012 dollars). They are in the range of \$10 to \$20 per MWH (\$0.01 to \$0.02 per kWh). These costs could be high enough to materially affect energy choices when the costs of new reactors or extension of the operating life of existing reactors are compared with energy efficiency and alternative energy sources.
5. Therefore, in my professional opinion, if the NRC were to include the costs of spent fuel storage and disposal in its cost-benefit analyses for reactor licensing and re-licensing decisions, these costs easily could tip the balance of the analysis away from licensing or re-licensing the reactors and in favor of other alternatives or the no-action alternative.

I declare that the foregoing statements of fact are true and correct to the best of my knowledge and that the statements of opinion expressed above are based on my best professional judgment.



Mark Cooper

Date: September 29, 2014

UNITED STATES OF AMERICA
BEFORE THE NUCLEAR REGULATORY COMMISSION

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

DECLARATION OF MARK COOPER

I. INTRODUCTION AND STATEMENT OF QUALIFICATIONS

Under penalty of perjury, I, Mark Cooper, declare as follows:

My name is Mark Cooper. I am a Senior Fellow for Economic Analysis at the Institute for Energy and the Environment at Vermont Law School. A copy of my curriculum vitae is attached. I am an expert in the field of economic and policy analysis with a focus on energy, technology, and communications issues.

For over thirty years I have analyzed the economics of energy production and consumption on behalf of consumer organizations and public interests groups, focusing in the past four years on cost of the alternative resources available to meet electricity needs for the next several decades. My analyses are presented in a series of articles,¹ reports,² and testimonies before state regulatory

¹ Cooper, Mark. “The Only Thing that is Unavoidable About Nuclear Power is its High Cost,” *Corporate Knights*, forthcoming; “Nuclear Safety and Affordable Reactors: Can We Have Both?,” *Bulletin of the Atomic Scientists*, 2012; “Nuclear Safety and Nuclear Economics, Fukushima Reignites the Never-Ending Debate: Is Nuclear Power Not Worth the Risk at Any Price?,” *Symposium on the Future of Nuclear Power*, University of Pittsburgh, March 27-28, 2012; “Post-Fukushima Case for Ending Price Anderson,” *Bulletin of the Atomic Scientists*, October 2011; “The Implications of Fukushima: The US Perspective,” *Bulletin of the Atomic Scientists*, July/August 2011 67: 8-13.

² Renaissance in Reverse: Competition Pushes Aging U.S. Nuclear Reactors to the Brink of

agencies³ and state and federal legislatures.⁴ I have served as an expert witness in several regulatory proceedings involving electricity and nuclear reactors, starting with proceedings before the Mississippi Public Service Commission almost thirty years ago regarding the proposed Grand Gulf II nuclear reactor and including proceedings before the Florida and South Carolina Commissions regarding the proposed reactors in those states.⁵

In the course of my economic analyses of electricity alternatives, I have developed a general framework that I refer to as a “multi-criteria portfolio analysis” for evaluating and choosing between the available alternatives in the increasingly complex and ambiguous conditions of the electricity market.⁶ My analysis has focused on comparative economic analysis of the nuclear-gas comparison

Economic Abandonment, July 2013; *Public Risk, Private Profit, Ratepayer Cost, Utility Imprudence: Advanced Cost Recovery for Reactor Construction Creates Another Nuclear Fiasco, Not a Renaissance*, March 2013; *Fundamental Flaws In SCE&G’s Comparative Economic Analysis*, October 1, 2012; *Policy Challenges of Nuclear Reactor Construction: Cost Escalation and Crowding Out Alternatives*, September, 2010; *All Risk, No Reward*, December 2009; *The Economics of Nuclear Reactors: Renaissance of Relapse*, June 2009; *Climate Change and the Electricity Consumer: Background Analysis to Support a Policy Dialogue*, June 2008.

³ “Testimony on Behalf of Utah Heal,” *Carbon County Court*; “Testimony and Surrebuttal Testimony on Behalf Of The Sierra Club,” Before the *South Carolina Public Service Commission*, Docket No. 2012-203-E; “Direct Testimony of Dr. Mark N Cooper in Re: Nuclear Plant Cost Recovery for the Southern Alliance for Clear Energy,” Before the *Florida Public Service Commission*, FPSC Docket No. 100009-EI, August 2010; “Direct Testimony of Dr. Mark N Cooper in Re: Nuclear Plant Cost Recovery for the Southern Alliance for Clear Energy,” Before the *Florida Public Service Commission*, FPSC Docket No. 090009-EI, July 15, 2009.

⁴ *Nuclear Economics after Fukushima*, Before the *Standing Committee on Natural Resources House of Commons*, Ottawa Canada, March 24, 2011; “Testimony of Dr. Mark Cooper on House File 9,” Before the *Minnesota House of Representatives Committee on Commerce and Regulatory Reform*, February 9, 2011; “Economic Advisability of Increasing Loan Guarantees for the Construction of Nuclear Power Plants,” Before the *Domestic Policy Subcommittee, Committee on Oversight and Government Reform, U.S. House of Representatives*, April 20, 2010.

⁵ See citations to written testimony in Note 3 above. I also provided oral testimony on the witness stand. “On Behalf of Mississippi Legal Services Coalition in the Matter of the Citation to Show Cause Why the Mississippi Power and Light Company and Middle South Energy Should Not Adhere to the Representation Relied Upon by the Mississippi Public Service Commission in Determining the Need and Economic Justification for Additional Generating Capacity in the Form of A Rehearing on Certification of the Grand Gulf Nuclear Project,” Before the *Mississippi Public Service Commission*, Docket No. U-4387, August 13, 1984.

⁶ “Least Cost Planning for 21st Century Electricity Supply: Meeting the Challenges of Complexity and Ambiguity in Decision Making,” *MACRUC Annual Conference*, June 5, 2011; “Risk, Uncertainty and Ignorance: Analytic Tools for Least-Cost Strategies to Meet Electricity Needs in a Complex

driven by utility concentration on these two technologies, but also including efficiency⁷ and wind.⁸ The analysis has covered regional, national, and international levels, as well as on the impact of specific institutional arrangements on ratepayers.⁹

PURPOSE AND FINDINGS

The purpose of my declaration is to evaluate whether the costs of nuclear waste management, including onsite spent nuclear reactor fuel storage and permanent disposal, are high enough to significantly affect the outcome of an analysis that compares the costs and benefits of nuclear reactors with other electricity sources. I understand that this type of analysis is generally conducted by the NRC in the course of its environmental review for new reactor license applications and applications for renewal of existing reactor licenses. In the discussion below, I analyze two of the most important costs of nuclear waste management – the cost of “temporary” storage of spent fuel at reactors and the cost of building, filling, and operating a permanent repository for that fuel. The cost of decommissioning the reactors and closing the permanent repository are also costs of nuclear waste management, but I do not include them in this analysis.

Age,” *Variable Renewable Energy and Natural Gas: Two Great Things that Go Together, or Best Not to Mix Them*. NARUC Winter Committee Meetings, Energy Resources, Environment and Gas Committee, February 15, 2011.

⁷ “Prudent Resource Acquisition in a Complex Decision Making Environment: Multidimensional Analysis Highlights the Superiority of Efficiency,” *Current Approaches to Integrated Resource Planning, 2011 ACEEE National Conference on Energy Efficiency as a Resource*, Denver, September 26, 2011; *Building on the Success of Energy Efficiency Programs to Ensure an Affordable Energy Future*, February 2010; *A Consumer Analysis of Energy Efficiency and Renewable Energy Standards: The Cornerstone of Consumer-Friendly Energy/Environmental Policy*, May 2009; *The Impact of Maximizing Energy Efficiency on Residential Electricity and Natural Gas Utility Bills in a Carbon-Constrained Environment: Estimates of National and State-By-State Consumer Savings*, 2009.

⁸ *Capturing the Value Of Offshore Wind To Promote a Secure, Affordable, Low-Carbon Electricity Future: A Multi-Criteria, Portfolio Approach to Electricity Generation Resource Acquisition in the United Kingdom*, October 2012.

⁹ *Public Risk, Private Profit: Ratepayer Cost, Utility Imprudence: Advanced Cost Recovery for Reactor Construction Creates Another Nuclear Fiasco, Not a Renaissance*, March 2013; *Advanced Cost Recovery for Nuclear Reactors*, March, 2011; *Economic Advisability of Increasing Loan Guarantees for the Construction of Nuclear Power Plants*, Domestic Policy Subcommittee, Committee on Oversight and Government Reform, U.S. House of Representatives, April 20, 2010; “Further Nuclear Power Subsidies are Wrongheaded,” *Bulletin of the Atomic Scientists*, December 2009.

At present, the public is paying for the management of nuclear waste in three ways. Utilities pay a fee to the U.S. Department of Energy (DOE) for a Nuclear Waste Fund that is intended to pay for the repository. This fee is collected from ratepayers. The cost of temporary at-reactor storage is also being recovered by utilities from taxpayers in the form of penalties imposed on the federal government for the failure to execute its contractual commitment to take the spent fuel off reactor sites.¹⁰ This penalty is paid out of the U.S. Treasury and has not decreased the Nuclear Waste Fund. Finally, utilities collect funds from ratepayers for the decommissioning of reactors. Questions about the use of the funds and whether they are adequate are not the subject of my declaration, which focuses only on the question of the magnitude of the costs relative to the cost of power from nuclear reactors and the other potential resources that could be used to meet the need for electricity. Nevertheless, as discussed below, these advance payments have a bearing on the applicability of a discount rate to nuclear waste disposal cost estimates.

My analysis shows that the costs of managing spent nuclear fuel are likely to be quite large in absolute value, running to hundreds of billions of dollars (in constant 2012 dollars). They are in the range of \$10 to \$20 per MWH (\$0.01 to \$0.02 per kWh), which is certainly large enough in relative value to affect the outcome of analyses that compare the cost of nuclear power to the alternatives available in the United States. Therefore, the cost of nuclear waste management is a significant cost that should be included in the NRC's economic comparisons of nuclear power with energy efficiency and other alternative energy sources.

II. ESTIMATING THE COST OF SPENT FUEL MANAGEMENT

For the purposes of this analysis, I start with the most recent U.S. government estimates of costs of electricity generation and costs of spent fuel disposal: “Levelized Cost of New Generation Resources in the Annual Energy Outlook,” prepared by the U.S. Energy Information

¹⁰ See, e.g., *Ntl. Assoc. of Regulatory Util. Comm'rs v. United States DOE*, 680 F.3d 819 (D.C. Cir. 2013).

Administration (EIA) in 2013¹¹ and the “Nuclear Waste Fund Fee Adequacy Assessment Report” prepared by the U.S. Department of Energy (DOE) in 2013.¹² Each of these studies has some limitations.

I believe that the EIA has been wildly optimistic about the cost of nuclear power over the past decade, but I suspect that the NRC would be inclined to rely heavily on its estimates, and therefore I use it as my base case. I also show that the same conclusion would be reached if I were to rely on recent estimates from utility industry sources and Wall Street analysts.

The DOE’s recent analysis of the cost of a permanent nuclear waste repository is the most recent in a series of government analyses of those costs.¹³ Because it was prepared as part of DOE’s legal obligation to assess whether current fees are adequate to fund a permanent repository, it takes a very narrow view of the costs considered. It does not consider at-reactor storage costs, and it assumes that the repository opens very quickly.¹⁴ Neither of these assumptions appears consistent with the current reality of nuclear waste management or sound economic analysis of waste management costs. As I show below, this view ignores at least half of the cost associated with nuclear waste management. Nevertheless, the DOE’s analysis provides a useful starting point for estimating the cost of one component of nuclear waste management.

REPOSITORY COSTS

The narrow costs of constructing and filling a permanent waste repository considered by the DOE can be a starting point for the analysis of the total cost of nuclear waste management. Exhibit MNC-1 shows a number of estimates, prepared by government agencies over the past thirty years,

¹¹ Energy Information Administration, “Levelized Cost of New Generation Resources in the Annual Energy Outlook,” *Annual Energy Outlook*, 2013 (hereinafter EIA 2013).

¹² U.S. Department of Energy Nuclear Waste Fund Fee Adequacy Assessment Report, January 2013 (hereafter DOE, 2013).

¹³ DOE, 2013.

¹⁴ *Id.* p. 9, DOE 2013 assumes one pilot consolidated storage facility and one full-scale consolidated storage facility. It also assumes a time period of 34 years between the siting and opening of a repository.

of the cost of this subset of waste management activities. I have endeavored to ensure that the comparisons involve only the specific set of costs associated with the repository. While at-reactor storage costs are included in some of the later estimates, I exclude these costs in order to maintain consistency with the DOE's analysis. I exclude historic costs that are sunk and not considered in each forward looking estimate. I convert all costs to real 2012 dollars using the Producer Price Index for intermediate goods (rather than the PPI for finished goods or the Consumer Price Index, which would include many types of distribution costs not included in an activity like the construction and operation of a repository).¹⁵ The cost per metric ton of uranium (used interchangeably with the term "heavy metal") is calculated based on the number of tons assumed in each of the individual studies.¹⁶ The most recent DOE estimate used just over 141,000 metric tons of heavy metal (MTHM) as the total amount of spent fuel that has been produced and will be produced given present reactor licenses and reactors under construction. Studies by the Government Accountability Office (GAO) and the Blue Ribbon Commission, in comparison, used just over 153,000 MTHM, but they counted civilian and defense material not associated with civilian nuclear reactors.

The early estimates and the most recent estimate are for generic waste repositories. The others were for Yucca Mountain, which is generally assumed to be a bit more costly than a generic site. The DOE analysis of repository costs takes this into account.¹⁷

¹⁵ GAO, "Nuclear Waste Management; Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives," Government Accountability Office, GAO-10-48, November 2010 (hereafter GAO 2009) presents analyses in discounted 2009 dollars where the discount rate reflects complex Monte Carlo simulations. Cliff W. Hamal, Julie M. Carey and Christopher L. Ring, Navigant, *Spent Nuclear Fuel Management: How Centralized Interim Storage Can Expand Options and Reduce Costs*, for the Blue Ribbon Commission on America's Nuclear Future, May 16, 2011. (Hereafter Hamal, 2011), have estimated the "best estimate," which is 1.34 times the mean from GAO. Stating that in 2012 dollars yields an adjustment factor of 1.47. I use this to restate all GAO estimates in real, 2012, undiscounted dollars.

¹⁶ This is the convention adopted by Hamal, 2011.

¹⁷ DOE 2013, p. 12: "To derive a cost estimate for a generic repository, rather than one located at

Exhibit MNC-1 shows the mid-point, or “best estimate” from each of the studies. Two things are clear from this history of cost estimation:

First, the estimated cost of spent fuel disposal in a repository has been escalating dramatically, which is typical of cost estimates involving nuclear power. The trend is slightly stronger for the cost estimates since the 1990s.

Second, the repository costs are very large in absolute value, reaching a hundred billion dollars. They are certainly large enough to be included in any economic analysis comparing the costs and benefits of nuclear reactor operation. As discussed below, the costs are also large enough to affect the economics of nuclear power compared to alternatives.

While using the “best estimates” is useful to demonstrate a strong and consistent pattern of rising estimated costs, it hides a great deal of uncertainty about the cost. Exhibit MNC-2 shows the range of costs in the two most recent estimates. There is a great deal of uncertainty about cost in the most recent DOE study, which is typical of estimates involving nuclear power.¹⁸ I will discuss my method for addressing this uncertainty below.

AT-REACTOR STORAGE

The recent GAO analysis¹⁹ and the Blue Ribbon Commission study²⁰ have recognized the increasing importance that onsite storage of nuclear waste plays in the overall cost of nuclear waste management. Onsite spent fuel storage is becoming the central cost driver of nuclear waste management because very long periods of onsite storage – up to 300 years – are being considered.²¹

Yucca Mountain, the TSLCC [Total System Life Cycle Cost] cost estimate was reviewed and costs that were deemed specific to the Yucca Mountain site were removed from the estimate.”

¹⁸ The standard deviation of the estimate of the repository costs is large compared to the “best estimate.” The coefficient of variation (the standard deviation divided by the mean) is 0.75.

¹⁹ GAO, 2009.

²⁰ Hamal, 2011.

²¹ Dennis Vinson, Ron Kesterson, and Adrian Mendez-Torres, “Inventory and Description of Commercial Reactor Fuels within the United States,” Prepared for U.S. Department of Energy Campaign Program Savannah River National Laboratory, March 31, 2011. Which is also noted in

These costs are reflected in Exhibit MNC-3, which includes the GAO scenario in which waste remains on site for a long period of time (100 to 500 years). The GAO estimates in Exhibit MNC-3 suggest that the longer waste remains in storage on site, the higher the cost is likely to be. The Blue Ribbon Commission “best estimate” for 100 year at-reactor storage restated in 2012 dollars is just over \$100 billion.²²

Given that much longer periods of time for at-reactor storage are being contemplated, even this figure is too low for three reasons:

First, when a nuclear reactor shuts down permanently, the waste at the reactor site becomes “stranded.” That is, the site must be operated solely for the purpose of attending to the waste. This means that the costs of many activities that were once attributed to operating the reactor must now be allocated to managing the waste. The Blue Ribbon Commission study suggests that the cost of managing stranded waste is five times as high as the cost of managing waste at an operating site.²³

Second, over hundreds of years, storage casks will deteriorate and have to be replaced. I have assumed that cask replacement will be necessary every 100 years at a cost of \$1.6 million per cask, assuming no escalation in real costs.²⁴ Given this cost and the amount of material that will

Eric M. Davied, *Long-Term Interim Storage for Used Nuclear Fuel: Dry Cask Storage in Centralized Storage Facilities*, Texas A& M University, 2011, identifying cask capacity at 10 to 15 MTU. (Hereafter, Davied 2011).

²² Hamal, 2011, estimates just under \$72 billion for the large repository (including transportation) compared to the GAO estimate of \$53 billion. I use the difference ($71.46/53 = 1.348$) to scale up to undiscounted dollars. Bringing the figure to 2012 dollars involves inflating by a factor of 1.096. The adjustment factor is 1.477. Hamal’s “best estimate” cost for the repository would \$78.3 billion in 2012 dollars compared to the DOE midpoint cost of \$88.9 billion.

²³ This cost difference is derived from Hamal, 2011, p. 27. GAO, 2009 shows no difference between the average at-reactor storage costs for 100 years, which would include a substantial period in which spent fuel is not stranded, and the cost of 500-years of at-reactor storage. This suggests that stranding has not been taken into account, which was the central thrust of Hamal, 2011.

²⁴ My assumption of cask replacement every 100 years is consistent with the NRC’s Draft Waste Confidence Environmental Impacts Statement, p. xxviii, 2013. Davied, 2011, identifies cask capacity at 10 to 15 MTU.

have to be stored, the GAO estimates of storage are low. Repackaging costs could be on the order to \$75 billion.²⁵

Third, as with all nuclear costs, repackaging cost appear to be increasing dramatically.²⁶

This analysis also excludes potentially significant costs associated with the repackaging and transportation of high burnup spent nuclear fuel over the next 30-50 years. For instance, in 2012 an expert with the National Academy of Engineering reported that “the technical basis for the spent fuel currently being discharged (high utilization, burnup fuels) is not well established... the NRC has not yet granted a license for the transport of the higher burnup fuels that are now commonly discharged from reactors. In addition, spent fuel that may have degraded after extended storage may present new obstacles to safe transport.”²⁷ Even the Nuclear Regulatory Commission (NRC) admits “there is limited data to show that the cladding of spent fuel with burnups greater than 45,000 MWd/MTU will remain undamaged during the licensing period” for dry spent fuel storage facilities.²⁸

COMBINING AT-REACTOR STORAGE AND PERMANENT REPOSITORY COSTS

Exhibit MNC-4 adds at-reactor storage costs to the most recent DOE estimates for the cost of the repository. The stranded waste costs are based on the difference in cost estimated in the Blue Ribbon Commission report between very rapid transfer of stranded waste to central storage and no

²⁵ GAO, 2009 uses the figure of \$1.6 million per cask. With 153,000 metric tons of waste and 10 tons per cask, the cost of repackaging all spent fuel is \$24.480 billion. Three repackaging operations would be just under \$75 billion.

²⁶ Michiel P.H. Brongers, *Appendix CC, Nuclear Waste Storage*, CC Technologies Solutions, Inc., N.D., p. cc-2, gives a figure of \$1.2 million; GAO, 2009, p. 56, puts the cost at \$1.6 million per cask, which is shown as a modification of the earlier assumption of \$1.2 million. GAO, 2009, reflects similar trends.

²⁷ National Academy of Engineering, “Managing Nuclear Waste”, Summer 2012, pp 21, 31, <http://www.nae.edu/File.aspx?id=60739>.

²⁸ U.S. Nuclear Regulatory Commission, “Standard Review Plan for Spent Fuel Dry Storage Facilities, Final Report” NUREG-1567, March 2000. p. 6-15, <http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1567/sr1567.pdf>.

transfer until 70 years later.²⁹ That difference is slightly more than \$24 billion over the first 70 years. Extrapolating to 300 years, the difference in the stranded waste cost would be \$105 billion.

Repackaging of waste is necessary as long as it is not deposited in a permanent repository.³⁰ Therefore, repackaging costs must be added. Assuming three rounds of repackaging in 300 years, repackaging adds another \$75 billion to the cost of managing spent fuel.

Combining these cost estimates for storage and disposal of spent fuel yields a cost range of approximately \$210 to \$350 billion.

OTHER POTENTIAL COSTS

The estimated cost range of \$210 to \$350 billion for spent fuel management leaves out significant costs. First, it does not include an escalation in the real cost of at-reactor storage and the escalation in the real cost of construction and operation of a permanent repository. Both of these have exhibited significant historical trends of increasing real cost. Second, the estimate in Exhibit MNC-4 does not include the cost or risk of accidents that may be significant with onsite storage of waste, especially during the very long period of onsite storage that is being contemplated. Large quantities of dangerous materials stored at sites close to population centers create a risk of accidents that can impose severe economic disruption and social dislocation. While much of the discussion of nuclear accidents focuses on public health issues, the economic and social impacts are substantial. The estimated economic costs of one accident run into the hundreds of billions, equaling or exceeding the entire cost of waste management and disposal.³¹ The fourth largest utility in the world

²⁹ Hamal, 2011 p. 41 shows stranded waste costs of \$477 million for a central storage facility taking 6000 MTU per year starting 2020 and \$22.716 billion for a central storage facility taking 3000 MTU per year starting in 2090. The difference of \$22.239 billion in 2009 dollars equals \$24.4 billion in 2012 dollars.

³⁰ Hamal, 2011, p. 52.

³¹ Cooper, Nuclear Safety, discusses the general magnitude of these costs. Gordon R. Thompson, "Risk-Related Impacts from Continued Operation of the Indian Point Nuclear Power Plants", November, 28, 2007 examines the potential economic cost of a severe onsite storage accident, showing it is similar in magnitude to the general accident risk.

was not thrown instantaneously into virtual bankruptcy by public health impacts, but it was destroyed by the economic cost of cleanup and compensation. While these are low probability events, keeping large quantities of nuclear waste onsite for long periods of time raises the probability of such an event.

In addition, the above analysis does not include any escalation in the cost of decommissioning reactors. Decommissioning costs theoretically are included in calculations of levelized cost. But these costs have been rising dramatically in recent years.³² For the reactors that were retired in the past year, the total is approaching \$1 billion per site, significantly above the amount originally estimated.³³

However, it is also important to recognize that the storage of spent fuel is included in the decommissioning cost estimates, and I have already included those costs in this discussion. In the case of Kewaunee, the spent fuel storage costs are one-third of the total decommissioning cost. At half a billion dollars per nuclear reactor, the total cost for decommissioning the entire fleet could be \$50 billion, which is quite significant, given the other costs that I have analyzed.

It appears that utilities are going to ask for rate increases to cover decommissioning costs, which means they have not been collecting enough. Given the rising costs of decommissioning, it remains to be seen if current cost estimates are adequate. For license renewals, there would be an additional question about whether extending the life of a reactor increases the decommissioning costs. In summary, I do not include decommissioning costs in this analysis, but these costs could well be another reason my estimate is low.

³² David A. Krause, “Historical NDT Fund Balances, Annual Contributions and Decommissioning Cost Estimates”, Nuclear Regulatory Commission Workshop, March 2011.

³³ *Decommissioning Cost Analysis for the Vermont Yankee Nuclear Power Station*, February 2012; *Kewaunee Power Station Post-Shutdown Decommissioning Activities Report*, TLG Services, Inc., 2013; *Decommissioning San Onofre Fact Sheet*, 2013; Robert McCullough, et al., *Economic Analysis of the Columbia Generating Station*, December 2013, pp. 92-101, 110-130. “Decommissioning Cost Escalation is a Global Phenomenon: Nuclear Decommissioning Authority, *Managing Risk Reduction at Sellafield*, Report by the Comptroller and Auditor General, November 7, 2012.

III. TRANSLATING NUCLEAR WASTE MANAGEMENT COSTS INTO THE COST OF ELECTRICITY

In order to bring these waste management costs into the economic evaluation of nuclear power compared to other resources, I translate the aggregate estimates of costs into per kWh costs. This involves several challenges. The bottom row in Exhibit MNC-4 shows an effort to do so. There are two important issues that affect this calculation: output of nuclear reactors and a determination of the appropriate discount rate.

OUTPUT OF NUCLEAR REACTORS

The amount of power that the costs will be spread across is uncertain. The DOE's assumption is too high for several reasons. The DOE estimate shows a stream of output from nuclear reactors that start with a base in 2012 that is already 5% higher than the actual output.³⁴ The output is lower than expected because nuclear reactors were offline and have been retired early. That trend is likely to continue.

The DOE assumption of a very high load factor is inconsistent with historical experience. It took a long time to build up to a high load factor; therefore, any new reactors that come online should not be assumed to immediately jump to a high load factor. Moreover, capacity factors for existing reactors have begun to decline as reactors age. In a recent paper, I showed that including early retirements in the calculation of load factors yields a load factor that is one-sixth lower than the very high assumptions being used in much comparative economic analyses.³⁵ The output of the nuclear fleet in 2013 will have declined from the peak in 2010 to the level achieved in 2004.

DOE and many other analysts of waste management assume that reactor life will be 60 years.³⁶ While the license period might run that long, virtually all reactors that have been retired

³⁴ DOE, 2013.

³⁵ Mark Cooper, *Renaissance in Reverse: Competition Pushes Aging U.S. Nuclear Reactors to the Brink of Economic Abandonment*, July 2013 (hereafter, *Aging Reactors*).

³⁶ DOE, 2013.

were retired before their licenses expired. The closure of Kewaunee and Vermont Yankee extend that pattern for reactors that were online when the retirement decision was made, while San Onofre and Crystal River extend the pattern of troubled reactors retiring early.

DOE assumes an increase in capacity of almost 10 percent due to large scale uprates at existing facilities,³⁷ but virtually all large scale uprates pending have been cancelled due to a severe deterioration in the comparative economics of nuclear power.³⁸

DOE assumes early online status for new reactors under construction and an “unplanned addition” of a new reactor which would add 2 percent to nuclear capacity.³⁹ Given the historical experience of new reactor cancellations and construction delays, the “unplanned addition” should certainly be dropped.

Combining these observations, one can argue that the base case for NRC analysis should include actual 2013 output, which is 5% lower than the DOE analysis, an 80 percent load factor, without uprates and “unplanned additions.” Under these assumptions, the output of the fleet would be at least 25% lower than assumed by DOE in its analysis of disposal system costs.⁴⁰

Lower output might lower the variable cost of at-reactor storage. Whether it lowers the cost of a permanent repository depends on whether one assumes that only one repository will be constructed. If adding nuclear capacity causes the construction of a second repository, fixed costs will increase substantially. The GAO analysis, adjusted for the discount rate and inflation, suggests that the cost of operating two repositories would be 32% higher than one, adding \$25 billion to the total cost.⁴¹ This would offset a substantial part of the variable cost savings. Put in another way, if denying licenses or license renewals allows a second repository to be avoided, the reduction in cost

³⁷ DOE, 2013.

³⁸ Cooper, Aging Reactors.

³⁹ DOE, 2013.

⁴⁰ This result is consistent with all remaining reactors plus five new ones – Vogtle, Summer, Watts Bar – running for a full 60 years at 90 percent capacity factor.

⁴¹ GAO, 2009.

would be substantial including both fixed costs for the reactor and variable cost for spent waste storage.

THE DISCOUNT RATE

There is a great deal of uncertainty and debate about the discount rate that should be used. In this case, as discussed below, it is my opinion that application of a discount rate is inappropriate. Therefore, the costs presented in Exhibit MNC-4 are not discounted.

For purpose of long term analysis, analysts generally believe discount rates should be quite low.⁴² The fact that costs of waste management are incurred a long time (i.e., hundreds or thousands of years) after the useful life of the facility creates an intergenerational issue, since future generations will be incurring large costs without deriving any benefit. As GAO states:

Although the concept of discounting is an accepted and standard methodology in economics, the concept of discounting values over a very distant future—known as “intergenerational discounting”—is still subject to considerable debate. Furthermore, no consensus exists among economists regarding the exact value of the discount rate that should be used to discount values that are spread over many hundreds or thousands of years.⁴³

Therefore the appropriate discount rate is a significant issue that should be addressed in the NRC analysis of the cost of waste management.

In my opinion, there are two additional, important reasons why application of a zero discount rate is appropriate in these circumstances. First, the real increase in the cost of at-reactor storage and the permanent repository has been increasing substantially faster than the real, discount rate. Given the long time frames being considered, the real price increase can have a very large impact. An annual real rate of increase above the discount rate of one-half of one percent would more than double the cost of waste management.

⁴² Hamal, 2011.

⁴³ GAO, 2009, p. 28.

The second reason stems from the unique way that the financing of the repository is being handled. To the extent that the discount rate represents the time value of money (*i.e.*, the value of the opportunity to use the money), the public is bearing the burden on the revenue side. The DOE analysis of fund adequacy takes credit for the earning of interest on the funds collected. Because those funds are being banked to make the fund whole, then the funds are not available to be used for other purposes. Much the same is true of the Treasury funds being paid to utilities because of the failure of the federal government to take the spent fuel. Because taxpayers are already being denied the opportunity to use their funds for other purposes, to discount the cost would be a double burden. Taxpayers and ratepayers would be bearing the full cost of the waste management, having been denied the opportunity to use the repository funds of penalties for storage costs for other purposes.

Given these considerations, I believe it is reasonable to estimate the combined costs of at-reactor storage and a permanent repository in the range of \$10 - \$20/MWH (\$0.01 to \$0.02/kWh). I have rounded this estimate to one significant figure, to account for the uncertainties inherent in such estimations at the present time.

In absolute value, given the EIA estimate of \$0.11/per kWh for the cost of nuclear power from new reactors, this is between 10% and 20% of the estimated cost.⁴⁴ That is a substantial portion of new reactor costs and therefore strongly merits consideration by the NRC in its economic analysis of the relative costs and benefits of new nuclear reactors as compared to energy efficiency and other energy sources.

For the above reasons, I believe that the bottom line in Exhibit MNC-5 provides cautiously low estimates of the cost of nuclear waste management. Therefore, in the remainder of this analysis

⁴⁴ See EIA, 2013.

I use the cost range of \$10/MWh to \$20/MWh to assess the importance of including nuclear waste management costs in the NRC's economic analysis.

As discussed in more detail in Section IV, the cost of nuclear waste management is a much larger fraction of the cost of operating existing reactors than for new reactors. And it is large enough to affect the comparative cost of nuclear power from existing and new plants, relative to the available energy alternatives. Therefore, in the case of both new reactor licensing and license renewal for existing reactors, the costs of nuclear waste management could be high enough to affect decisions about which energy resources to develop.

IV. IMPACT OF NUCLEAR WASTE MANAGEMENT COST ON THE COMPARATIVE ECONOMICS IN RESOURCE SELECTION

In the previous section I showed that a very cautious estimate of waste management costs would be in the range of \$0.01 to \$0.02 per kWh. In this section I examine whether costs of that magnitude could affect the economic analysis of nuclear power compared to other resources. For the analysis of licenses for new reactors I examine the addition of waste management costs to the levelized cost of energy that are frequently used to evaluate new resources. For the analysis of the renewal of licenses for existing reactors I analyze the addition of waste management costs to the operating costs and margins of existing reactors.

LEVELIZED COST ANALYSIS FOR NEW REACTOR LICENSES

The traditional approach to comparative resource selection for new reactors relies on the calculation of the levelized cost of electricity.⁴⁵ For the purposes of this analysis, I start with the levelized cost of alternatives as estimated by EIA. I then add the cost of nuclear waste management

⁴⁵ Levelized cost is often cited as a convenient summary measure of the overall competitiveness of different generating technologies. It represents the per-kilowatt-hour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle. Key inputs to calculating levelized costs include overnight capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type. http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

to those costs and observe, qualitatively, whether it would alter the evaluation of the cost of nuclear power compared to the other options available. Exhibit MNC-5 shows the results using the range of estimates in the EIA analysis.

Nuclear waste management costs of \$20/MWH would change the location of nuclear in the relation to other resources significantly.

Nuclear moves:

- Out of the range of
 - Conventional coal costs
 - Gas Combined Cycle with CCS
 - Advanced gas turbines
- Into the range of
 - Advanced coal
 - Advanced coal with CCS
- Much closer to and
 - Slightly below gas turbines
 - Slightly above Biomass

Waste disposal costs of \$10/MWH move nuclear costs in the same directions, but more modestly.

Exhibit MNC-6 shows levelized cost estimates for a similar set of resources from the Pennsylvania, Jersey, Maryland Power Pool (PJM), a major Regional Transmission Organization (RTO) in an area of the country that is not especially well endowed with renewable resources (e.g. compared to the Midwest with a great deal of wind or the Southwest with a great deal of solar, or the Northwest with a great deal of hydro). Exhibit MNC-7 shows estimates from Lazard, which is a financial analysis firm. I include these two estimates because they not only represent different institutional points of view but also because both include efficiency as a resource. Both estimates demonstrate that efficiency is the least-cost resource by far. In fact, a significant amount of efficiency could be delivered at a cost that is close to the cost of nuclear waste management alone.

Lazard also projects declining costs for solar, which I include in Exhibit MNC-7, which would make it cost competitive with even natural gas within a decade. As shown in Exhibit MNC-8,

the cost trends for solar and offshore wind are expected to make them much more competitive over the next decade and would significantly affect all of the comparisons affecting nuclear power.

Adding \$10 to \$20 per MWh to the cost of nuclear power generation would make a material difference in its attractiveness. Nuclear becomes even less attractive when one considers that other energy sources have little risk due to the short time from start of construction to finish. Looking at the cost of nuclear compared to the more costly alternatives in these analyses, the \$10 to \$20/MWh certainly can make a difference. Nuclear, which is almost the most expensive resource, could become the most costly.

PORTFOLIO ANALYSIS

In the realm of electricity resource selection, I and many others have argued for an approach to analysis that deals more systematically with risk, uncertainty, vagueness, and ambiguity in the decision-making environment. I have developed a multi-criteria portfolio approach based on financial risk hedging and real option analysis, as well as a number of other efforts to deal with the challenge of ambiguity in the decision-making environment. For the purpose of incorporating the cost of nuclear waste management into the analysis, I will briefly describe the basic portfolio approach.

The top graph in Exhibit MNC-9 presents the basic approach to financial portfolio analysis, as a publication from the National Regulatory Research Institute (NRRI) attempted to introduce it to regulators.⁴⁶ As shown in the upper graph, investors want to be on the efficient frontier, where risk and reward are balanced. They can improve their expected returns if they can increase their reward without increasing their risk or if they can lower their risk without reducing their reward. In the financial literature, risk is measured by the standard deviation of the value of the reward.

⁴⁶ Ken Costello, *Making the Most of Alternative Generation Technologies: A Perspective on Fuel Diversity*, NRRI, March 2005.

In applying this framework to the evaluation of generation options, analysts frequently measure reward as kilowatts per dollar (a measure of economic efficiency). Reward is the inverse of cost (i.e., the lower the cost the greater the reward). Indeed, they use efficiency and cost interchangeably.⁴⁷ The lower graph in Exhibit MNC-9 shows the cost/risk relationship. Options that would move the portfolio toward the origin should be adopted since they embody lower cost and/or risk. Movement along the risk-cost frontier is neutral. Movement away from the origin raises either the cost or the risk.

I use the array of resources to calculate a measure of the attractiveness of the reward. The distance of a resource from the origin measures the risk-cost characteristics of the resource (giving risk and cost equal weight). Resources that are farther from the origin (measured as the distance with each factor weighted equally) are less attractive. The distance from the origin can be expressed as the risk-adjusted cost or the expected cost.

Exhibit MNC-10 shows the result of applying my approach to the EIA cost estimates, assuming that waste costs increase both the point estimate and the standard deviation of the cost estimates. Exhibit MNC-10 provides quantitative estimates that support the observations in the previous section. Waste disposal costs of the magnitude I have estimated make nuclear a much “closer” call in comparison to other alternatives, and they even reverse the direction of the conclusion in several comparisons. The top graph in MNC-10 focuses on the comparisons between resource costs that would be most affected by inclusion of waste management costs in the NRC’s economic analysis. The bottom graph includes all of the resources. There are nine comparisons in which nuclear would be seen as a significantly less attractive asset to include in a resource portfolio. Including the trends for wind and solar cost and the cost of waste management, nuclear becomes almost the least attractive resource.

⁴⁷ J.C. Jansen, L.W. M. Beurskens, and X. van Tilburg, *Application of Portfolio Analysis to the Dutch Generating Mix*, ECN, February 2006, p. 13 argue for a risk-cost frontier.

ANALYSIS FOR LICENSE RENEWAL OF EXISTING REACTORS

I approach the analysis of the impact of waste management costs on the economics of aging reactors by examining these costs in relation to operating costs and margins. The economics of old reactors is already fraying and many are already on the economic "razor's edge."⁴⁸ Upgrades are already being abandoned because they are too costly. Old reactors are being shuttered because they are no longer economic. Proper consideration of waste disposal costs could play a part in pushing them over the edge.

In my recent analysis of aging reactors I used a Credit Suisse analysis of operating costs and operating margins as the basic data to make the point that analysis of the economics of aging reactors that are still operating is challenging. Exhibit MNC-11 contains the estimated operating costs for almost all nuclear reactors online in 2012. Exhibit MNC-12 shows the "cash margins" that the reactors would yield, given the "round-the-clock prices" at different power hubs. It shows that in all but a few cases the cash margins – revenues per MWh in excess of the offered hub price – are less than \$20 per MWh. It also shows that the cash margins are less than \$10 per MWh in many cases. Exhibit MNC-12 also identifies reactors that have been retired recently or are scheduled to retire early, even though they were online and had significant periods before their licenses would expire. Major upgrades that have recently been cancelled are also identified.

The exhibit makes the point that cash margins of about \$9/MWh put reactors on the razor's edge because the cash margins are very thin.⁴⁹ Exhibit MNC-12 shows that 12 of the 18

⁴⁸ Cooper, Aging Reactors.

⁴⁹ Credit Suisse, 2013, pp. 11-17, "Using current 2014 power price forwards and unit economics, we see modest cash margin expectations... Layering in typical parent overhead of \$5-7 / MWh, unit economics look even worse... We worry that rising operating and capital costs along with operational problems at some aging plants will force owners to continuously re-evaluate the useful lives of plants independent of license extensions especially as the time to absorb ongoing capex grows shorter."

license renewals pending or expected in the near future are on this razor's edge. The waste management costs identified above are clearly material in these circumstances.

CONCLUSION

In conclusion, the calculations in this declaration indicate that spent fuel storage and disposal costs could be high enough to materially affect energy choices when the costs of new reactors or extension of the operating life of existing reactors are compared with energy efficiency and alternative energy sources. Therefore, in my opinion, the NRC should consider these costs in its licensing decisions for new reactors and renewal of existing reactor licenses.

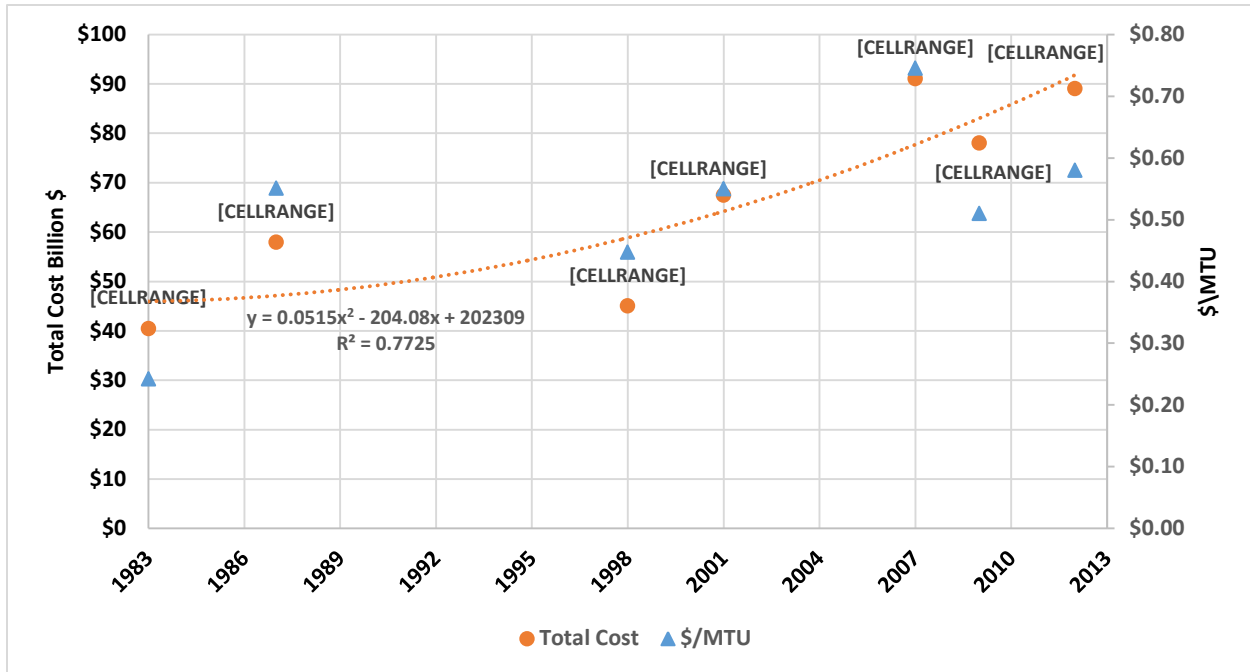
I declare that the foregoing statements of fact are true and correct to the best of my knowledge and that the statements of opinion expressed above are based on my best professional judgment.

A handwritten signature in cursive script, reading "Mark Neal Cooper", is displayed on a light blue, textured background.

Mark Cooper

Date: December 16, 2013

EXHIBIT MNC-1, Page 1 of 1
REPOSITORY COST ESTIMATES ACROSS TIME



Sources:

GAO 1998: “Nuclear Waste: Fourth Annual Report on DOE’s Nuclear Waste Program,” United States General Accounting Office, GAO/FECD-88-131, September 1988.

DOE 1998: “Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program,” DOE/RW-510, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Washington, DC-20586, December 1998.

DOE 2008: “Analysis of the Total System Lifecycle Cost of the Civilian Radioactive Waste Management Program,” Fiscal Year 2007, DOE/RW-0591, Washington, D.C., July 2008.

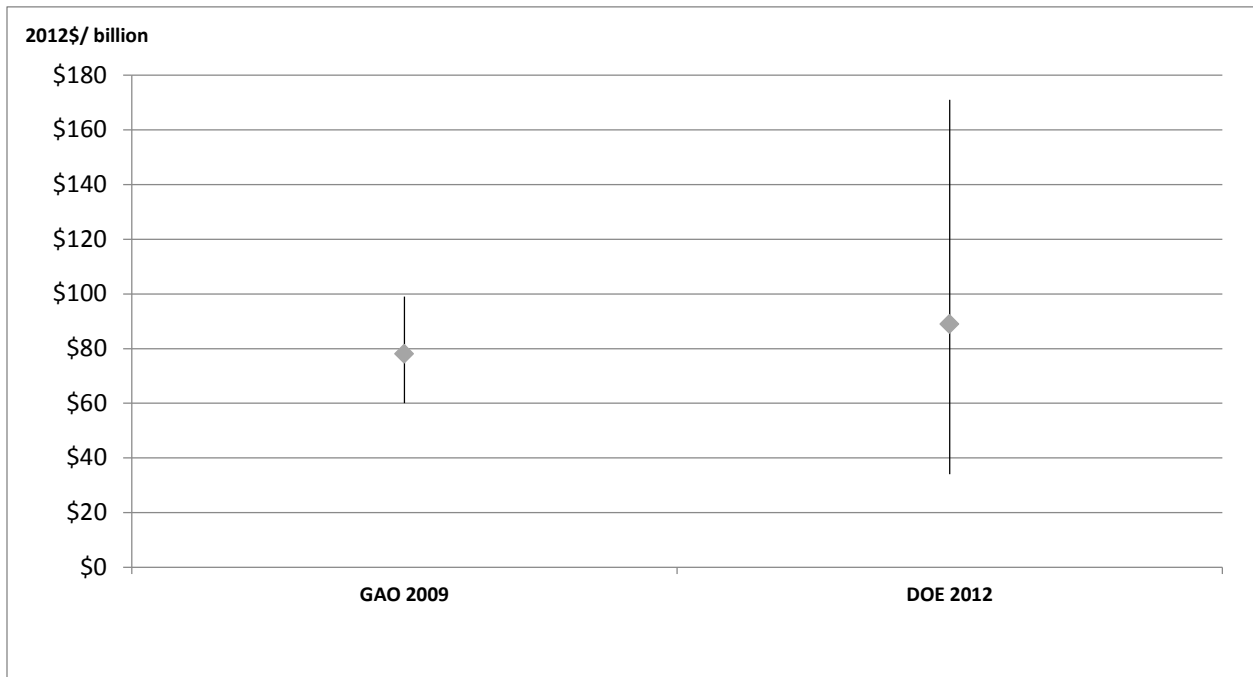
GAO 2009: “Nuclear Waste Management; Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives,” Government Accountability Office, GAO-10-48, November 2010.

Using the “best estimate” identified by Cliff W. Hamal, Julie M. Carey and Christopher L. Ring, Navigant, *Spent Nuclear Fuel Management: How Centralized Interim Storage Can Expand Options and Reduce Costs*, for the Blue Ribbon Commission on America’s Nuclear Future, May 16, 2011.

DOE 2013: U.S. Department of Energy, “Nuclear Waste Fund Fee Adequacy Assessment Report,” January 2013.

EXHIBIT MNC-2, Page 1 of 1

RANGE OF REPOSITORY COST ESTIMATES WITHIN STUDIES



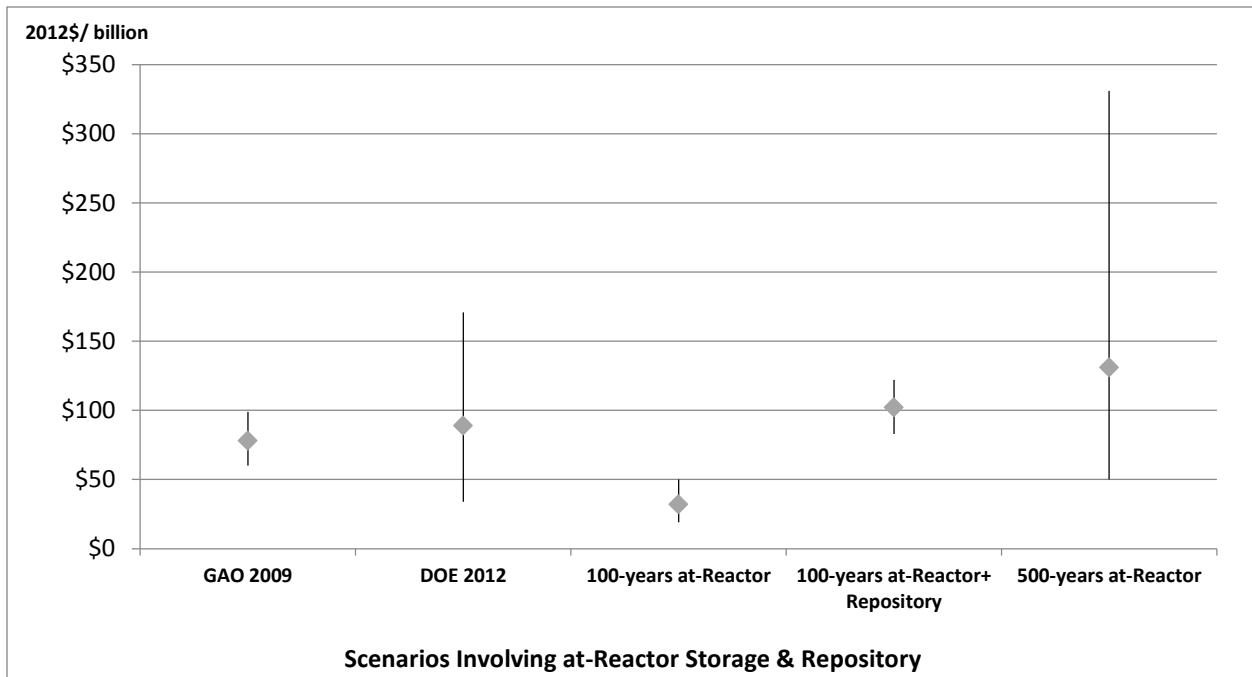
Sources:

GAO 2009: “Nuclear Waste Management; Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives,” Government Accountability Office, GAO-10-48, November 2010 (p.71).

Using the “best estimate” identified by Cliff W. Hamal, Julie M. Carey and Christopher L. Ring, Navigant, *Spent Nuclear Fuel Management: How Centralized Interim Storage Can Expand Options and Reduce Costs*, for the Blue Ribbon Commission on America's Nuclear Future, May 16, 2011 (p.27), which is 1.34 times the GAO mean. Estimates are adjusted from 2009 to 2012 dollars using the Producer Price Index for Intermediate materials and supplies (PPI change factor = 1.096). Storage costs are excluded.

DOE 2013: U.S. Department of Energy, “Nuclear Waste Fund Fee Adequacy Assessment Report,” January 2013.

EXHIBIT MNC-3, Page 1 of 1
AT-REACTOR STORAGE + REPOSITORY COST SCENARIO



Sources:

GAO 2009: “Nuclear Waste Management; Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives,” Government Accountability Office, GAO-10-48, November 2010 (p.71).

Using the “best estimate” identified by Cliff W. Hamal, Julie M. Carey and Christopher L. Ring, Navigant, *Spent Nuclear Fuel Management: How Centralized Interim Storage Can Expand Options and Reduce Costs*, for the Blue Ribbon Commission on America's Nuclear Future, May 16, 2011 (p.27), which is 1.34 times the GAO mean. Estimates are adjusted from 2009 to 2012 dollars using the Producer Price Index for Intermediate materials and supplies (PPI change factor = 1.096).

DOE 2013: U.S. Department of Energy, “Nuclear Waste Fund Fee Adequacy Assessment Report,” January 2013.

EXHIBIT MNC-4, Page 1 of 1
NUCLEAR WASTE MANAGEMENT COST ESTIMATES

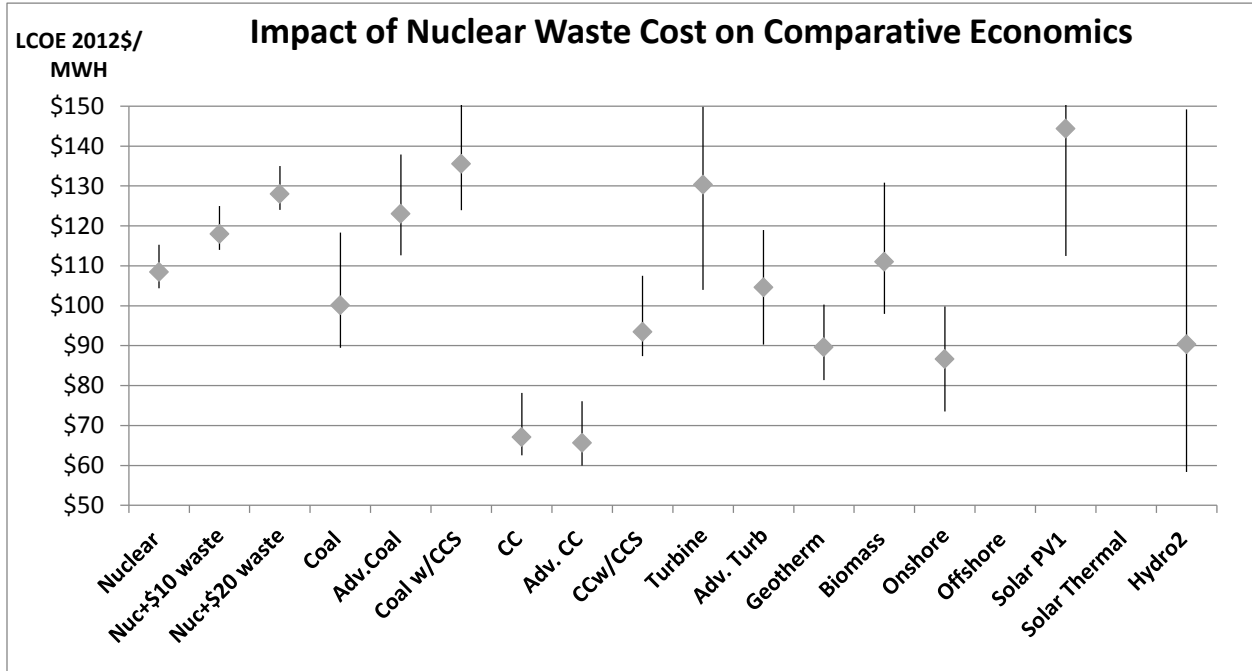
Cost Category	DOE Repository + At-Reactor Storage Cost in Billions of 2012 Dollars	
	Low	High
Repository	\$34	\$171
Stranded Waste 300 years	\$105	\$105
3 repacks over 300 years	\$75	\$75
Total	\$214	\$351

Cost in \$/KWH		
DOE Assumption (29,000 TWH)	\$0.0074	\$0.012
DOE Corrected (22,000 TWH)	\$0.0097	\$0.016

Source: see text for discussion. Repository costs are the most recent DOE estimates. Stranded waste costs are based on the Hamal, 2011, estimate that shows stranding adds \$22 billion over the first 70 years. Repackaging costs are estimated by multiplying the cost per cask (\$1.6 million) times the number of casks (15,000). The output of the nuclear fleet is assumed to be 25% lower than estimated by DOE based on declining load factors, early retirements, and abandoned uprates not considered by DOE. This is also consistent with all remaining reactors plus five new ones – Vogtle, Summer, Watts Bar – running for a full 60 years at 90 percent capacity factor.

EXHIBIT MNC-5, Page 1 of 1

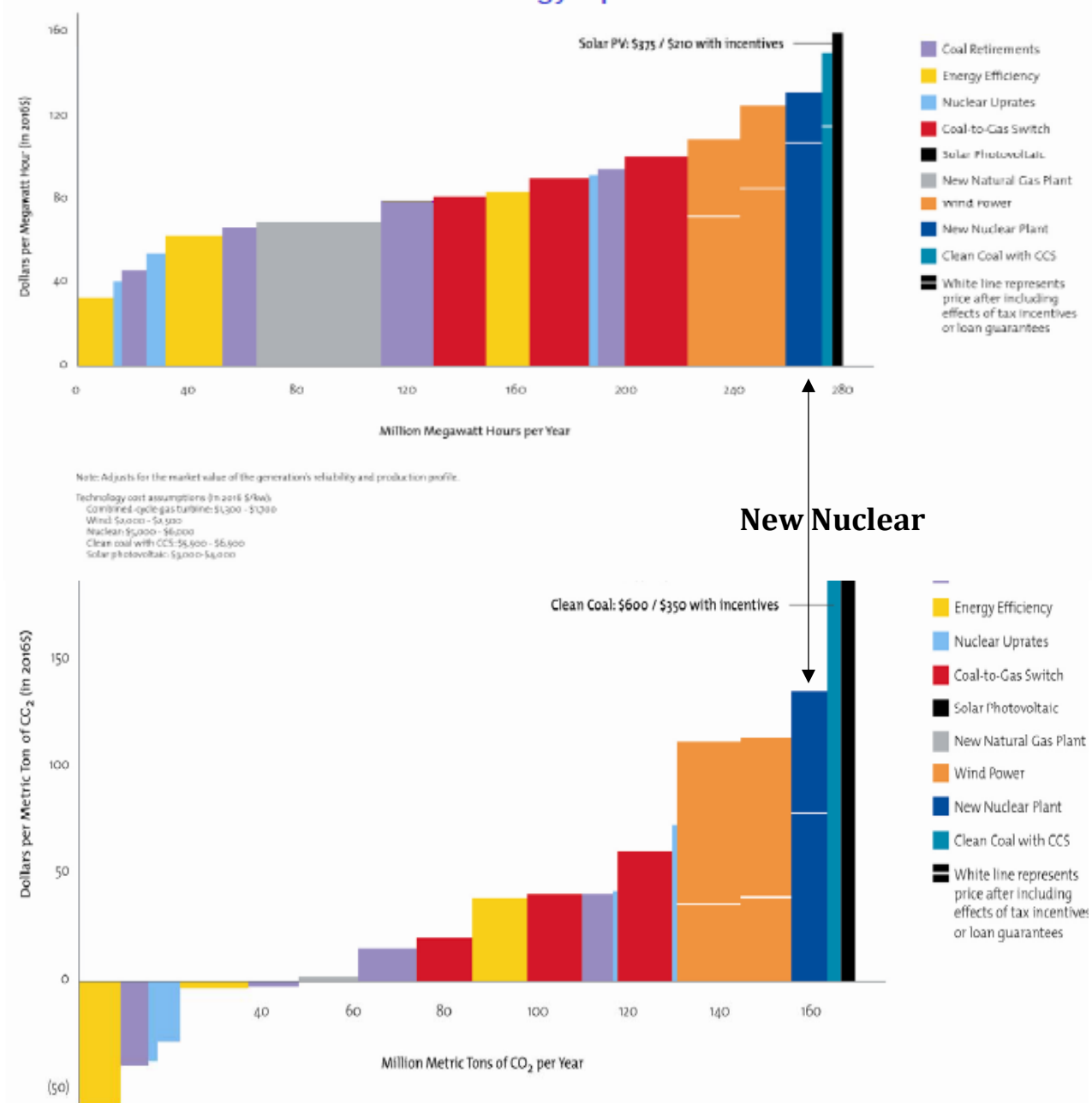
IMPACT OF WASTE MANAGEMENT COSTS ON RESOURCE COST COMPARISONS



Source: Energy Information Administration, “Levelized Cost of New Generation Resources in the Annual Energy Outlook,” *Annual Energy Outlook*, 2013.

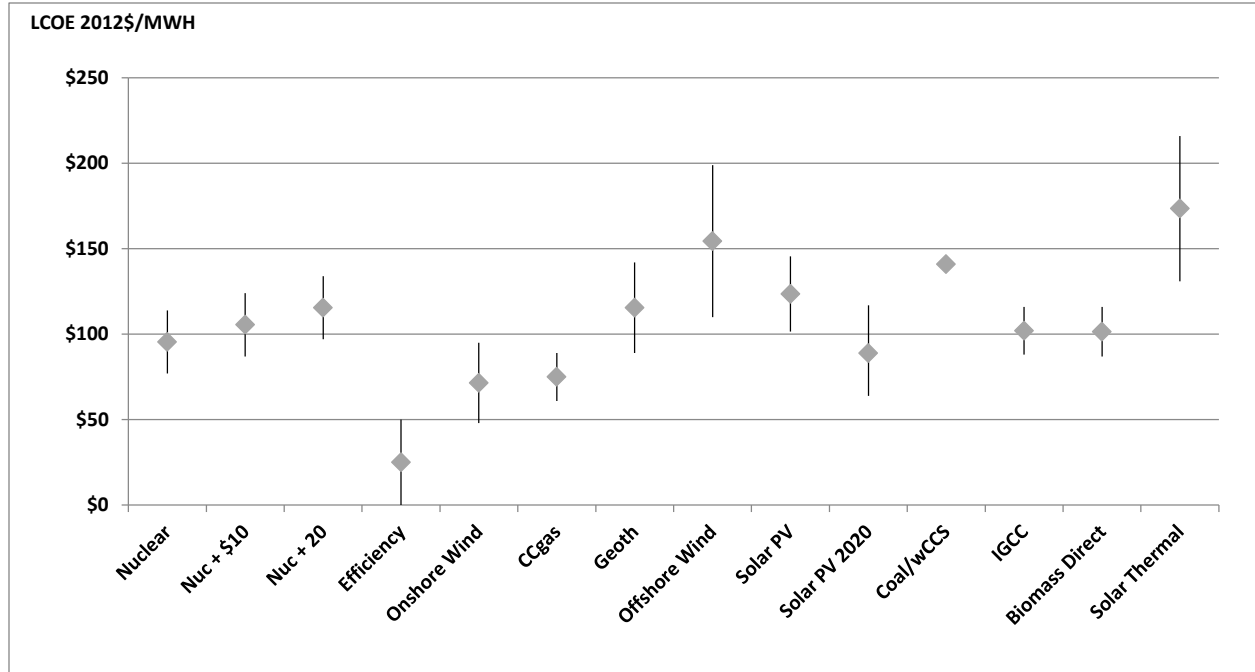
There are Cheap Ways and Costly Ways to Clean the Generation Fleet

Levelized Cost of Clean Energy Options in PJM



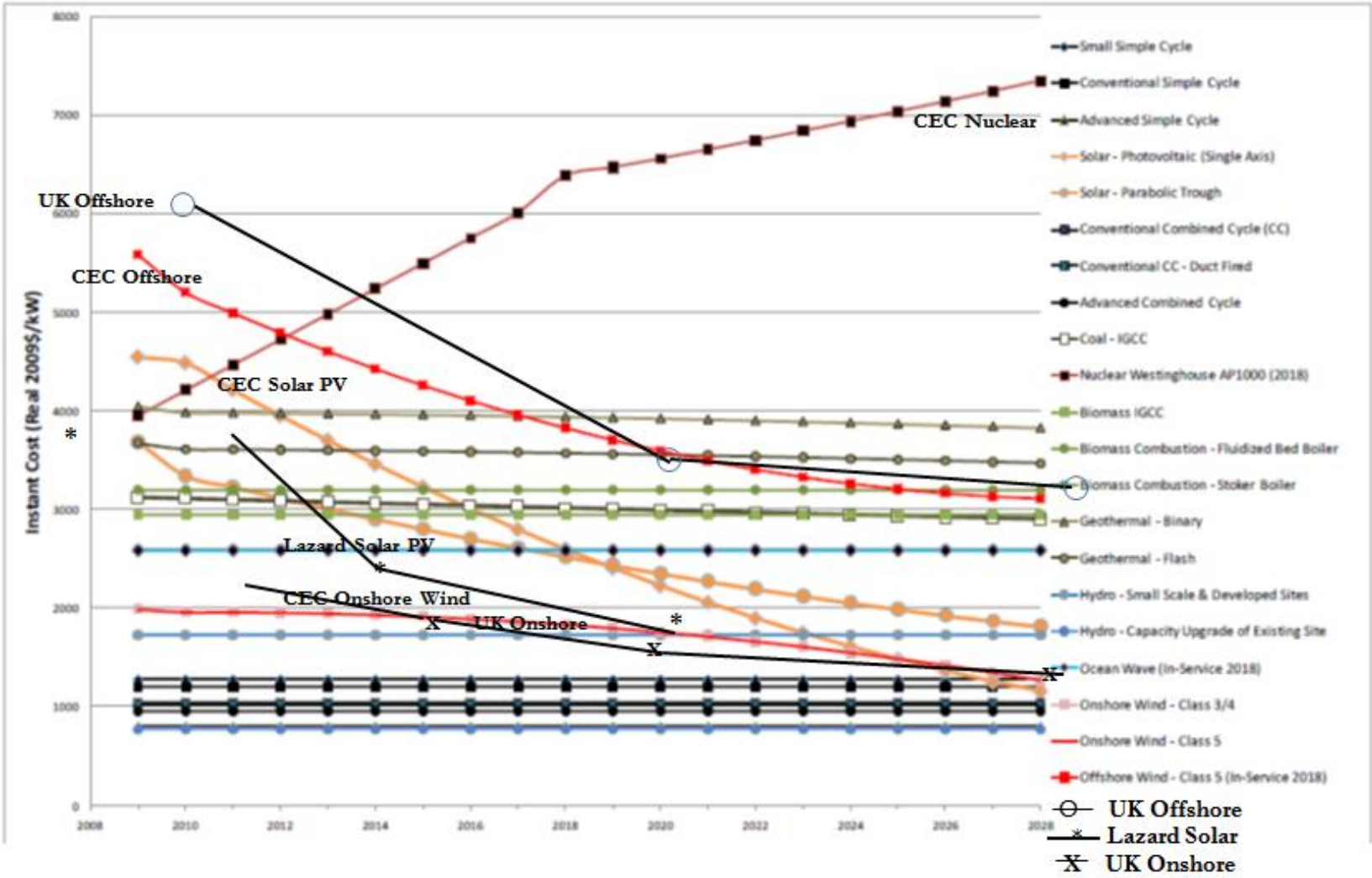
Source: John Rowe, *Energy Policy: Above All, Do No Harm*, American Enterprise Institute, March 8, 2011.

EXHIBIT MNC-7, PAGE 1 OF 1
LAZARD, LEVELIZED COST OF ELECTRICITY



Sources: Lazard, Levelized Cost of Electricity 6.0 for all except solar PV 202, which is Lazard, Levelized Cost of Electricity 5.0.

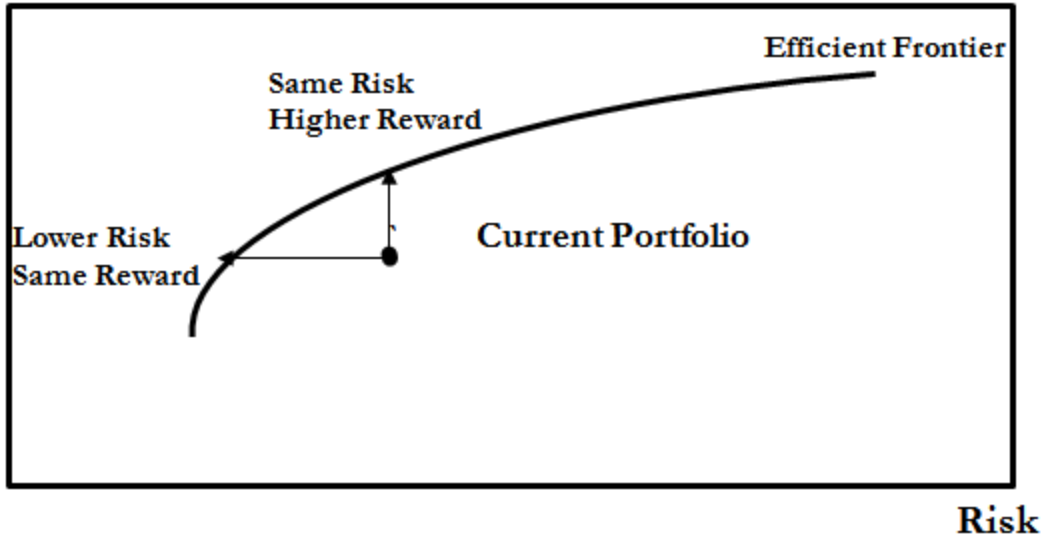
EXHIBIT MNC-8, PAGE 1 OF 1
 OVERNIGHT COST TRENDS IN THE U.S. AND UK



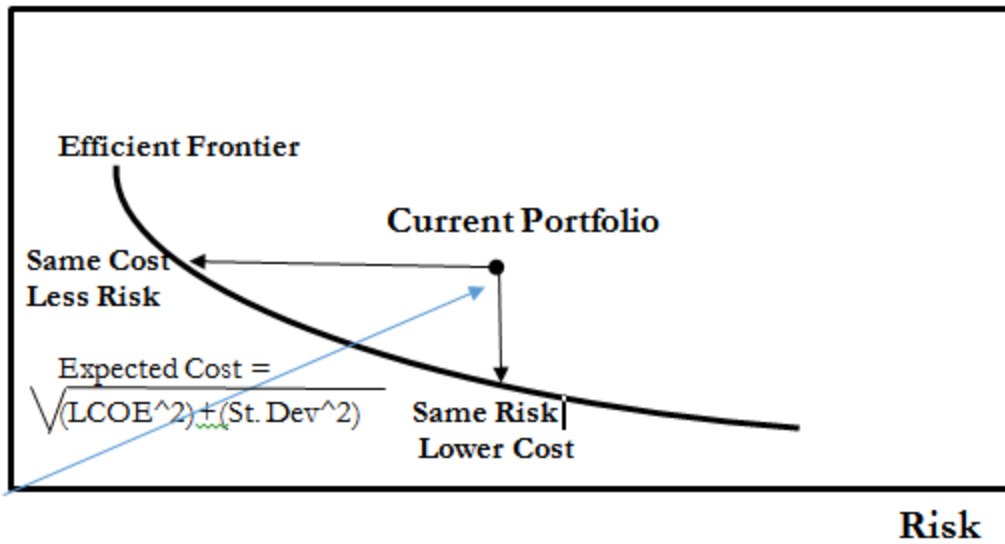
Source: California Energy Commission, *Cost of Central Station Generation*, January 2010; Mott MacDonald, *Cost of Low-carbon Generation Technologies: 2011*; Lazard, *Levelized Cost of Energy Analysis - Version 5.0*, June 2011.

EXHIBIT MNC-9, PAGE 1 OF 1
 PORTFOLIO ANALYSIS OF RISK/COST REWARD ANALYSIS

Reward

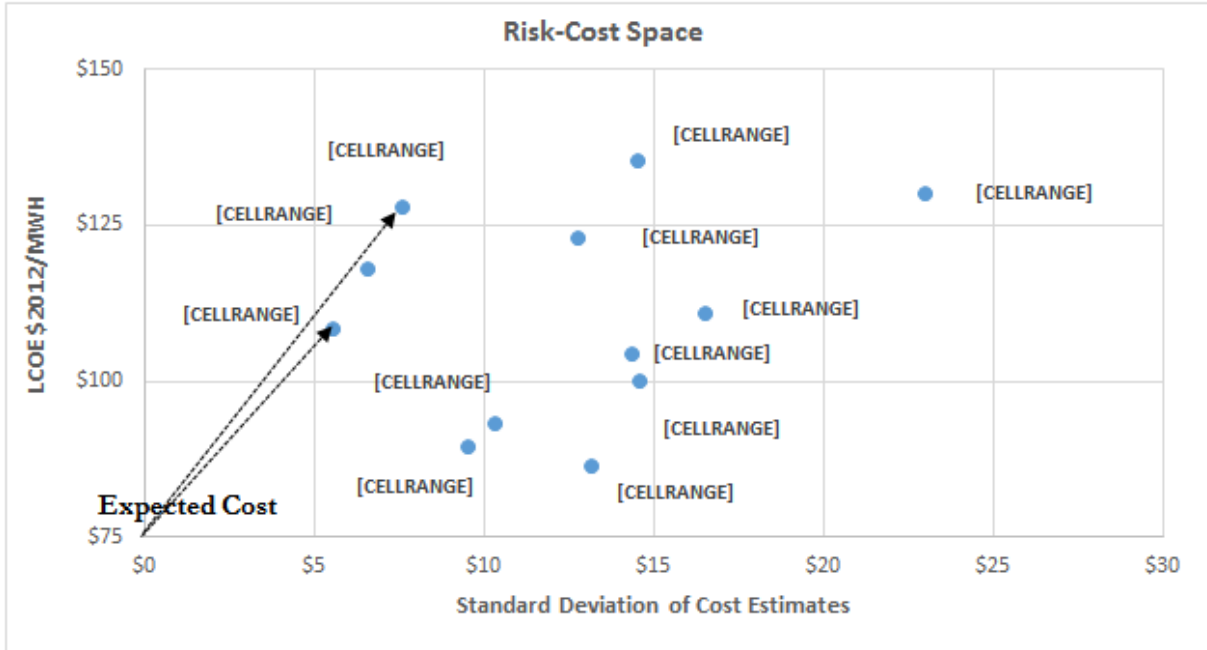


Cost

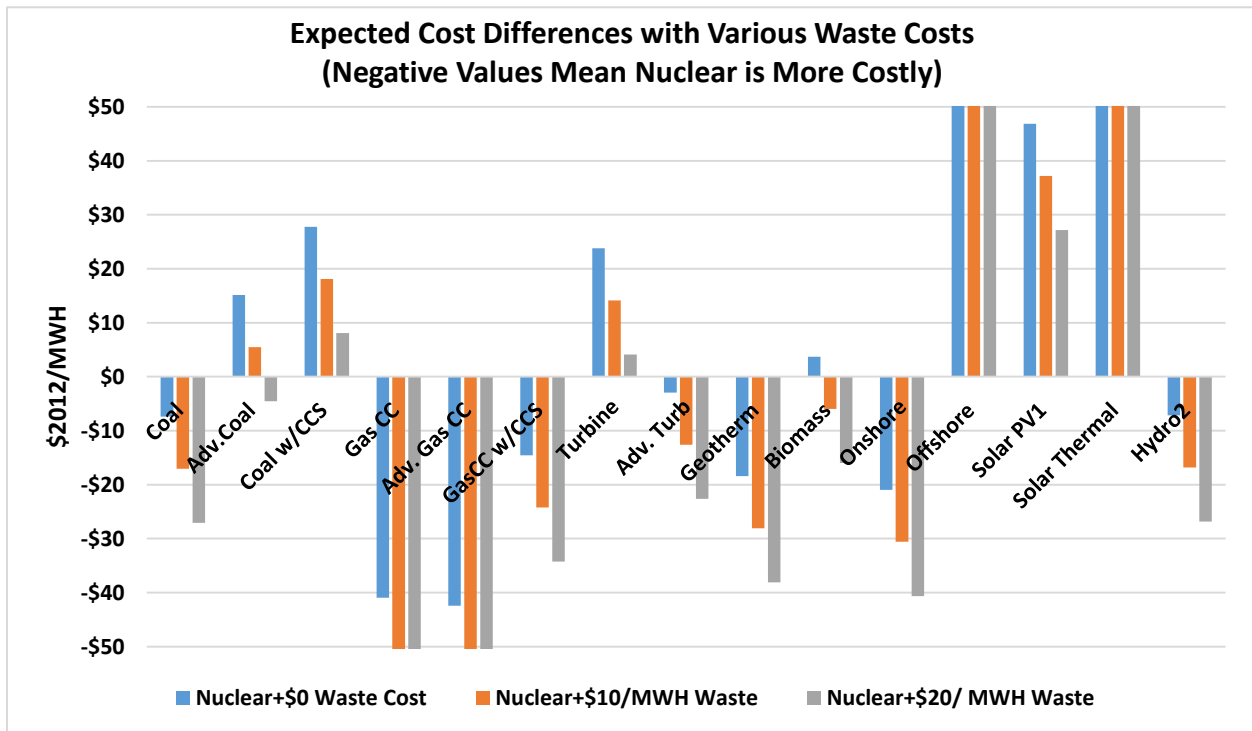


Source: Ken Costello, *Making the Most of Alternative Generation Technologies: A Perspective on Fuel Diversity*, NRRI, March 2005), p. 12, upper graph

EXHIBIT MNC-10, Page 1 of 1
RISK FRAMEWORK EXPECTED COST WHERE WASTE COSTS AFFECT
PERCEIVED ATTRACTIVENESS OF RESOURCES



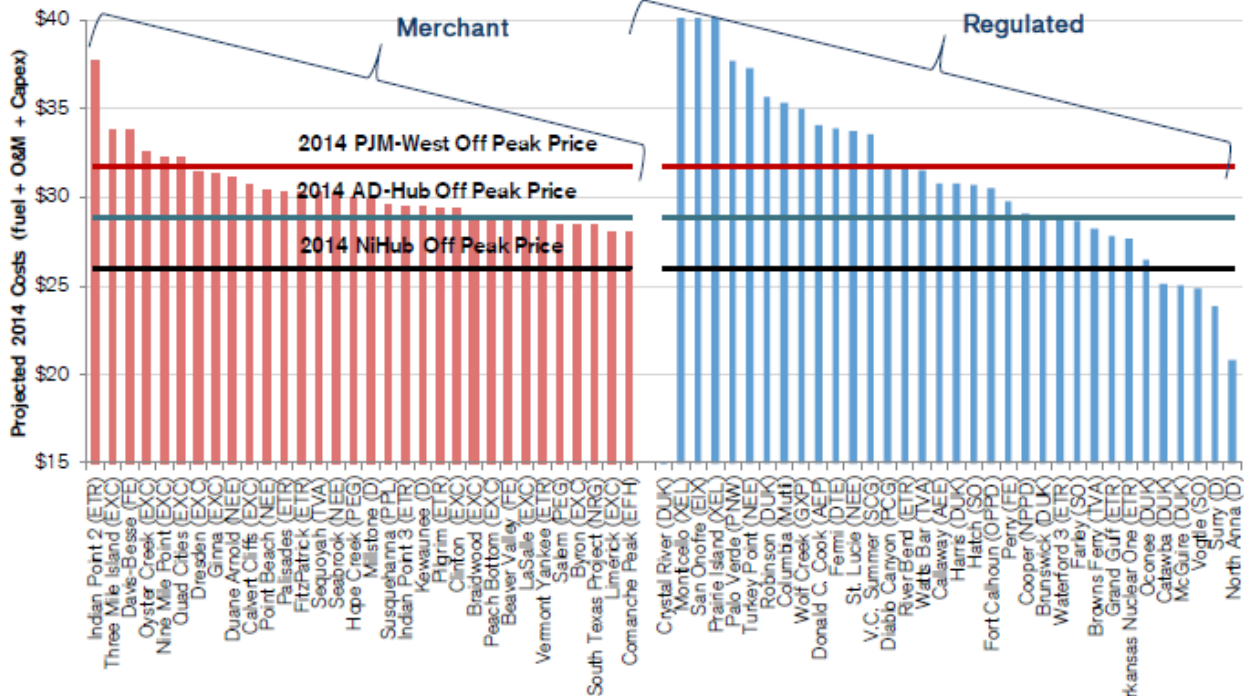
Source: Expected cost is distance from the origin. See text for discussion.



Source: Expected cost is distance from the origin. See text for discussion.

EXHIBIT MNC-11, PAGE 1 OF 1
 CREDIT SUISSE ANALYSIS OF AGING REACTOR ECONOMICS

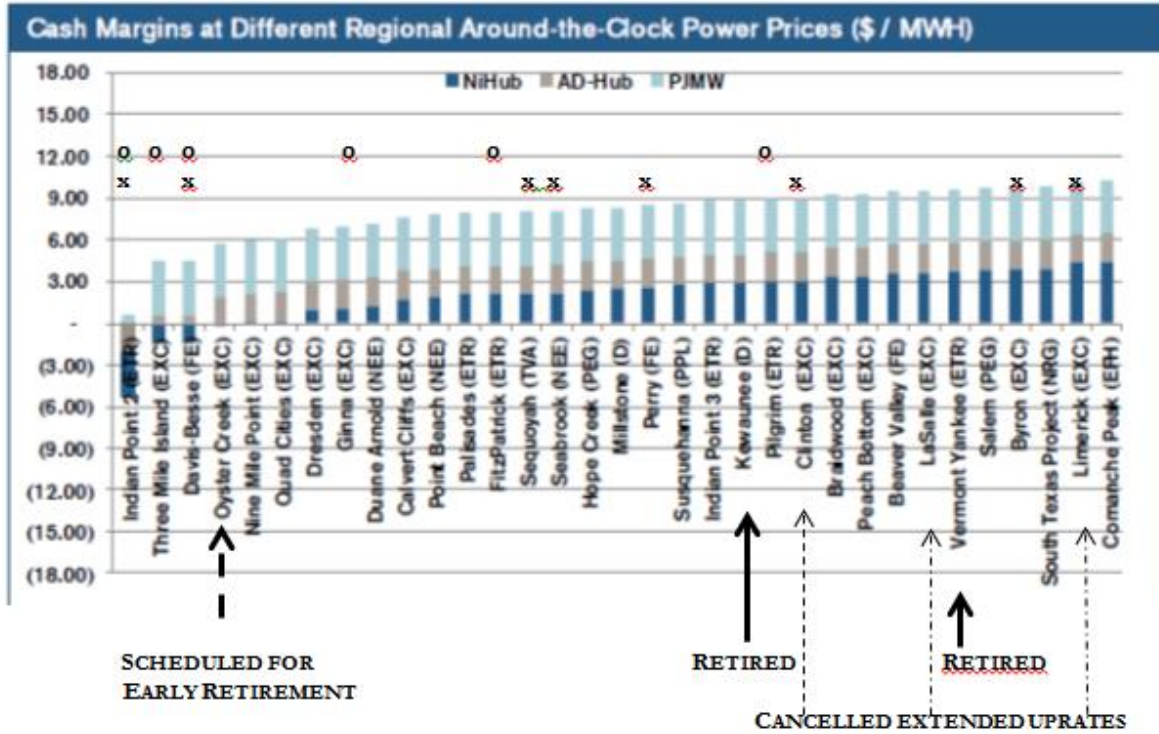
All-in Nuclear Plant Economics are Thin in Off-Peak



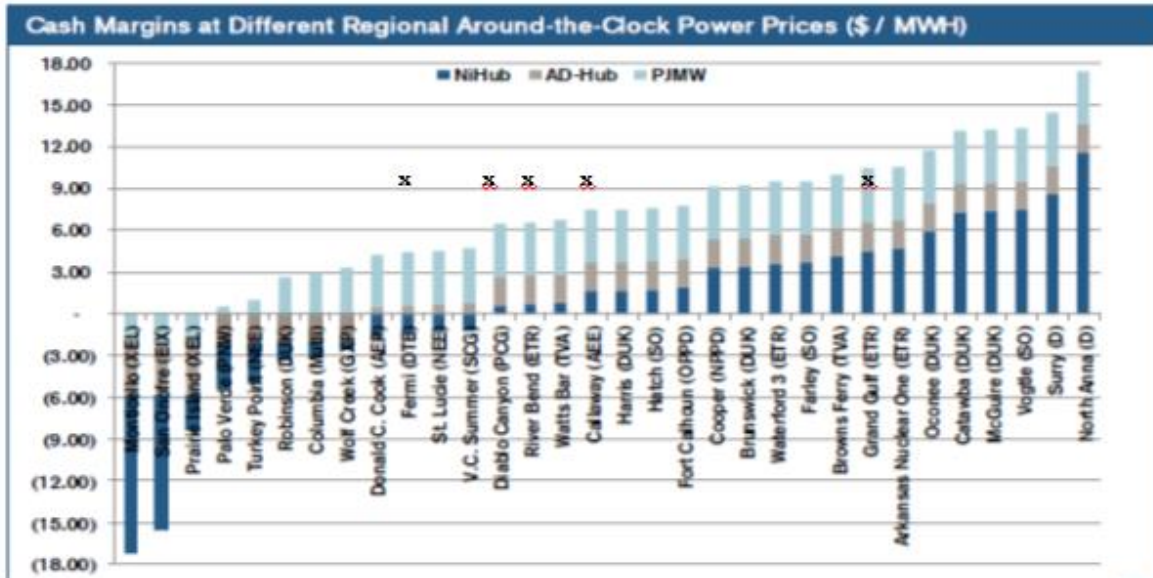
Source: Credit Suisse, *Nuclear... The Middle Age Dilemma?, Facing Declining Performance, Higher Costs, Inevitable Mortality*, February 19, 2013, p. 10.

EXHIBIT MNC-12, PAGE 1 OF 1 AGING REACTOR CASH MARGINS

MERCHANT 'CASH MARGINS' AT DIFFERENT POWER HUBS



REGULATED 'CASH MARGINS' AT DIFFERENT POWER HUBS



Legend: o= reactors that are being considered for early shut down
x= license renewals pending or expected in the near future.

Source: Credit Suisse, *Nuclear... The Middle Age Dilemma?, Facing Declining Performance, Higher Costs, Inevitable Mortality*, February 19, 2013, p. 11.

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EDUCATION:

Yale University, Ph.D., 1979, Sociology
University of Maryland, M.A., 1973, Sociology
City College of New York, B.A., 1968, English

PROFESSIONAL EXPERIENCE:

President, Citizens Research, 1983 - present
Research Director, Consumer Federation of America, 1983-present
Associated Fellow, Columbia Institute on Tele-Information, 2003-present
Fellow, Donald McGannon Communications Research Center, Fordham University, 2005-present
Senior Fellow for Economic Analysis, Institute for Energy and the Environment, Vermont Law School, 2009-present
Fellow, Silicon Flatirons, University of Colorado, 2009-present
Fellow, Stanford Center on Internet and Society, 2000-2010
Principle Investigator, Consumer Energy Council of America, Electricity Forum, 1985-1994
Director of Energy, Consumer Federation of America, 1984-1986
Director of Research, Consumer Energy Council of America, 1980-1983
Consultant, Office of Policy Planning and Evaluation, Food and Nutrition Service, United States Department of Agriculture, 1981-1984
Consultant, Advanced Technology, Inc., 1981
Technical Manager, Economic Analysis and Social Experimentation Division, Applied Management Sciences, 1979
Research Associate, American Research Center in Egypt, 1976-1977
Research Fellow, American University in Cairo, 1976
Staff Associate, Checchi and Company, Washington, D.C., 1974-1976
Consultant, Division of Architectural Research, National Bureau of Standards, 1974
Consultant, Voice of America, 1974
Research Assistant, University of Maryland, 1972-1974

TEACHING EXPERIENCE:

Lecturer, Washington College of Law, American University, Spring, 1984 - 1986, Seminar in Public Utility Regulation
Guest Lecturer, University of Maryland, 1981-82, Energy and the Consumer, American University, 1982, Energy Policy Analysis
Assistant Professor, Northeastern University, Department of Sociology, 1978-1979, Sociology of Business and Industry, Political Economy of Underdevelopment, Introductory Sociology, Contemporary Sociological Theory; College of Business Administration, 1979, Business and Society
Assistant Instructor, Yale University, Department of Sociology, 1977, Class, Status and Power
Teaching Assistant, Yale University, Department of Sociology, 1975-1976, Methods of Sociological Research, The Individual and Society
Instructor, University of Maryland, Department of Sociology, 1974, Social Change and Modernization, Ethnic Minorities
Instructor, U.S. Army Interrogator/Linguist Training School, Fort Hood, Texas, 1970-1971

PROFESSIONAL ACTIVITIES:

Member, Advisory Committee on Appliance Efficiency Standards, U.S. Department of Energy, 1996 - 1998

Member, Energy Conservation Advisory Panel, Office of Technology Assessment, 1990-1991
Fellow, Council on Economic Regulation, 1989-1990
Member, Increased Competition in the Electric Power Industry Advisory Panel, Office of Technology Assessment, 1989
Participant, National Regulatory Conference, The Duty to Serve in a Changing Regulatory Environment, William and Mary, May 26, 1988
Member, Subcommittee on Finance, Tennessee Valley Authority Advisory Panel of the Southern States Energy Board, 1986-1987
Member, Electric Utility Generation Technology Advisory Panel, Office of Technology Assessment, 1984 - 1985
Member, Natural Gas Availability Advisor Panel, Office of Technology Assessment, 1983-1984
Participant, Workshop on Energy and the Consumer, University of Virginia, November 1983
Participant, Workshop on Unconventional Natural Gas, Office of Technology Assessment, July 1983
Participant, Seminar on Alaskan Oil Exports, Congressional Research Service, June 1983
Member, Thermal Insulation Subcommittee, National Institute of Building Sciences, 1981-1982
Round Table Discussion Leader, The Energy Situation: An Open Field For Sociological Analysis, 51st Annual Meeting of the Eastern Sociological Society, New York, March, 1981
Member, Building Energy Performance Standards Project Committee, Implementation Regulations Subcommittee, National Institute of Building Sciences, 1980-1981
Participant, Summer Study on Energy Efficient Buildings, American Council for an Energy Efficient Economy, August 1980
Member, University Committee on International Student Policy, Northeastern University, 1978-1979
Chairman, Session on Dissent and Societal Reaction, 45th Annual Meeting of the Eastern Sociological Society, April, 1975
Member, Papers Committee, 45th Annual Meeting of the Eastern Sociological Society, 1975
Student Representative, Programs, Curricula and Courses Committee, Division of Behavioral and Social Sciences, University of Maryland, 1973-1974
President, Graduate Student Organization, Department of Sociology, University of Maryland, 1973-1974

HONORS AND AWARDS:

Ester Peterson Award for Consumer Service, 2010
American Sociological Association, Travel Grant, Uppsala, Sweden, 1978
Fulbright-Hayes Doctoral Research Abroad Fellowship, Egypt, 1976-1977
Council on West European Studies Fellowship, University of Grenoble, France, 1975
Yale University Fellowship, 1974-1978
Alpha Kappa Delta, Sociological Honorary Society, 1973
Phi Delta Kappa, International Honorary Society, 1973
Graduate Student Paper Award, District of Columbia Sociological Society, 1973
Science Fiction Short Story Award, University of Maryland, 1973
Maxwell D. Taylor Award for Academic Excellence, Arabic, United States Defense Language Institute, 1971
Theodore Goodman Memorial Award for Creative Writing, City College of New York, 1968
New York State Regents Scholarship, 1963-1968
National Merit Scholarship, Honorable Mention, 1963

PUBLICATIONS:

ENERGY

Books and Chapters

“Recognizing the Limits of Markets, Rediscovering Public Interest in Utilities,” in Robert E. Willett (ed), *Electric and Natural Gas Business: Understanding It* (2003 and Beyond) (Houston: Financial Communications: 2003)

"Protecting the Public Interest in the Transition to Competition in Network Industries," The Electric Utility Industry in Transition (Public Utilities Reports, Inc. & the New York State Energy Research and Development Authority, 1994)

"The Seven Percent Solution: Energy Prices, Energy Policy and the Economic Collapse of the 1970s," in *Energy Concerns and American Families in the 1980s* (Washington, D.C.: The American Association of University Women Educational Foundation, 1983)

"Natural Gas Policy Analysis," in Edward Mitchell (Ed.), Natural Gas Pricing Policy (Washington, D.C.: American Enterprise Institute, 1983)

Equity and Energy: Rising Energy Prices and the Living Standard of Lower Income Americans (Boulder, Colorado: Westview Press, 1983)

Articles and Papers:

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"Nuclear Safety and Affordable Reactors: Can We Have Both?," *Bulletin of the Atomic Scientists*, 68(2), 2012

"Nuclear Safety and Nuclear Economics, Fukushima Reignites the Never-ending Debate: Is Nuclear Power not worth the risk at any price?," *Symposium on the Future of Nuclear Power*, University of Pittsburgh, March 27-28, 2012

"Prudent Resource Acquisition in a Complex Decision Making Environment: Multidimensional Analysis Highlights the Superiority of Efficiency," *Current Approaches to Integrated Resource Planning, 2011 ACEEE National Conference on Energy Efficiency as a Resource*, Denver, September 26, 2011

"The Implications of Fukushima: The US perspective," *Bulletin of the Atomic Scientists* July/August 2011 67: 8-13
Least Cost Planning for 21st Century Electricity Supply: Meeting the Challenges of Complexity and Ambiguity in Decision Making, MACRUC Annual Conference, June 5, 2011

"Risk, Uncertainty and Ignorance: Analytic Tools for Least-Cost Strategies to Meet Electricity Needs in a Complex Age," *Variable Renewable Energy and Natural Gas: Two Great Things that Go Together, or Best Not to Mix Them*. NARUC Winter Committee Meetings, Energy Resources, Environment and Gas Committee, February 15, 2011

"The Failure of Federal Authorities to Protect American Energy Consumers From Market Power and Other Abusive Practices," *Loyola Consumer Law Review*, 19:4 (2007)

"Too Much Deregulation or Not Enough," *Natural Gas and Electricity*, June 2005

"Real Energy Crisis is \$200 Billion Natural Gas Price Increase," Natural Gas and Electricity, August 2004

"Regulators Should Regain Control to Prevent Abuses During Scarcity," Natural Gas, August 2003

"Economics of Power: Heading for the Exits, Deregulated Electricity Markets Not Working Well," *Natural Gas*, 19:5, December 2002

"Let's Go Back," Public Power, November-December 2002

"Conceptualizing and Measuring the Burden of High Energy Prices," in Hans Landsberg (Ed.), High Energy Costs: Assessing the Burden (Washington, D.C.: Resources For the Future, 1982)

"Energy Efficiency Investments in Single Family Residences: A Conceptualization of Market Inhibitors," in Jeffrey Harris and Jack Hollander (Eds.), *Improving Energy Efficiency in Buildings: Progress and Problems* (American Council for An Energy Efficient Economy, 1982)

"Policy Packaging for Energy Conservation: Creating and Assessing Policy Packages," in Jeffrey Harris and Jack Hollander (Eds.), *Improving Energy Efficiency in Buildings: Progress and Problems* (American Council for An Energy Efficient Economy, 1982)

"The Role of Consumer Assurance in the Adoption of Solar Technologies," *International Conference on Consumer Behavior and Energy Policy*, August, 1982

"Energy and the Poor," *Third International Forum on the Human Side of Energy*, August, 1982

"Energy Price Policy and the Elderly," *Annual Conference, National Council on the Aging*, April, 1982

"Energy and Jobs: The Conservation Path to Fuller Employment," *Conference on Energy and Jobs conducted by the Industrial Union Department of the AFL-CIO*, May 1980

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- A Boom for Big Oil – A Bust for Consumers: Ana analysis of Policies to Meet American Energy Needs, Consumer Federation of America, September 2008
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Debunking Oil Industry Myths and Deception: The \$100 Billion Consumer Rip-Off (Consumer Federation of America and Consumers Union, May 3, 2006)

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Record Prices, Record Oil Company Profits: The Failure Of Antitrust Enforcement To Protect American Energy Consumers (Consumer Federation of America, Consumers Union, September 2004)

Fueling Profits: Industry Consolidation, Excess Profits, & Federal Neglect: Domestic Causes of Recent Gasoline and Natural Gas Price Shocks (Consumer Federation of America and Consumers Union, May 2004)

Spring Break in the U.S. Oil Industry: Price Spikes, Excess Profits and Excuses (Consumer Federation of America, October 2003)

How Electricity Deregulation Puts Pressure On The Transmission Network And Increases It's Cost (Consumer Federation of America, Consumers Union and U.S. PIRG, August 2003)

A Discouraging Word (or Two, or Three, or Four) About Electricity Restructuring in Texas, Pennsylvania, New England and Elsewhere Consumer Federation of America, U.S. Public Interest Research Group and Consumers Union, March 2003)

All Pain, No Gain: Restructuring and Deregulation in the Interstate Electricity Market (Consumer Federation of America, September 2002)

U.S. Capitalism and the Public Interest: Restoring the Balance in Electricity and Telecommunications Markets (Consumer Federation of America, August 2002)

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Behind The Headlines Of Electricity Restructuring A Story Of Greed, Irresponsibility And Mismanagement Of A Vital Service In A Vulnerable Market (Consumer Federation of America, March 20, 2001)

Reconsidering Electricity Restructuring: Do Market Problems Indicate a Short Circuit or a Total Blackout? (Consumer Federation of America, November 30, 2000)

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Consumer Issues in Electric Utility Restructuring (Consumer Federation of America, February 12, 1998)

A Consumer Issue Paper on Electric Utility Restructuring (American Association of Retired Persons and the Consumer Federation of America, January, 1997)

Transportation, Energy, and the Environment: Balancing Goals and Identifying Policies, August 1995

A Residential Consumer View of Bypass of Natural Gas Local Distribution Companies, February 1988

The National Energy Security Policy Debate After the Collapse of Cartel Pricing: A Consumer Perspective, January 1987

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The Consumer Economics of CWIP: A Short Circuit for American Pocketbooks, April, 1984

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Concept Paper for a Non-profit, Community-based, Energy Services Company, November 1983

The Consumer and Energy Impacts of Oil Exports, April 1983

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The Impact of Rising Energy Prices on the Delivery of Public Service by Local Governments, August 1982

The Impact of Rising Energy Prices on the Low Income Population of the Nation, the South, and the Gulf Coast Region, July, 1982

A Comprehensive Analysis of the Impact of a Crude Oil Import Fee: Dismantling a Trojan Horse, April 1982

The Past as Prologue II: The Macroeconomic Impacts of Rising Energy prices, A Comparison of Crude Oil Decontrol and Natural Gas Deregulation, March, 1982

The Past as Prologue I: The Underestimation of Price Increases in the Decontrol Debate, A Comparison of Oil and Natural Gas, February 1982

Oil Price Decontrol and the Poor: A Social Policy Failure, February 1982

Natural Gas Decontrol: A Case of Trickle-Up Economics, January 1982

A Comprehensive Analysis of the Costs and Benefits of Low Income Weatherization and Its Potential Relationship to Low Income Energy Assistance, June 1981

Summary of Market Inhibitors, February 1981

Program Models and Program Management Procedures for the Department of Energy's Solar Consumer Assurance Network Project: A Rapid Feedback Evaluation, February 1981

An Analysis of the Economics of Fuel Switching Versus Conservation for the Residential Heating Oil Consumer, October 1980

Energy Conservation in New Buildings: A Critique and Alternative Approach to the Department of Energy's Building Energy Performance Standards, April, 1980

The Basics of BEPS: A Descriptive Summary of the Major Elements of the Department of Energy's Building Energy Performance Standards, February, 1980

COMMUNICATIONS AND MEDIA

Books and Chapters

The Future of Journalism: Addressing Pervasive Market Failure with Public Policy,” in R.W. McChesney and Victor Picard (eds.), *Will the Last Reporter Turn out the Lights* (New York: New Press, 2011)

“Broadband in America: A Policy of Neglect is not Benign,” in Enrico Ferro, Yogesh K. Dwivedi, J. Ramon Gil-Garcia, and Michael D. Williams, Eds., *Overcoming Digital Divides: Constructing an Equitable and Competitive Information Society*, IGI Global Press, 2009.

“Political Action And Internet Organization: An Internet-Based Engagement Model,” in Todd Davies and Seeta Pena Gangaharian, Eds., *Online Deliberation: Design, Research and Practice*, CSLI press.

“When Counting Counts: Marrying Advocacy and Academics in the Media Ownership Research Wars at the FCC,” forthcoming in Lynn M. Harter, Mohan J. Dutta, and Courtney Cole, Eds., *Communicating for Social Impact: Engaging Communication Theory, Research, and Pedagogy*, Hampton Press.

The Case Against Media Consolidation (Donald McGannon Communications Research Center, 2007)

Open Architecture as Communications Policy (Stanford Law School, Center for Internet and Society: 2004)

Media Ownership and Democracy in the Digital Information Age: Promoting Diversity with First Amendment Principles and Rigorous Market Structure Analysis (Stanford Law School, Center for Internet and Society: 2003)

Cable Mergers and Monopolies: Market Power In Digital Media and Communications Networks (Washington, D.C.: Economic Policy Institute, 2002)

“When Law and Social Science Go Hand in Glove: Usage and Importance of Local and National News Sources, Critical Questions and Answers for Media Market Analysis,” forthcoming in, Philip Napoli, Ed. *Media Diversity and Localism: Meaning and Metrics*, (Lawrence Erlbaum, 2007)

- “The Importance of Open Networks in Sustaining the Digital Revolution,” in Thomas M. Lenard and Randolph J. May (Eds.) *Net Neutrality or Net Neutering* (New York, Springer, 2006)
- “Reclaiming The First Amendment: Legal, Factual And Analytic Support For Limits On Media Ownership,” Robert McChesney and Benn Scott (Eds), *The Future of Media* (Seven Stories Press, 2005)
- “Building A Progressive Media And Communications Sector,” Elliot Cohen (Ed.), *News Incorporated: Corporate Media Ownership And Its Threat To Democracy* (Prometheus Books, 2005)
- “Hyper-Commercialism In The Media: The Threat To Journalism And Democratic Discourse,” Snyder-Gasher-Compton-(Eds), *Converging Media, Diverging Politics: A Political Economy Of News In The United States And Canada* (Lexington Books, 2005)
- “The Digital Divide Confronts the Telecommunications Act of 1996: Economic Reality versus Public Policy,” in Benjamin M. Compaine (Ed.), *The Digital Divide: Facing a Crisis or Creating a Myth?* (Cambridge: MIT Press, 2001)

Articles and Papers:

- “The Long History and Increasing Importance of Public Service Principles For 21st Century Public Digital Communications Networks,” *Journal on Telecommunications and High Technology Law*, forthcoming
- “From the Public Switched Telephone Network to the Public Digital Communications Network: Interconnection, Interoperability, Universal Service & Innovation at the Edge,” *Interconnection Policy for the Internet Age, The Digital Broadband Migration: The Future of Internet-Enabled Innovation, Silicon Flatirons*, February 10-11, 2013
- “Why Growing Up is Hard to Do: Institutional Challenges for Internet Governance in the “Quarter Life Crisis of the Digital Revolution,” *Journal on Telecommunications and High Technology Law*, 2013. 11(1).
- “Structured Viral Communications: The Political Economy and Social Organization of Digital Disintermediation,” *Journal on High Telecommunications and High Technology Law*, 9:1, 2011.
- “Crowd Sourcing Enforcement: Building a Platform for Participatory Regulation in the Digital Information Age,” presentation at *The Digital Broadband Migration: The Dynamics of Disruptive Innovation, Silicon Flatirons Ctr.* Feb. 12, 2011
- “The Central Role of Wireless in the 21st Century Communications Ecology: Adapting Spectrum and Universal Service Policy to the New Reality,” *Telecommunications Policy Research Conference*, September 2011
- “Round #1 in the Digital Intellectual Property Wars: Economic Fundamentals, Not Piracy, Explain How Consumers and Artists Won in the Music Sector,” *Telecommunications Policy Research Conference*, September 2008.
- “When The Market Does Not Reign Supreme: Localism And Diversity In U.S. Media Policy,” *International Communications Association*, forthcoming, May 2008
- “Minority Programming: Still at The Back of the Bus,” *International Communications Association*, May 2008, with Adam Lynn
- “Traditional Content Is Still King as the Source of Local News and Information,” *International Communications Association*, forthcoming, May 2008
- “Junk Science And Administrative Abuse In The Effort Of The FCC To Eliminate Limits On Media Concentration,” *International Communications Association*, May 2008.
- “Contentless Content Analysis: Flaws In The Methodology For Analyzing The Relationship Between Media Bias And Media Ownership,” forthcoming, *International Communications Association*, May 2008.
- “Network Neutrality,” *Toll Roads? The Legal and Political Debate Over Network Neutrality*, University of San Francisco Law School, January 26, 2008
- “The Lack of Racial and Gender Diversity in Broadcast Ownership and The Effects of FCC Policy: An Empirical Analysis,” *Telecommunications Research Policy Conference*, September 2007, with Derek Turner
- “New Media and Localism: Are Local Cable Channels and Locally Focused Websites Significant New and Diverse Sources of Local News and Information? An Empirical Analysis,” *Telecommunications Research Policy Conference*, September 2007, with Adam Lynn
- “A Case Study of Why Local Reporting Matters: Photojournalism Framing of the Response to Hurricane Katrina in Local and National Newspapers,” *International Communications Association*, May 2007.
- “Will the FCC Let Local Media Rise from the Ashes of Conglomerate Failure,” *International Communications Association*, May 2007.
- “The Failure of Federal Authorities to Protect American Energy Consumers From Market Power and Other Abusive Practices,” *Loyola Consumer Law Review*, 19:4 (2007)

- “The Central Role of Network Neutrality in the Internet Revolution,” *Public Interest Advocacy Center*, Ottawa Canada, November 24, 2006
- “Governing the Spectrum Commons,” September 2006. *Telecommunications Policy Research Conference*, October 2006
- “Accessing the Knowledge Commons in the Digital Information Age,” *Consumer Policy Review*, May/June 2006
- “Independent, Non-Commercial Video,” *Beyond Broadcast*, Berkman Center, Harvard University, May 12, 2006
- “Defining Appropriation Right in the Knowledge Commons of the Digital Information Age: Rebalancing the Role of Private Incentives and Public Circulation in Granting Intellectual Monopoly Privileges,” *Legal Battle Over Fair Use, Copyright, and Intellectual Property*, March 25, 2006
- “The Economics of Collaborative Production: A Framework for Analyzing the Emerging Mode of Digital Production,” *The Economics of Open Content: A Commercial Noncommercial Forum*, MIT January 23, 2006
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- “Information is a Public Good,” *Extending the Information Society to All: Enabling Environments, Investment and Innovation, World Summit on the Information Society*, Tunis, November 2005
- “The Importance of Collateral Communications and Deliberative Discourse in Building Internet-Based Media Reform Movements,” *Online Deliberation: Design, Research and Practice/DLAC*, November, 2005
- “Collaborative Production in Group-Forming Networks: The 21st Century Mode of Information Production and the Telecommunications Policies Necessary to Promote It,” *The State of Telecom: Taking Stock and Looking Ahead*, Columbia Institute on Tele-Information, October 2005
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- “Spectrum as Speech in the 21st Century,” *The Public Airwaves as a Common Asset and a Public Good: Implications for the Future of Broadcasting and Community Development in the U.S.*, Ford foundation, March 11, 2005
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- “Limits on Media Ownership are Essential,” *Television Quarterly*, Spring Summer 2004
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- “Cable Market Power, Pricing And Bundling After The Telecommunications Act Of 1996: Explorations Of Anti-Consumer, Anticompetitive Practices,” *Cable TV Rates: Has Deregulation Failed?*, Manhattan Institute, November 2003
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- “Picking Up The Public Policy Pieces Of Failed Business And Regulatory Models,” *Setting The Telecommunications Agenda*, Columbia Institute For Tele-Information November 3, 2000
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- "Direct Testimony of Dr. Mark N. Cooper on Behalf of the Office of Consumer Counsel," before the Public Utilities Commission of the State of Colorado, In the Matter of the Investigatory Docket Concerning Integrated Service Digital Network, Docket No. 92I-592T
- "Direct Testimony of Dr. Mark N. Cooper on Behalf of the People's Counsel," before the Florida Public Service Commission, Comprehensive Review of the Revenue Requirement and Rate Stabilization Plan of Southern Bell Telephone and Telegraph Company, Docket No. 900960-TL, November 16, 1992
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- "Direct Testimony on Behalf of the "Consumer Advocate," Public Service Commission State of South Carolina, In the Matter of the Application of Southern Bell Telephone and Telegraph Company for Approval of Revision to its General Subscribers Service Tariff (Caller ID), Docket No. 89-638-C, December 23, 1991
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- "Comments of the Consumer Federation of America," Before the Public Service Commission, State of Maryland, In the Matter of a Generic Inquiry by the Commission Into the Plans of the Chesapeake and Potomac Telephone Company of Maryland to Modernize the Telecommunications Infrastructure, Case No. 8388, November 7, 1991
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- "On Behalf of the Office of Consumer Advocate," before the State of Iowa, Department of Commerce, Utilities Division, In Re: Caller ID and Related Custom Service, Docket No. INU-90-2, December 3, 1990
- "On Behalf of the Office of Public Counsel," before the Florida Public Service Commission, In Re: Proposed Tariff Filings by Southern Bell Telephone and Telegraph Company When a Nonpublished Number Can be Disclosed and Introducing Caller ID to Touchstar Service, Docket No. 891194-TI, September 26, 1990
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- "On Behalf of the Office of Attorney General," before the Commonwealth of Kentucky, Public Service Commission, In the Matter of the Tariff Filing of GTE South Incorporated to Establish Custom Local Area Signaling Service, Case No. 90-096, August 14, 1990
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- "Testimony of Dr. Mark N. Cooper on Caller Identification" before the Committee on Constitutional and Administrative Law, House of Delegates, Annapolis, Maryland, February 22, 1990
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- "On Behalf of Manitoba Anti-poverty Organization, the Manitoba Society of Seniors and the Consumers Association of Canada (Manitoba)" before the Public Utilities Board in the Matter of the Request of Manitoba Telephone System for a General Rate Review, February 16, 1989
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- "On Behalf of the Universal Service Alliance, in the Matter of the Application of New York Telephone Company for Changes in its Rates, Rules, and Regulations for Telephone Service, State of New York Public Service Commission, Case No. 28961, April 1, 1985
- "On Behalf of North Carolina Legal Services, in the Matter of Application of Continental Telephone Company of North Carolina for an Adjustment of its Rates and Charges, Before the North Carolina Utilities Commission, Docket No. P-128, Sub 7, February 20, 1985
- "On Behalf of the Consumer Advocate in re: Application of Southern Bell Telephone and Telegraph Company for Approval Increases in Certain of Its Intrastate Rates and Charges," Before the South Carolina Public Service Commission, Docket No. 84-308-c, October 25, 1984
- "On Behalf of the Office of the Consumers' Counsel in the Matter of the Commission Investigation into the Implementation of Lifeline Telephone Service by Local Exchange Companies," Before the Public Utilities Commission of Ohio, Case No. 84-734-TP-COI, September 10, 1984
- "On Behalf of North Carolina Legal Services Resource Center in the Matter of Application Southern Bell Telephone and Telegraph Company for an Adjustment in its Rates and Charges Applicable to Intra-state Telephone Service in North Carolina," Before the North Carolina Utilities Commission, Docket No. P-55, Sub 834, September 4, 1984
- "On Behalf of Mississippi Legal Services Coalition in the Matter of the Citation to Show Cause Why the Mississippi Power and Light Company and Middle South Energy Should not Adhere to the Representation Relied Upon by the Mississippi Public Service Commission in Determining the Need and Economic Justification for Additional Generating Capacity in the Form of A Rehearing on Certification of the Grand Gulf Nuclear Project," Before the Mississippi Public Service Commission, Docket No. U-4387, August 13, 1984

"On Behalf of the Mississippi Legal Services Corporation Re: Notice of Intent to Change Rates of South Central Bell Telephone Company for Its Intrastate Telephone Service in Mississippi Effective January 1, 1984," before the Mississippi Public Service Commission, Docket No. U-4415, January 24, 1984

"The Impact of Rising Energy Prices on the Low Income Population of the Nation, the South, and the Gulf Coast Region," before the Mississippi Public Service Commission, Docket No. U4224, November 1982

"In the Matter of the Joint Investigation of the Public Service Commission and the Maryland Energy Office of the Implementation by Public Utility Companies Serving Maryland Residents of the Residential Conservation Service Plan," before the Public Service Commission of the State of Maryland, October 12, 1982

"The Impact of Rising Utility Rates on the Budgets of Low Income Households in the Region of the United States Served by the Mississippi Power Company and South Central Bell Telephone Company," before the Chancery Court of Forrest County, Mississippi, October 6, 1982

"The Impact of Rising Energy Prices on the Low Income Population of the Nation, the South and the Gulf Coast Region," before the Mississippi Public Service Commission, Docket No. U-4190, August 1982

September 29, 2014

**DECLARATION OF DR. ARJUN MAKHIJANI
IN SUPPORT OF MOTIONS TO REOPEN THE RECORD
OF NRC REACTOR LICENSING AND RE-LICENSING PROCEEDINGS**

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

1.0 STATEMENT OF QUALIFICATIONS

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

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

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

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

1.5. I have served on a number of oversight and advisory committees and boards with respect to my areas of expertise. I have served as an expert consultant to numerous organizations regarding technical, economic, and public health issues related to radioactive waste management. And 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. In 2007, I was

elected a Fellow of the American Physical Society (APS), an honor granted to at most one-half of one percent of APS members.

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

1.7. In 2009 and 2013, I prepared technical comments on NRC regulatory issuances related to storage and disposal of spent fuel. In 2009, I submitted comments on the NRC's proposed Waste Confidence Update and Temporary Storage Rule, 73 Fed. Reg. 59,551, 59,547 (Oct. 9, 2008).¹ In 2013, I submitted a declaration on the proposed rule regarding "Continued Storage of Spent Nuclear Fuel," 78 Fed. Reg. 56,776 (Sept. 13, 2013) and the Draft Waste Confidence Generic Environmental Impact Statement (Sept. 2013).²

2.0 PURPOSE OF DECLARATION

2.1. The purpose of my declaration is to describe the process by which fuel is irradiated in a nuclear reactor creates a grave public health and environmental hazard that cannot be undone and that lasts for millennia. I will also discuss the reasons for my professional opinion that the only effective way to protect the public and the environment from the severe hazards of spent reactor fuel in the long-term would be to place it in a properly selected and engineered deep geologic repository. Finally, I will explain the reasons for my professional opinion that the NRC should not license reactors to generate this hazardous material unless and until it has made safety findings regarding the technical feasibility and sufficiency of capacity of repository disposal, and until it has supported those findings with an environmental analysis.

¹ Comments of the Institute for Energy and Environmental Research on the Nuclear Regulatory Commission's Proposed Waste Confidence Rule Update and Proposed Rule Regarding Environmental Impacts of Temporary Spent Fuel Storage (Feb. 6, 2009) (Makhijani 2009); Declaration by Dr. Arjun Makhijani in Support of Comments of the Institute for Energy and Environmental Research on the Nuclear Regulatory Commission's Proposed Waste Confidence Rule Update (Feb. 6, 2009) (Makhijani Declaration 2009).

² Declaration of Dr. Arjun Makhijani Regarding the Waste Confidence Proposed Rule and Draft Generic Environmental Impact Statement (Dec. 20, 2013; corrected Jan. 7, 2014) (Makhijani Declaration 2013-12).

3.0 DOCUMENTS REVIEWED

3.1. In preparing this declaration, I reviewed the relevant portions of the Final Rule regarding Continued Spent Fuel Storage, 79 Fed. Reg. 56,238 (Sept. 19, 2014) (“Continued Storage Rule”) and NUREG-2157, the Continued Spent Fuel Storage Generic Environmental Impact Statement (Sep. 2014) (“Continued Storage GEIS”). I also reviewed and commented on the proposed version of the Continued Storage Rule, 78 Fed. Reg. 56,777 (Sept. 13, 2013) and the Draft Waste Confidence Generic Environmental Impact Statement (Sept. 2013).³

3.2. In addition, I have reviewed a number of other relevant documents. These documents include the relevant reference documents cited in the Continued Storage GEIS. I have also reviewed spent fuel storage and disposal-related portions of the NRC’s Final Rule regarding Revisions to Environmental Review for Renewal of Nuclear Power Plant Operating Licenses.⁴ In addition, I have reviewed the relevant spent fuel storage and disposal-related portions of the License Renewal Generic Environmental Impact Statement.⁵

3.3. In addition, I am familiar with the proposed and final versions of the 2010 Temporary Storage Rule.⁶

3.4. Further, I am familiar with the NRC’s uranium fuel cycle rule and relevant associated reference documents. And I am familiar with the NRC’s now-suspended Long-Term Waste Confidence Project and related documents.⁷

3.5. Finally, I am familiar with relevant aspects of governing law and guidance, including the National Environmental Policy Act (NEPA) and relevant NRC implementing regulations.

4.0 PROCESS FOR GENERATION OF SPENT FUEL IN NUCLEAR REACTORS

4.1 The purpose of a nuclear power plant is to generate electricity through the process of nuclear fission, or the splitting apart of uranium-235 atoms. The uranium-235 atom is split by bombarding it with neutrons, which causes a chain reaction of splitting uranium atoms that generates energy in the form of heat. This process is also known as “irradiation” of the reactor fuel.

4.2. Reactor fuel is made starting with uranium oxide (U₃O₈) or “yellowcake” as the raw material. In the fuel fabrication process, uranium oxide is first converted to uranium hexafluoride, then “enriched” by increasing the concentration of the fissile isotope of uranium (uranium-235), relative to the non-fissile isotope of uranium (uranium-238), after which it is

³ See par. 1.7 above.

⁴ 78 Fed. Reg. 37,282 (June 20, 2013) (“License Renewal Rule”).

⁵ NUREG-1437 (2013), Generic Environmental Impact Statement for License Renewal of Nuclear Plants (“License Renewal GEIS”).

⁶ NRC 2008b and NRC 2010b

⁷ See, e.g., NRC 2010a, p. 81040 and Borchardt 2012

converted into uranium dioxide and fabricated into pellets. (A fissile material can sustain a chain reaction with neutrons of very low, even zero energy.) These fuel pellets are put into long fuel rods. Bundles of fuel rods, called “assemblies,” are loaded into the cores of nuclear reactors.

4.3. In reactors, uranium fuel typically is used over three refueling cycles. The length of the cycle depends on the enrichment of the fresh fuel; in the United States a typical refueling cycle would take place every 1 to 1.5 years.⁸ Once it is no longer efficient to use the fuel, it is called “spent fuel” and discharged from the reactor. A given batch of fuel assemblies is generally removed from the reactor core every third refueling cycle.

5.0 SPENT REACTOR FUEL POSES IMMEDIATE, LONG-LASTING AND IRREVERSIBLE RISKS TO PUBLIC HEALTH AND THE ENVIRONMENT.

5.1. Fresh uranium fuel is only slightly radioactive. The risk of uranium arises mainly if it is inhaled. Once the uranium dioxide is made into fuel pellets, which are ceramics, there is very low risk of inhalation; indeed, there is relatively little risk from handling it since the external radiation from unirradiated uranium is quite low. Figure 1 is a Department of Energy photograph showing fresh nuclear fuel pellets being handled by a worker wearing gloves. The photograph also shows a fuel rod.

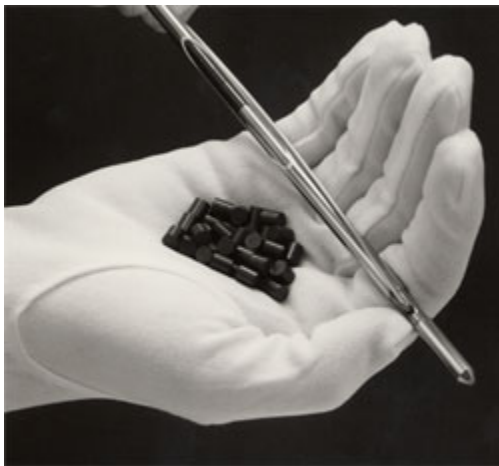


Figure 1: Fresh nuclear fuel pellets and a cutaway view of a fuel rod
Source: DOE, at http://commons.wikimedia.org/wiki/File:Nuclear_fuel_pellets.jpeg

When it is initially placed in a reactor, a metric ton of 4.4 percent enriched fuel generates just 90 milliwatts (0.09 watts) of thermal power from the radioactive decay of the uranium in the fuel pellets.⁹ An entire core of a nuclear power reactor would generate between a few watts and about 10 watts of thermal power, depending on the reactor. A person standing next to an unirradiated fuel equal to the amount in a reactor core would not feel such a small amount of

⁸ IPFM 2011, p. 122

⁹ Calculated using a specific activity of 3 microcuries per gram of 4.4 percent enriched uranium from equation 3 in Rucker and Johnson 1997. Weight of fuel is in terms of uranium metal, unless otherwise mentioned.

heat; for comparison, a single adult emits (in the infrared spectrum) about 100 watts of thermal energy simply from the process of living (consuming the energy content of food). This is more than 1,000 times the thermal energy of a metric ton of fresh enriched fuel.

5.2. In order to generate electricity, it is necessary first to create a nuclear chain reaction in the reactor core. This chain reaction consists of a succession nuclear fission events, each of which splits a uranium-235 nucleus.¹⁰ Each fission leads to one more fission. This sustained reaction results in heat, which is then used to make steam. The steam drives a turbine, which in turn drives an electricity generator.

5.3. By bombarding the reactor fuel's uranium-235 atoms with neutrons, the fission process drastically changes the characteristics of reactor fuel. The atomic fragments resulting from fission, known as fission products, are generally far more radioactive (in the sense of radioactivity per unit weight of material) than the uranium-235 itself. The longer the uranium-235 fission process goes on, the more new fission products are created. Many fission products are short-lived with half-lives of a few days, a few hours, or even much less. But these fission products also include long-lived radionuclides such as cesium-135, cesium-137, iodine-129, strontium-90, and technetium-99. As discussed below, plutonium-239 and other long-lived radionuclides are also created by nuclear reactions in the reactor.

5.4. The exact amount of fission products at the time the spent fuel is discharged depends on the initial enrichment of the fuel and the reactor type and the length of irradiation in the reactor. The weight of the fission products in spent fuel is typically 3.5 to 5 percent of the initial weight of the uranium loaded into the fuel rods. While the short lived radioactive materials decay away in days, weeks, or a few years, there is still a vast amount of radioactivity in the spent fuel even after 23 years of decay, the reference time used by the Department of Energy in calculating radionuclide inventories in spent fuel for the purpose of the Yucca Mountain EIS.¹¹

5.5. The large amount of accumulated radioactivity in the spent fuel, mainly due to fission products, also makes spent fuel very hot thermally in comparison to the thermal power of unirradiated (fresh) fuel. In contrast to very low thermal energy emitted by a core of fresh fuel, the core of a reactor just after shutdown for refueling generates millions of times more heat than the uranium fuel. This can cause the entire contents of a huge reactor vessel to boil if the heat is not removed by cooling. Essentially all of that heat comes from the radioactive decay of the fission and other radionuclides created during reactor operation. A prolonged failure of cooling after the shutdown of the reactor leads to a meltdown of the fuel, as occurred at Three Mile Island and three reactors at Fukushima Daiichi. A person standing near (e.g., within a foot) of unshielded spent fuel at the time of shutdown would be dead in seconds from the intense radiation. While the rate of heat generated by spent fuel declines over time, spent fuel from a pressurized water reactor would still generate tens of thousands of times more heat than the corresponding fresh fuel even after ten years of storage.¹² Even after 100 years of storage, the

¹⁰ Initially only uranium-235 nuclei are fissioned. As explained below, plutonium-239 nuclei are also fissioned once it begins to build up in the reactor. Fresh uranium fuel made starting with natural uranium contains no plutonium.

¹¹ DOE 2002, v. II, Appendix A, Tables A-9, A-10, and A-11.

¹² Calculated from IPFM 2011, Figure 1.2, and Rucker and Johnson 1997.

radiation from spent fuel is enough to give a lethal dose¹³ to someone standing about a yard away within a few hours.¹⁴

5.6. Many fission products have short half-lives. Iodine-135, for instance, has a half-life of 6.6 hours.¹⁵ This means that it presents an intense danger if released to the environment, but only for a few days. In contrast, several important fission products have long half-lives. Strontium-90, which is extremely radiotoxic and targets the bone marrow and bone surface, has a half-life of 28 years. Cesium-137, which mimics the potassium in our bodies, has a half-life of about 30 years. This means that they pose risks for hundreds of years. Contamination with cesium-137 is the central reason why the areas with heavy fallout from the Chernobyl and Fukushima accident cannot be safely reoccupied for hundreds of years.

5.7. Some fission products last for hundreds of thousands or even millions of years. Technetium-99 (half-life 213,000 years), cesium-135 (half-life 2.3 million years) and iodine-129 (half-life 15.7 million years) are important examples. Other important radionuclides that present risks over long periods are americium-241 (half-life 432 years) and neptunium-237 (half-life 2.14 million years). Both are bone seeking radionuclides.

5.8. Further, some of the uranium-238 in a reactor turns into plutonium-239 as a result of continued reactor operation. This is because some uranium-238 nuclei absorb some of the neutrons liberated by the fission of U-235. Radioactive decay processes then convert this heavier uranium isotope (uranium-239) into plutonium-239. While uranium-238 is not fissile, plutonium-239 is. Continued reactor operation results both in the fission of some of the plutonium that has been created and a buildup of a considerable amount of un-fissioned plutonium. Other plutonium isotopes are also created. Each 1,000 megawatt-electrical reactor creates enough plutonium each year to make roughly 30 Nagasaki-size bombs, if separated from the spent fuel. Plutonium-239 has a half-life of over 24,000 years; this means that spent fuel represents a proliferation threat for tens of thousands of years.

5.9. These characteristics mean that the serious public health and environmental risks posed by spent fuel will persist from hundreds of years to millions of years. For instance, the risk from strontium-90, with a half-life of 29 years, will last for hundreds of years. In its Yucca Mountain EIS, the Department of Energy projected the inventory of strontium-90 in U.S. spent fuel to be 5 billion curies.¹⁶ If diluted uniformly, this inventory could contaminate the entire fresh water supply (groundwater and surface water) of the world¹⁷ to about 60 times the U.S. drinking water

¹³ A “lethal dose” is generally defined as the dose that would result in the death of half the exposed people in 60 days if they were to receive no medical treatment. It is called the LD 50/60 dose.

¹⁴ IPFM 2011, p. 7

¹⁵ A half-life is the amount of time that half the nuclei of a radioactive material decay, thereby transmuting to another isotope or element. The amount of a radionuclide declines by a factor of about 1,000 in 10 half-lives.

¹⁶ DOE 2002, v. II, Appendix A, Table A-11. All inventories in this paragraph are from this reference and are rounded for the purpose of these calculations. Drinking water limits are in EPA regulations at 40 CFR 141.66.

¹⁷ USGS 2014. The water contamination calculations in this paragraph are order of magnitude estimates meant to illustrate the longevity of the threats from prolonged surface storage of spent fuel.

limit of 8 picocuries per liter. Even after 300 years, it would contaminate the world's fresh surface water supply to almost 50 times the drinking water limit.¹⁸ The strontium-90 inventory of a single twin-reactor nuclear power plant on Lake Michigan, such as the Donald C. Cook plant, would contaminate all the water in Lake Michigan to more than the drinking water limit even after a time lapse of more than 300 years. Dispersal of strontium-90 and other radionuclides in the environment would cause devastating health and ecological impacts; it would make a wide area around the plant unlivable. There are other more long-lived radionuclides that would present severe risks of water contamination for thousands of years. The inventory of americium-241 (half-life 432 years) from that same twin-reactor plant would contaminate Lake Michigan water to more than the drinking water limit (in this case 15 picocuries per liter) for nearly 3,000 years.¹⁹ Other more long-lived fission products like technetium-99, cesium-135, and iodine-129, while produced in considerably smaller quantities, would still pose significant health risks for unimaginably long periods. Consider plutonium-239. Its inventory at that same Lake Michigan plant would be sufficient to contaminate all its water to more than the drinking water limit for about 80,000 years. Moreover, since the contamination would not be uniformly dispersed, the water, lake sediments (where much of the plutonium would wind up), ecosystems, and economy around the plant where the contamination would be concentrated would likely be severely damaged essentially forever were a large fraction of the inventory at a single site dispersed into and near the water.

5.10. After spent fuel has been stored for several hundred years and its thermal and radioactivity levels have declined, risk of theft also poses a serious public security and safety concern. Theft of a single dry-storage cask containing ten metric tons of spent fuel would cause grave security risks since it would have enough plutonium, if separated, to make on the order of a dozen Nagasaki-size bombs. This risk *increases with time*, since the radiation barrier to theft decreases with time.²⁰

5.11. The intense heat generation and radioactivity of spent fuel require it to be stored in pools of water for several years both for cooling and protection of personnel. After that it can be stored in dry casks, but these casks must be heavily shielded.

5.12. Storage in pools for prolonged periods of time increases the risk of radioactivity releases from loss of coolant accidents (triggered, for instance, by an earthquake) or from terrorist attacks. Cask storage of spent fuel also poses the risk that the casks and fuel rods will degrade over long periods of time. In such a case, the consequences of deterioration of the spent fuel and the casks would be disastrous, since radioactivity would be dispersed by the rain, wind, and snow over wide areas, severely harming the environment and creating large public health risks. Casks could also suffer degradation and accidents during inter-cask transfers, which will be necessary if the storage continues for hundreds or thousands of years. The degradation and accidents would

¹⁸ Fresh surface water is one percent of total freshwater. (USGS 2014)

¹⁹ See List of lakes by volume, at http://en.wikipedia.org/wiki/List_of_lakes_by_volume (Wikipedia 2014)

²⁰ This dynamic of the risk of theft increasing with time was also noted by Chairman Macfarlane in the statement accompanying her vote on the Continued Storage rule: "As spent fuel ages, its radioactivity decreases, and hence it loses its self-protecting qualities that increase vulnerability to theft. As a result, security requirements for storage facilities will increase over time." (Macfarlane 2014, p. 5)

allow radioactive material to escape, causing environmental contamination. Further, as noted in paragraph 5.10 above, if spent fuel is stored on site for hundreds of years, it becomes more and more vulnerable to theft as its radioactivity declines and it becomes less dangerous to steal. If spent fuel were stolen, unauthorized parties could separate the plutonium in the spent fuel and use it to make nuclear bombs or dirty radiation bombs. The release of radioactivity from spent fuel through accidental environmental contamination or intentional theft could have catastrophic consequences for human and environmental health.

5.13. The severity and longevity of the risks are the central reasons that government authorities worldwide have concluded that long-term safety demands disposal of high-level waste and spent fuel in an appropriately sited and engineered repository. For instance, as stated by the Secretary of Energy's Blue Ribbon Commission on America's Nuclear Future:

Deep geologic disposal capacity is an essential component of a comprehensive nuclear waste management system for the simple reason that very long-term isolation from the environment is the *only* responsible way to manage nuclear materials with a low probability of re-use, including defense and commercial reprocessing wastes and many forms of spent fuel currently in government hands. The conclusion that disposal is needed and that deep geologic disposal is the scientifically preferred approach has been reached by every expert panel that has looked at the issue and by every other country that is pursuing a nuclear waste management program.²¹

5.14. Consistent with this federal policy, the Chairman of the U.S. Nuclear Regulatory Commission recently asserted, in the statement accompanying her vote on the Continued Storage rule, "Deep geologic disposal is necessary."²² Previously, she had explained her view as follows:

[T]he best way to ensure long-term isolation of high-level waste from the environment is emplacement of that material in a deep geologic repository. A policy of indefinite storage relies upon active controls and maintenance that will be an increasingly costly burden to our society. The continual maintenance and physical protection of thousands of storage casks spread among the current 69 sites in the U.S. would be an economic, logistical, and security burden to future generations. As the Nuclear Energy Agency has noted, "an 'open' solution such as indefinite storage, is probably not sustainable, because it relies upon speculations concerning future scientific, societal, or technological developments, and implies use of resources which cannot be quantified." Worst yet, failure to safely manage spent fuel for unknown times could lead to unacceptable environmental or security consequences.²³

5.15. I share this view. While a repository may have some leakage of radionuclides over long periods of time after closure (tens of thousands or hundreds of thousands of years), a properly selected and engineered repository is the only reasonable means of safeguarding the public from the kinds of catastrophic environmental and security harm described above that can occur from

²¹ BRC 2012, p. xi (emphasis in original).

²² Macfarlane 2014, p. 1

²³ Macfarlane 2013, p. 8 (ML13217A261).

prolonged surface storage. For instance, repository disposal makes theft extremely difficult, and much more so than any surface measures could accomplish. This drastically reduces the security risks from spent fuel. As another example, repository disposal would also greatly diminish the risks from the most plentiful long-lived fission products in the spent fuel, strontium-90 and cesium-137.

Currently, however, no geologic repository for spent fuel exists in the United States.

6.0 NRC LACKS AN ADEQUATE BASIS FOR LICENSING NUCLEAR REACTORS BECAUSE IT HAS NOT MADE CURRENTLY VALID “WASTE CONFIDENCE” SAFETY FINDINGS REGARDING FUTURE DISPOSAL OF SPENT FUEL OR CONDUCTED AN ENVIRONMENTAL ANALYSIS TO SUPPORT THOSE FINDINGS.

6.1. In my professional opinion, the NRC lacks an adequate basis for licensing nuclear reactors because it has not made currently valid “waste confidence” safety findings regarding future disposal of spent fuel or conducted an environmental analysis to support those findings. A waste confidence finding with an adequate technical basis is needed for assurance that future generations are not being put at severe risk.

6.2. Until 2014, as part of its licensing and re-licensing decisions for nuclear reactors, the NRC made generic safety findings regarding the feasibility and capacity of repository disposal of spent fuel. Starting in 1977, the NRC stated that it “would not continue to license reactors if it did not have reasonable confidence that the wastes can and will in due course be disposed of safely.”²⁴ And the NRC based all of its reactor licensing and re-licensing decisions in part on generic findings regarding the safety of waste disposal, including after the passage of the Nuclear Waste Policy Act in 1982, when spent fuel disposal in a geologic repository became the formal path for long-term disposition of spent fuel. These findings were published in the NRC’s 1984 Waste Confidence Decision (“WCD”), as updated in 1990 and 2010.²⁵

6.3. NRC’s Waste Confidence findings were supported by a technical approach to the feasibility and capacity of a repository, including geologic characteristics, waste packaging, and engineered safety barriers.²⁶ The NRC explained the role of this approach in the WCD as follows:

The conclusion that safe radioactive waste disposal is technically feasible is based on consideration of the basic features of repository design and the problems to be solved in developing the final design. A mined geologic repository for disposal of high-level radioactive waste, as developed during the past three decades, will be based on

²⁴ Denial of Petition for Rulemaking, 42 Fed. Reg. 34,391, 34,393 (July 5, 1977).

²⁵ Waste Confidence Decision, 49 Fed. Reg. 34,658 (Aug. 31, 1984) (“1984 WCD”); Waste Confidence Decision Review, 55 Fed. Reg. 38,474 (Sept. 18, 1990) (“1990 Revised WCD”); Waste Confidence Decision Update, 75 Fed. Reg. 81,037 (Dec. 23, 2010) (“2010 WCD Update”) (NRC 2010a). The 2010 WCD Update was vacated by the U.S. Court of Appeals in *New York v. NRC*, 681 F.3d 471 (D.C. Cir. 2012).

²⁶ See, e.g., 1984 WCD, 49 Fed. Reg. at 34,667-79; 1990 WCD Revision, 55 Fed. Reg. at 38,475-79; 2010 WCD Update, 75 Fed. Reg. at 81,059-67 (NRC 2010a).

application of the multi-barrier approach for isolation of radionuclides. The high-level radioactive waste or spent fuel is to be contained in a sealed package and any leakage from the package is to be retarded from migrating to the biosphere by engineered barriers. These engineered barriers include backfilling and sealing of the drifts and shafts of the mined repository. We believe that the isolation capability and long-term stability of the geologic setting provide a final barrier to migration to the biosphere.²⁷

6.4. With each revision to the WCD, the NRC updated the technical analysis and schedule underlying its findings. For instance, in 1990, the NRC revised the WCD to, among other things “reflect revised expectations for the date of availability of the first repository.”²⁸

6.5. As stated most recently in the 2010 WCD Update, the NRC’s findings regarding the technical feasibility and capacity of safe repository disposal of spent fuel were as follows:

Finding 1: The Commission finds reasonable assurance that safe disposal of high-level radioactive waste and spent fuel in a mined geologic repository is technically feasible.²⁹

Finding 2: The Commission finds reasonable assurance that sufficient mined geologic repository capacity will be available to dispose of the commercial high-level radioactive waste and spent fuel generated in any reactor when necessary.³⁰

These updated findings are similar to the 1984 and 1990 findings regarding repository safety and capacity.

6.6. The NRC never prepared any Environmental Impact Statement (“EIS”) or Environmental Assessment (“EA”) in support of its Waste Confidence findings, however. As a result, the 2010 WCD Update was vacated by the U.S. Court of Appeals in *New York v. NRC*, 681 F.3d 471 (D.C. Cir. 2012) for failure to comply with the National Environmental Policy Act (“NEPA”).³¹

6.7. In the Final Continued Storage Rule, recently issued by the NRC on remand from the Court’s decision, the NRC chose not to replace the vacated Waste Confidence findings.³² Instead, the NRC incorporated some of the language of Findings 1 and 2 into the Continued Storage GEIS as assumptions for that environmental analysis.³³

6.8. In my professional opinion, the NRC should not license reactors to produce spent fuel unless it can affirmatively make predictive safety findings that it will be technically feasible to site repositories that are safe, in the sense of conforming to radiation protection norms similar to the ones that are in force for nuclear licensees at present, and have sufficient capacity to

²⁷ 49 Fed. Reg. at 34,667.

²⁸ 73 Fed. Reg. at 59,552 (Oct. 9, 2008)

²⁹ 2010 WCD Update, 75 Fed. Reg. at 81,058 (NRC 2010a) (capitalization of some words omitted).

³⁰ 75 Fed. Reg. at 81,038 (NRC 2010a).

³¹ 42 U.S.C. §§ 4321-4370h.

³² Continued Storage Rule, 79 Fed. Reg. at 56,244; Continued Storage GEIS at B-30 (NUREG-2157 (2014))

³³ Continued Storage GEIS Section B.2.1 (NUREG-2157 (2014))

accommodate the spent fuel those reactors will generate, along with the spent fuel that already exists or will be generated under existing licenses. The findings should be supported by an up-to-date technical analysis of the factors that the NRC has previously analyzed in its Waste Confidence decision and updates: geologic characteristics, waste packaging, and engineered safety barriers. It is important to revise these technical findings and take public comment on a regular basis because the common technical understanding of repository feasibility may change over time. For instance, in 1979, the NRC believed that bedded salt would be suitable for spent fuel disposal. In the 2010 WCD, however, the NRC reversed that determination. *See* pars. 6.14 - 6.16 below.

6.9. Moreover, the NRC's technical safety findings regarding the feasibility and capacity of repository disposal must be accompanied by an environmental analysis. The NRC's feasibility determination, for example, should be supported by an environmental analysis of the probability that a repository will safely contain radioactivity for the hundreds of thousands of years required to a degree sufficient to keep radiation doses to future members of the public to levels similar to the ones society has deemed acceptable today. In order to evaluate that probability, it is necessary to evaluate the environmental impacts of disposing of spent fuel in a range of geologic media, with a range of engineered barriers and repository sealing systems.

6.10. Similarly, technical findings regarding the capacity of one or more repositories to accommodate all spent fuel to be generated would require both safety and environmental analyses of various factors. Every geologic location would have some limit to the amount of spent fuel it can hold due to considerations such as the characteristics of the host rock, seismic faults running through the site, groundwater characteristics, natural resources availability, and other factors. Yucca Mountain, for instance, had a legal limit of 70,000 metric tons (equivalent) of commercial and military waste. Proponents of disposal there argued that the technical limits could be raised to allow disposal of a much greater quantity of spent fuel. But no one, so far as I am aware, has asserted that there was no technical limit. Such a limit was considered, for instance, in a paper by Professor Per Peterson of the University of California at Berkeley in the context of a prospective increase in nuclear reactor orders in 2003. He argued that the technical capacity of Yucca Mountain could be increased, but it would still have a limit:

This [analysis] suggests a minimum "technical" site capacity of approximately 75 x 2,000 = 150,000 MT of spent fuel, with a maximum site capacity greater by perhaps a factor of two or three. *Thus any substantial construction of new U.S. nuclear power infrastructure in the coming decades will almost certainly create a technical requirement (perhaps as soon as 2030 to 2050) either for additional repositories or for the construction of infrastructure for recycling spent fuel.*³⁴

Thus, one of the most prominent authorities on nuclear power and nuclear waste in the United States³⁵ has opined that, in the absence of reprocessing, the capacity of Yucca Mountain may not be capable of expansion sufficient for a nuclear future, and therefore a second repository may be needed in the United States. Indeed, he stated that a new repository would "almost certainly" be

³⁴ Peterson 2003, italics added

³⁵ Professor Peterson was a member of the Blue Ribbon Commission on America's Nuclear Future which delved into the problem of spent fuel at the behest of then-Energy Secretary Steven Chu.

needed in the event of a nuclear power resurgence. From a spent fuel disposal point of view, there is no practical difference between extending licenses of existing reactors to 60 and even 80 years (as is now being considered) and building new reactors licensed for 40 years as was the practice in the past. Accordingly, for every additional repository that is needed, questions must be addressed regarding the availability of additional geologic sites that have the characteristics required for safe disposal.

6.11. Further, the NRC has no valid environmental analysis on which it can rely for an evaluation of spent fuel disposal impacts. The NRC has never prepared an EA or EIS to support the WCD or any of its revisions. Neither of the two regulations on which NRC relies for a determination that spent fuel disposal impacts are insignificant -- Table B-1 of Appendix B to Subpart A to 10 C.F.R. Part 51 and Table S-3 of 10 C.F.R. § 51.51 -- was issued in connection with waste confidence findings. In fact, the technical basis for both regulations is both illogical and fundamentally inconsistent with the NRC's most recent pronouncement on the technical infeasibility of spent fuel disposal in salt in the 2010 WCD Update.

6.12. Table B-1, for instance, concludes that the environmental impacts of spent fuel disposal are too small to influence license renewal decisions³⁶:

For the high-level waste and spent-fuel disposal component of the fuel cycle, the EPA established a dose limit of 0.15 mSv (15 millirem) per year for the first 10,000 years and 1.0 mSv (100 millirem) per year between 10,000 years and 1 million years for offsite releases of radionuclides at the proposed repository at Yucca Mountain, Nevada.

The Commission concludes that the impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the impacts of spent fuel and high level waste disposal, this issue is considered Category 1.³⁷

But the central assertion in Table B-1 is illogical. To say that environmental impacts will be small because higher impacts have been forbidden is like saying that the existence of a law against drunken driving allows society to conclude that the impacts of drunken driving would in fact not be large enough to worry about. One of the purposes of a NEPA analysis is to evaluate the likelihood that protective measures will fail and environmental harm will occur.

6.13. The NRC also asserts that the DOE's license application for Yucca Mountain supports a conclusion that spent fuel disposal is technically feasible.³⁸ But the NRC has never actually ruled on the impacts of Yucca Mountain and whether that site is licensable. Equally important, Yucca Mountain is only one possible site out of many. An EIS or EA to support reactor licensing should evaluate the range of geologic media that may be used, not just one. In any

³⁶ Table B-1 is published in the Final Continued Storage Rule. 79 Fed. Reg. at 56,263

³⁷ 79 Fed. Reg. (Sept. 19, 2014) at 56,263

³⁸ 79 Fed. Reg. (Sept. 19, 2014) at 56,251

event, the licensing proceeding for Yucca Mountain was suspended for several years and has not been completed at this juncture, and thus no conclusions have been reached, upon which the NRC could rely, regarding the question of whether Yucca Mountain would meet the performance standards specified in 40 C.F.R. Part 197.

6.14. Table S-3 summarizes the NRC's conclusion that radioactive releases from a repository will be zero (and therefore the impacts of spent fuel disposal will be nil), based on the assumption that spent fuel will be disposed of in a bedded salt repository. But Table S-3 is not the product of an EA or an EIS. Instead it is the product of an Environmental "Survey" and a "Policies and Procedures" statement issued with 10 CFR Part 51 in 1979.³⁹ And the Environmental Survey, which was prepared in 1974-79, is decades out of date. It is not consistent with more current NRC determinations regarding repository risks. For instance, it is not consistent with Table B-1. Table B-1 appears to acknowledge that long-term doses could be as high as 100 millirem per year – a far cry from the zero dose assumed in Table S-3.

6.15 Table S-3 is also inconsistent with the NRC's most recent determination regarding the technical feasibility of spent fuel disposal as stated in the 2010 WCD Update. Table S-3 is based on the assumption that spent fuel will be disposed of in bedded salt and will have no radioactive releases of solid fission products.⁴⁰ But the 2010 WCD Update rejected bedded salt as infeasible for spent fuel disposal:

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.⁴¹

6.16. It is also clear from the Environmental Survey Supplement (NUREG-0116) that Table S-3's assumption of zero releases after repository closure from spent closure was **merely an untested assumption**: "With both uranium recycle and spent-fuel disposal, the salt is assumed to retain the solid radioactive fission products. *The validity of this assumption has not been tested for spent fuel.*"⁴²

6.17. Thus, it would be at odds with the minimal standards of scientific soundness should the NRC rely on Table S-3 for support of any safety decision regarding the technical feasibility of safe spent fuel disposal in a repository. The safety and environmental impacts of any given geologic medium for spent fuel disposal must be the *subject* of analysis, not its foregone conclusion.

³⁹ WASH-1248, Environmental Survey of the Uranium Fuel Cycle (1974) (WASH-1248 (1974)); WASH-1248 Supp. 1, also known as NUREG-0116 (1976), and the NRC statement of considerations, NRC 1979

⁴⁰ NUREG-0116 (1976), p. 4-114

⁴¹ NRC 2010a, p. 81,059, emphasis added.

⁴² NUREG-0116 (1976), p. 4-114, italics added.

7.0 CONSIDERATION OF WHETHER REPOSITORY DISPOSAL OF SPENT FUEL CAN BE DONE SAFELY AND WITH SUFFICIENT CAPACITY COULD LEAD TO A CONCLUSION THAT LICENSING OF REACTORS IS NOT JUSTIFIED UNDER THE ATOMIC ENERGY ACT OR COST-BENEFICIAL UNDER NEPA.

7.0. As discussed above, before licensing or re-licensing any reactors, the NRC should prepare waste confidence findings regarding the technical feasibility and capacity of repositories and whether they would conform to the kinds of safety and radiological norms prevalent today. As required by NEPA, the NRC's analysis should also include an evaluation of the costs of spent fuel storage and disposal.

7.1. It is essential for the NRC to examine a variety of sites, engineered barriers, and repository sealing systems. The suitability of any particular approach cannot be taken as a foregone conclusion. For instance, the NRC previously relied on the assumption that spent fuel could be safely disposed of in bedded salt repositories, only to conclude years later that salt is not a suitable medium for spent fuel disposal. So long as a repository is not actually licensed, it is important for the NRC to continually update and evaluate existing information regarding the safety of future spent fuel disposal. It is also critical to evaluate the cost consequences of enabling the creation of even more spent fuel when there is as yet no clear path to a suitable repository for the huge amounts of spent fuel that have already been created.

7.2. In this context, it is important to note that a reasonable evaluation of the feasibility and capacity of repository disposal would involve significant cost considerations. Long-term storage (or longer) followed by disposal in one repository could add up to between \$214 billion and \$351 billion, in 2012 dollars. A second repository could add \$34 billion to \$171 billion.⁴³ These are huge sums of money that the NRC should take into account when assessing the reasonableness of its assumptions regarding long-term storage followed by disposal – or indefinite storage, which would be even more expensive. If these costs were considered in the cost-benefit analysis for initial reactor licensing decisions under NEPA, they are high enough to affect the outcome of a comparison of the costs of nuclear power compared to the alternatives.⁴⁴ It could therefore materially affect the cost-benefit analysis and tip the balance against licensing or re-licensing of a nuclear reactor.

8.0 CONCLUSION

8.1. In sum, unirradiated reactor fuel presents few risks and those that it does are very small. It can be and is routinely handled in the process of fuel fabrication. The main reason is that uranium-238 and uranium-235, which constitute almost the entire mass of fresh fuel, are only slightly radioactive. This changes drastically once the fuel is used in a nuclear power reactor to sustain a chain reaction. The radioactivity in the fuel rods increases by millions of times in the course of reactor operation. Both heat and radiation rise to lethal levels. Further, plutonium-239 builds up during the course of reactor operation – roughly 30 Nagasaki bombs worth every year in every 1,000-megawatt reactor.

⁴³ Cooper 2013, p. 25

⁴⁴ Cooper 2013, p. 7

8.2. The severe environmental, safety, and proliferation risks from spent fuel storage on the surface last for thousands of years and longer. The only way to materially decrease these long-term risks beyond a few decades of storage is to dispose of spent fuel in a properly selected, sized, and engineered deep geologic repository (or repositories).

8.3. The NRC has no currently valid safety findings regarding spent fuel disposal, nor has it done any environmental analysis on which it could rely for such findings. In my professional opinion, given the severe hazards posed by spent fuel to public health and the environment, the NRC should not license reactors until it has made the requisite safety findings regarding the disposal of spent fuel in a repository and supported them with an adequate environmental analysis.

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



Dr. Arjun Makhijani

September 29, 2014

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

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

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

Education:

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

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

Current Employment:

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

Other Long-term Employment

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

Professional Societies:

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

Awards and Honors:

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

Advisory Council, Maryland Clean Energy Center, 2013

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

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

Consulting Experience, 1975-1987

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

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

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

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

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- 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.
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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.

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CV updated September 25, 2014

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD PANEL

In the Matter of)	
)	
PROGRESS ENERGY FLORIDA, INC.)	Docket Nos. 52-029-COL,
(Levy County Nuclear Power Plant,)	52-030-COL
Units 1 and 2))	
)	

DECLARATION OF EMILY CASEY

Under penalty of perjury, I, **EMILY CASEY**, declare as follows:

1. I make this declaration of my own personal knowledge. If called to testify as a witness, I could and would testify competently regarding its contents.
2. I am a current member of the Ecology Party of Florida. I agree with the Ecology Party of Florida's mission of protecting its members and the environment through electoral and legal challenges and I believe my health and well-being depend upon the health of the environment in the region where I live. I have authorized the Ecology Party of Florida to submit a contention on my behalf challenging the NRC's failure to make findings regarding the safety of disposing of spent fuel to be generated by the proposed Levy Nuclear Plant..
3. I know that the Ecology Party of Florida submitted comments to the U.S. Nuclear Regulatory Commission ("NRC") in 2013 regarding the NRC's proposed rule entitled "Waste Confidence Decision - Continued Storage of Spent Nuclear Fuel," which was published at 78 Fed. Reg. 56,776 on September 13, 2013 and its accompanying "Waste Confidence Generic Environmental Impact Statement," published the same day.
4. I live at 1430 East Hartford Street, Inverness, FL 34453. My home is approximately 20 miles from the proposed Levy Nuclear Plant. This is less than the fifty-mile radius distance at which the U.S. Nuclear Regulatory Commission ("NRC") presumes a reactor accident will cause harm to my health and safety.
5. I am concerned about the health and safety risks posed by the spent fuel that will be generated by the proposed Levy Nuclear Plant if it is licensed. I am aware that Congress has established a policy that the spent fuel should be removed from the proposed Levy Nuclear Plant site to a repository for permanent disposal. But, I am concerned that permanent disposal of spent fuel may not be feasible. I am also concerned that the government will not find sufficient capacity in a repository or multiple

repositories to accommodate the spent fuel to be generated by the proposed Levy Nuclear Plant. For these reasons, I am concerned that the proposed Levy Nuclear Plant may become a *de facto* long-term storage depot or even a waste disposal site. I am concerned that spent fuel stored for a lengthy period at the proposed Levy Nuclear Plant site may leak into the environment and harm my health and threaten my safety. Additionally, I am concerned about the health and safety of future generations in my family, and protection of the environment.

6. I am aware that NRC must conduct a full safety and environmental review whenever it licenses or re-licenses a nuclear power plant. However, I am concerned that NRC has not adequately evaluated the question of whether the spent fuel that will be generated by the proposed Levy Nuclear Plant can be safely disposed of in a repository, or the environmental, health, and safety consequences of storing spent nuclear fuel at facilities like the proposed Levy Nuclear Plant in the interim. In the absence of adequate safety findings and environmental analyses regarding these issues, I do not have confidence that my health and safety or the integrity of my environment will be protected from the adverse effects of exposure to spent reactor fuel.

7. I have authorized the Ecology Party of Florida to file a contention that seeks to raise my concerns in this proceeding. I believe this contention will redress my concerns by forcing the NRC to either make the required safety findings or deny the license for the proposed Levy Nuclear Plant.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge, information and belief.


EMILY CASEY

September 22, 2014

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD PANEL

_____)	
In the Matter of)	
PROGRESS ENERGY FLORIDA, INC.)	Docket Nos. 52-029-COL,
(Levy County Nuclear Power Plant,)	52-030-COL
Units 1 and 2))	
_____)	

DECLARATION OF DAVID LEE MCSHERRY

Under penalty of perjury, I, David Lee McSherry, declare as follows:

1. I make this declaration of my own personal knowledge. If called to testify as a witness, I could and would testify competently regarding its contents.
2. I am a current member of the Ecology Party of Florida. I agree with the Ecology Party of Florida's mission of protecting its members and the environment through electoral and legal challenges and I believe my health and well-being depend upon the health of the environment in the region where I live. I have authorized the Ecology Party of Florida to submit a contention on my behalf challenging the NRC's failure to make findings regarding the safety of disposing of spent fuel to be generated by the proposed Levy County Units 1 and 2.
3. I know that the Ecology Party of Florida submitted comments to the U.S. Nuclear Regulatory Commission ("NRC") in 2013 regarding the NRC's proposed rule entitled "Waste Confidence Decision - Continued Storage of Spent Nuclear Fuel," which was published at 78 Fed. Reg. 56,776 on September 13, 2013 and its accompanying "Waste Confidence Generic Environmental Impact Statement," published the same day.
4. I live at 5212 SW 79th Avenue, Archer, Florida 32618. My home is approximately 36 miles from the proposed Levy Nuclear Plant. This is less than the fifty-mile radius distance at which the U.S. Nuclear Regulatory Commission ("NRC") presumes a reactor accident will cause harm to my health and safety.
5. I am concerned about the health and safety risks posed by the spent fuel that will be generated by the proposed Levy Nuclear Plant if it is licensed. I am aware that Congress has established a policy that the spent fuel should be removed from the Levy Nuclear Plant site to a repository for permanent disposal. But, I am concerned that permanent disposal of spent fuel may not be feasible. I am also concerned that the government will not find sufficient capacity in a repository or multiple repositories to accommodate the spent fuel to be generated by the proposed Levy Nuclear Plant. For these reasons, I am concerned that the proposed Levy Nuclear

Plant may become a *de facto* long term storage depot or even waste disposal site. I am concerned that spent fuel stored for a lengthy period at the proposed Levy Nuclear Plant site may leak into the environment and harm my health and threaten my safety. Additionally, I am concerned about the health and safety of future generations in my family, and protection of the environment.

6. I am aware that NRC must conduct a full safety and environmental review whenever it licenses or re-licenses a nuclear power plant. However, I am concerned that NRC has not adequately evaluated the question of whether the spent fuel that will be generated by the proposed Levy Nuclear Plant can be safely disposed of in a repository or the environmental, health, and safety consequences of storing spent nuclear fuel at facilities like the Levy Nuclear Plant in the meantime. In the absence of adequate safety findings and environmental analyses regarding these issues, I do not have confidence that my health and safety or the integrity of my environment will be protected from the adverse effects of exposure to spent reactor fuel.

7. I have authorized the Ecology Party of Florida to file a contention that seeks to raise my concerns in this proceeding. I believe this contention will redress my concerns by forcing the NRC to either make the required safety findings or deny the license of the proposed Levy Nuclear Plant.

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I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge, information and belief.


David Lee McSherry

9-22-14
Date signed

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD PANEL

_____)	
In the Matter of)	
PROGRESS ENERGY FLORIDA, INC.)	Docket Nos. 52-029-COL,
(Levy County Nuclear Power Plant,)	52-030-COL
Units 1 and 2))	
_____)	

DECLARATION OF DECEMBER DUKE MCSHERRY

Under penalty of perjury, I, December Duke McSherry, declare as follows:

1. I make this declaration of my own personal knowledge. If called to testify as a witness, I could and would testify competently regarding its contents.
2. I am a current member of the Ecology Party of Florida. I agree with the Ecology Party of Florida's mission of protecting its members and the environment through electoral and legal challenges and I believe my health and well-being depend upon the health of the environment in the region where I live. I have authorized the Ecology Party of Florida to submit a contention on my behalf challenging the NRC's failure to make findings regarding the safety of disposing of spent fuel to be generated by the proposed Levy County Units 1 and 2.
3. I know that the Ecology Party of Florida submitted comments to the U.S. Nuclear Regulatory Commission ("NRC") in 2013 regarding the NRC's proposed rule entitled "Waste Confidence Decision - Continued Storage of Spent Nuclear Fuel," which was published at 78 Fed. Reg. 56,776 on September 13, 2013 and its accompanying "Waste Confidence Generic Environmental Impact Statement," published the same day.
4. I live at 5212 SW 79th Avenue, Archer, Florida 32618. My home is approximately 36 miles from the proposed Levy Nuclear Plant. This is less than the fifty-mile radius distance at which the U.S. Nuclear Regulatory Commission ("NRC") presumes a reactor accident will cause harm to my health and safety.
5. I am concerned about the health and safety risks posed by the spent fuel that will be generated by the proposed Levy Nuclear Plant if it is licensed. I am aware that Congress has established a policy that the spent fuel should be removed from the Levy Nuclear Plant site to a repository for permanent disposal. But, I am concerned that permanent disposal of spent fuel may not be feasible. I am also concerned that the government will not find sufficient capacity in a repository or multiple repositories to accommodate the spent fuel to be generated by the proposed Levy Nuclear Plant. For these reasons, I am concerned that the proposed Levy Nuclear

Plant may become a *de facto* long term storage depot or even waste disposal site. I am concerned that spent fuel stored for a lengthy period at the proposed Levy Nuclear Plant site may leak into the environment and harm my health and threaten my safety. Additionally, I am concerned about the health and safety of future generations in my family, and protection of the environment.

6. I am aware that NRC must conduct a full safety and environmental review whenever it licenses or re-licenses a nuclear power plant. However, I am concerned that NRC has not adequately evaluated the question of whether the spent fuel that will be generated by the proposed Levy Nuclear Plant can be safely disposed of in a repository or the environmental, health, and safety consequences of storing spent nuclear fuel at facilities like the Levy Nuclear Plant in the meantime. In the absence of adequate safety findings and environmental analyses regarding these issues, I do not have confidence that my health and safety or the integrity of my environment will be protected from the adverse effects of exposure to spent reactor fuel.

7. I have authorized the Ecology Party of Florida to file a contention that seeks to raise my concerns in this proceeding. I believe this contention will redress my concerns by forcing the NRC to either make the required safety findings or deny the license of the proposed Levy Nuclear Plant.

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I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge, information and belief.

December Duke McSherry
December Duke McSherry
4

9-22-2014
Date signed

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD PANEL

In the Matter of)	
PROGRESS ENERGY FLORIDA, INC.)	Docket Nos. 52-029-COL,
(Levy County Nuclear Power Plant,)	52-030-COL
Units 1 and 2))	

DECLARATION OF AMANDA HANCOCK ANDERSON

Under penalty of perjury, I, Amanda Hancock Anderson, declare as follows:

1. I make this declaration of my own personal knowledge. If called to testify as a witness, I could and would testify competently regarding its contents.

2. I am a current member of Nuclear Information and Resource Service (NIRS). I agree with NIRS’s mission of working for a sustainable, non-nuclear energy policy and I believe my health and well-being depend upon the health of the environment in the region where I live. I have authorized NIRS to submit a contention on my behalf challenging the NRC’s failure to make findings regarding the safety of disposing of spent fuel to be generated by Levy County Units 1 and 2.

3. I know that NIRS submitted comments to the U.S. Nuclear Regulatory Commission (“NRC”) in 2013 regarding the NRC’s proposed rule entitled “Waste Confidence Decision - Continued Storage of Spent Nuclear Fuel,” which was published at 78 Fed. Reg. 56,776 on September 13, 2013 and its accompanying “Waste Confidence Generic Environmental Impact Statement,” published the same day.

4. I live at 516 NW 19th Avenue in Gainesville, FL. My home lies 48 miles from the Levy County Units 1 and 2 site. This is less than the fifty-mile radius distance at which the U.S. Nuclear Regulatory Commission (“NRC”) presumes a reactor accident will cause harm to my health and safety.

5. I am concerned about the health and safety risks posed by the spent fuel that will be generated by Levy County Units 1 and 2 if licensed. I am aware that Congress has established a policy that the spent fuel should be removed from the Levy County 1 and 2 site to a repository for permanent disposal. But, I am concerned that permanent disposal of spent fuel may not be feasible. I am also concerned that the government will not find sufficient capacity in a repository or multiple repositories to accommodate the spent fuel to be generated by Levy County 1 and 2. For these reasons, I am concerned that Levy County 1 and 2 may become a *de facto* long term

storage depot or even waste disposal site. I am concerned that spent fuel stored for a lengthy period at the Levy County 1 and 2 site may leak into the environment and harm my health and threaten my safety. Additionally, I am concerned about the health and safety of future generations in my family, and protection of the environment.

6. I am aware that NRC must conduct a full safety and environmental review whenever it licenses or re-licenses a nuclear power plant. However, I am concerned that NRC has not adequately evaluated the question of whether the spent fuel that will be generated by Levy County 1 and 2 can be safely disposed of in a repository or the environmental, health, and safety consequences of storing spent nuclear fuel at facilities like Levy County 1 and 2 in the meantime. In the absence of adequate safety findings and environmental analyses regarding these issues, I do not have confidence that my health and safety or the integrity of my environment will be protected from the adverse effects of exposure to spent reactor fuel.

7. I have authorized Nuclear Information and Resource Service to file a contention that seeks to raise my concerns in this proceeding. I believe this contention will redress my concerns by forcing the NRC to either make the required safety findings or deny the license Levy County 1 and 2

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I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge, information and belief.

Amanda Hancock Anderson
Amanda Hancock Anderson

9/26/14
Date

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD PANEL

_____)	
In the Matter of)	
PROGRESS ENERGY FLORIDA, INC.)	Docket Nos. 52-029-COL,
(Levy County Nuclear Power Plant,)	52-030-COL
Units 1 and 2))	
_____)	

DECLARATION OF W. RUSSELL ANDERSON

Under penalty of perjury, I, W. Russell Anderson, declare as follows:

1. I make this declaration of my own personal knowledge. If called to testify as a witness, I could and would testify competently regarding its contents.
2. I am a current member of Nuclear Information and Resource Service (NIRS). I agree with NIRS's mission of working for a sustainable, non-nuclear energy policy and I believe my health and well-being depend upon the health of the environment in the region where I live. I have authorized NIRS to submit a contention on my behalf challenging the NRC's failure to make findings regarding the safety of disposing of spent fuel to be generated by Levy County Units 1 and 2.
3. I know that NIRS submitted comments to the U.S. Nuclear Regulatory Commission ("NRC") in 2013 regarding the NRC's proposed rule entitled "Waste Confidence Decision - Continued Storage of Spent Nuclear Fuel," which was published at 78 Fed. Reg. 56,776 on September 13, 2013 and its accompanying "Waste Confidence Generic Environmental Impact Statement," published the same day.
4. I live at 516 NW 19th Avenue in Gainesville, FL. My home lies 48 miles from the Levy County Units 1 and 2 site. This is less than the fifty-mile radius distance at which the U.S. Nuclear Regulatory Commission ("NRC") presumes a reactor accident will cause harm to my health and safety.
5. I am concerned about the health and safety risks posed by the spent fuel that will be generated by Levy County Units 1 and 2 if licensed. I am aware that Congress has established a policy that the spent fuel should be removed from the Levy County 1 and 2 site to a repository for permanent disposal. But, I am concerned that permanent disposal of spent fuel may not be feasible. I am also concerned that the government will not find sufficient capacity in a repository or multiple repositories to accommodate the spent fuel to be generated by Levy County 1 and 2. For these reasons, I am concerned that Levy County 1 and 2 may become a *de facto* long term

storage depot or even waste disposal site. I am concerned that spent fuel stored for a lengthy period at the Levy County 1 and 2 site may leak into the environment and harm my health and threaten my safety. Additionally, I am concerned about the health and safety of future generations in my family, and protection of the environment.

6. I am aware that NRC must conduct a full safety and environmental review whenever it licenses or re-licenses a nuclear power plant. However, I am concerned that NRC has not adequately evaluated the question of whether the spent fuel that will be generated by Levy County 1 and 2 can be safely disposed of in a repository or the environmental, health, and safety consequences of storing spent nuclear fuel at facilities like Levy County 1 and 2 in the meantime. In the absence of adequate safety findings and environmental analyses regarding these issues, I do not have confidence that my health and safety or the integrity of my environment will be protected from the adverse effects of exposure to spent reactor fuel.

7. I have authorized Nuclear Information and Resource Service to file a contention that seeks to raise my concerns in this proceeding. I believe this contention will redress my concerns by forcing the NRC to either make the required safety findings or deny the license Levy County 1 and 2

[The remainder of this page has been intentionally left blank]

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge, information and belief.

W. Russell Anderson
W. Russell Anderson

09/26/14
Date