April 6, 2015

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the matter of
Pacific Gas and Electric Company — Docket Nos. 50-275-LR
Diablo Canyon Nuclear Power Plant — 50-323-LR
Units 1 and 2

DECLARATION OF MARK COOPER
IN SUPPORT OF SAN LUIS OBISPO MOTHERS FOR PEACE'S
MOTION TO FILE NEW CONTENTIONS
REGARDING ADEQUACY OF ENVIRONMENTAL REPORT
FOR DIABLO CANYON LICENSE RENEWAL APPLICATION

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

I. QUALIFICATIONS

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. A copy of my curriculum vitae is attached as Attachment 1.

2. 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, reports, and testimonies before state regulatory agencies and state and federal legislatures. 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.

3. On November 24, 2014, I filed comments on the Environmental Protection Agency's Clean Power Rule, which updated my ongoing analysis of the economics and availability of alternatives resources.[1] My EPA comments document the dramatic reduction in cost and increasing potential to transform how the need for electricity is met in a low carbon environment. That analysis focused on the mid-term, roughly the next decade and a half, which is exactly the time period that is relevant to this license renewal proceeding. A copy of my comments is attached as Attachment 2.

II. PURPOSE OF MY DECLARATION

4. The purpose of this declaration is to support two contentions submitted by the San Luis Obispo Mothers for Peace in SLOMFP's Motion to File New Contentions Regarding Adequacy of Environmental Report for Diablo Canyon License Renewal Application (April 6, 2015). These contentions challenge the adequacy of Pacific Gas & Electric Co.'s ("PG&E's) Amended Environmental Report (2015) to evaluate energy alternatives to the proposed re-licensing of Diablo Canyon nuclear power plant. The factual statements in SLOMFP's contentions are true and correct to the best of my knowledge, and the conclusions are based on my best professional judgment. In addition, this declaration provides further support for the contentions.

III. ANALYSIS

5. As the NRC has recognized in the Generic Environmental Impact Statement for License Renewal (NUREG-1437, 2013), the energy field is evolving very rapidly, and therefore the NRC makes a case-by-case analysis of energy alternatives in license renewal proceedings, using "state-of-the-science" information:

[1] In the Matter of Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, 79 Fed. Reg. 34,830 (June 18, 2014) (RIN 2060-AR33).

> **Recent advances in (replacement power alternatives.** Several commenters asserted that much of the information describing replacement power alternatives did not reflect the state-of the-science. In some cases, commenters noted facts and events that occurred after the publication date of the draft GEIS.
>
> The NRC has updated the final GEIS to incorporate the latest information on replacement power alternatives, but it is inevitable that rapidly evolving technologies will outpace information presented in the GEIS. Incorporation of this information is more appropriately made in the context of plant-specific license renewal reviews, rather than in the GEIS. As with renewable energy technologies, energy policies are evolving rapidly. While the NRC acknowledges that legislation, technological advancements, and public policy can underlie a fundamental paradigm shift in energy portfolios, the NRC cannot make decisions based on anticipated or speculative changes. Instead, the NRC considers the status of alternatives and energy policies when conducting plant-specific environmental reviews.[2]

6. In a number of respects, PG&E's energy alternatives analysis is seriously outdated. First, in Section 7.2.1.2, PG&E focuses its analysis on "standalone" alternatives, using that to disqualify a number of renewable alternatives that have proven reliable and effective in providing electricity:

> This section identifies standalone alternatives that PG&E deemed unreasonable, and the bases for these determinations. PG&E accounted for the fact that DCPP provides baseload generation and that any feasible alternative to DCPP would also need to be able to provide baseload power. In performing this evaluation, PG&E relied heavily upon NRC's GElS (References 21 and 29). [3]

7. PG&E's focus on "standalone" energy sources reflects two irrational and unsupported biases: first, towards reliance on "baseload" generation by a single source, and second towards "utility-scale" generation. But these biases have been outdated by the ongoing transformation of the electric utility sector. As one prominent financial firm that specializes in analysis of the electricity sector, UBS, put it, "Large-scale power generation . . . will be the dinosaur of the future energy system." [4] They are: "Too big, too inflexible, not even

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[2] License Renewal GEIS, p. 1-30 – 1-31.
[3] Diablo Canyon Environmental Report, p. 7.2-14.
[4] UBS, 2014, *Global Utilities, Autos & Chemicals Will solar, batteries and electric cars re-shape the electricity system?,* August 20, p. 1. UBS "is considered the world's largest manager of private wealth

relevant for backup power in the long run."[5] While UBS ties the shift to the spread of battery technology other major firms see the shift being driven by the development of other technologies including solar,[6] wind,[7] efficiency,[8] as well as the increasing ability to actively integrate and manage supply and demand. [9]

8. These powerful forces for change have not gone unnoticed in the electricity industry.[10] Disruptive change is the watchword for the utilities, consumers and environmentalists. There is an intense struggle to define the configuration of the 21st century electricity sector, but there is no doubt that it will be fundamentally different than the 20th century sector. In fact, by late 2012, the EEI Fall Board and Chief Executives Meeting, had a session entitles "Accommodating Distributed Energy Resources" driven by the premise that consumers want these resources and they will grow resulting in the "potential obsolescence of existing business and regulatory models."[11]

9. PG&E also assumes that a significant amount of natural gas generation will be needed to replace the amount of electricity generated by Diablo Canyon. But this is not a reasonable assumption. There are a large number of possible combinations of many resources that can

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assets," http://en.wikipedia.org/wiki/UBS

[5] *Id.*

[6] *Bernstein Energy and Power Blast: If solar wins, Who Loses?*, Bernstein Research, April 2. Lazard, 2013, Levelized *Cost of Energy Analysis* – Version 8.0, June.

[7] Eggers, Dan, et al., 2014, A Thought... The Transformational Impact of Renewables, Credit Suisse, December 20; CITI Research, 2012, *Shale & Renewables: A Symbiotic Relationship*, September 12.

[8] Eggers, Dan, 2013, A Thought... Energy Efficiency: The Reality of Slower Power Demand Growth, Credit Suisse, February 11; McKinsey and Company, 2010, Energy Efficiency: A Compelling Global Resource.

[9] UBS, 2014, Global Utilities, Autos & Chemicals Will solar, batteries and electric cars re-shape the electricity system?, August 20; Frankel, David , Kenneth Ostrowski, and Dickon Pinner, 2014, "The disruptive potential of solar power: As costs fall, the importance of solar power to senior executives is rising," *McKinsey Quarterly,* April.

[10] Kind, Peter, 2013, Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business, Edison Electric Institute, January; EEI/NRDC, *Joint Statement To State Utility Regulators*, February 12, 2014.

[11] The EEI Fall Board and Chief Executives Meeting, September 2012.

meet the need for electricity in a low carbon environment. PGE has chosen a single combination that relies on a large amount of gas, which increases the environmental impact of that alternative. More renewables, distributed generation, geothermal and efficiency would achieve the same outcome with a much more environmental and consumer friendly impact.

IV. PG&E's WOEFULLY INADEQUATE ANALYSIS

10. To appreciate why these developments deserve much more consideration than PG&E has given them, one need only compare PG&E's Amended Environmental Report with the California Energy Commission documents PG&E cites as Reference 29. PG&E reject the option of geothermal energy based on the assumption that a single new geothermal plant would have to be built in PG&E's service territory.[12] As the attached Figure 1 shows, making the conservative assumption that the PG&E service territory includes half the geothermal resources in the state, the State of California has alternative energy capacity that is four times greater than the capacity of Diablo Canyon. Three quarters of this capacity (geothermal and efficiency) is not intermittent, meaning that the 24-hour energy supply providing by Diablo Canyon could be replaced three times. Adding in renewables with storage would increase 24-hour availability of capacity to 3.5 times the capacity of Diablo Canyon. The ability of a well-managed 21st century electricity grid that actively integrates supply and demand to rely on renewable generation at much higher levels is well-documented. One recent study done for Europe by major industry consulting firms puts the figure as high as 60%,[13]

[12] Diablo Canyon Environmental Report, p. 7.2-12.
[13] Imperial College, NEA and DNV-GL, *Integration of Renewable Energy in Europe, Final Report,* for the European Commission, June 2014.

11. Because PG&E is so focused on disqualifying alternatives based on the erroneous standard of "sufficient, single resource baseload power," it fails to conduct a responsible analysis of its own data. For example, in updating the Environmental Report from 2010 to 2015, PG&E provides data to show that the dramatic transformation of the sector is well under way. This trend includes reduced energy demand, greater capacity for managing demand, and greater reserve margins than existed even ten years ago. The following quote, reproduced with PG&E's cross-outs and italicized additions preserved, provides clear evidence of the shift in electricity demand:

> In 2014, California *planning* reserve margins were ~~approximately~~ *projected to be* ~~22~~ *34* percent (Reference 8). The California Energy Commission defines planning reserve margin as the minimum level of electricity supplies needed to cover a range of unexpected contingencies, such as increased air conditioning demand on a hotter than average day, or an unplanned maintenance outage at a power plant. California energy demand is projected to increase from ~~277,479~~ *266,754* GWh in 2014 to ~~313,671~~ *279,632* GWh in ~~2018~~ *2024* (Reference 5, Form 1.1c). Of these statewide energy demand projections, PG&E would comprise approximately ~~37~~ *38* percent of the energy (Reference 5, Form 1.1c).[14]

This shift is also summarized in Figure 2 below.

12. The dramatic decrease in demand and sharp increase in reserve margins between 2008 and 2014 suggests that there is a lot more leeway to retire large, costly, inflexible reactors like those at Diablo Canyon. As shown in Figure 2 (attached), the reduction in projected peak demand in a short six years equals almost twice the total output of Diablo Canyon.

13. PG&E's analysis of the supply-side of the California electricity sector also obscures a simple fact: non-hydro renewables, i.e. wind as solar, have increased dramatically and are poised to surpass nuclear generation in the state, which has been in decline, as shown in Figure 3, which summarizes the most recent available energy data from the California Energy Commission.

[14] Diablo Canyon Amended Environmental Report, p. 7.2-1

14. PG&E makes the argument that Diablo Canyon is needed to reduce carbon emissions:

> Finally, overlaying these concerns about the alternative generation technologies are federal and state greenhouse gas emissions reduction goals. According to EPRI, even while adding renewable capacity equal to 4 times today's wind and solar capacity in 2008, the United States would need to maintain all of its current nuclear capacity, and add 45 more nuclear facilities, to meet greenhouse gas emissions reduction goals.[15]

But PG&E relies on the results of a dated, 2009, EPRI analysis with no effort to consider its relevance to the current market situation. When change is as rapid as is taking place in the electricity sector at present, half a decade is a long time.

15. The challenge of building 45 nuclear reactors in less than three decades in a nation that has not brought one online in the past two decades suggests the utter impossibility of this scenario. In fact, that scenario is not the only approach to reaching climate change goals by any stretch of the imagination. Since 2008, the wind and solar capacity brought online in the U.S. has increased its total seven fold. Moreover, as noted above and shown in Figures 4 and 5, many analysts think that much larger contributions from these resources are possible. The recent analysis from EIA suggested that wind alone could grow sufficiently to cover three-quarters of the amount of nuclear suggested. A simple projection of recent deployments would not only cover the shortfall, but retire a substantial part of the aging nuclear fleet.

16. PG&E's analysis is also fundamentally weak because it fails to recognize the dramatic development in battery technology that has been occurring over the past several years. Instead, PG&E focuses on pumped storage and compressed air. PG&E's failure to address battery technology is particularly egregious in light of the fact that many analysts conclude that batteries will play a key role in the transformation of the electricity system. Declining

[15] Diablo Canyon Amended Environmental Report, p. 7.2-2.

costs are a key driver, as shown in Figure 6, but so too is the increasing array of technologies and applications. Lazard and others see batteries as becoming the lowest cost peak resource, which will team with renewables. As shown in Figure 7, batteries have already surpassed compressed air and are rapidly expanding, as a storage medium.

17. Pursuing policies to actively manage and integrate supply and demand with intelligence, information and control technologies, has a "bonus" in terms of lowering total demand and peak use of gasoline. Figure 8, shows the effect PV with battery storage, but there are numerous other policies that can compound this effect, as shown in Figure 9. A demand and carbon dividend of 10 to 20 percent is possible, which would reduce the need to replace a significant part of Diablo Canyon capacity and output. The Regulatory Analysis Project identifies almost a dozen policies that can be implemented in a dynamic electricity system that actively manages supply and demand, which can lower the peak by 30%, dramatically increasing the system-wide load factor.[16] In fact, they count as a benefit to developing the integrated system of supply and demand management steps to "Retire inflexible generating plants with high off-peak must run requirements." The reduction of use of generation in the short term is place in the range of 10% to 20%. This should be considered a transformation dividend with respect to carbon reduction. The downward pressure on peak and average prices, which has been observed in systems that are, at best partially designed to exploit this aspect of the emerging electricity system, are an economic dividend that would be reinforced by a successful transformation of the system. The Regulatory Analysis Project describes the result as follows.

[16] Jim Lazar, Jim Lazar, *Teaching the "Duck" to Fly*, Regulatory Analysis Project, January 2014. Needless to say, there are many other general analyses of the possibility and benefits to aggressively integrating renewable supply and demand in the long term. The RAP analysis provides a clear, concrete basis for translating these benefits into cost analysis of presently deployed systems.

> Thus, our modified post-renewable load is easier to serve than the actual load projected to exist would have been without the addition of renewable resources. This is desirable for almost any electric utility system, including those without significant renewable energy deployment issues.
>
> It's evident that the net load (including solar and wind) after application of the ten strategies is a much more uniform load to serve from dispatchable resources even with the non-solar/wind resources than the load that was forecast for this period without solar and wind. The peaks have been lowered, the troughs raised, and the utility has control over a portion of the load to schedule when it can most economically charge water heaters, air conditioners, and batteries. In essence, the effect of the ten strategies is to reduce both peaking needs and ramping requirements.

18. Driven by its baseload bias, PG&E's Amended Environmental Report is riddled with incorrect and/or misleading statements. For instance, PG&E asserts:

> Comparison of actual utilization of generation capacity in California indicates that nuclear, natural gas, and hydroelectric are used by electric generators in the State more than other methods of generation. This condition reflects the relatively low fuel cost for nuclear, natural gas, and hydroelectric power plants for baseload, and the relatively higher use of oil and gas-fired units to meet peak loads.[17]

19. In making this assertion, PG&E misrepresents the merit order cost relationship between nuclear and renewables. As shown in Figure 10, the cost of operating aging reactors is rising, while costs of operating wind and solar are declining, thus making nuclear far more costly. This situation is likely to get much worse over the next decades as the operating costs of nuclear continue to rise. It is fundamental economics that underlies the current experience that a number of aging reactors are closing for economic reasons. As shown in Figure 9 (which is taken from a pro-nuclear group trying to explain the margin squeeze on aging reactors), low-operating-cost renewables back out high- cost peak gas, lowering the market clearing price. This reduces the margin to cover the cost of central station facilities that are not flexible and dispatchable. As a result, nuclear utilities that sell into markets where wholesale prices are set by supply and demand have experienced years of operating losses. Some (i.e. Exelon in Illinois) are now seeking subsidies to reverse their losses.

[17] Diablo Canyon Environmental Report, p. 7.2-1.

20. As my summary analysis of aging reactors in Figure 10 shows, Diablo Canyon is an aging reactor that appears to exhibit this problem. It is one of the more expensive reactors to operate and has significant safety issues, two factors that I have identified as critical in my analysis of the early retirement of reactors. Thus, the cost of operating Diablo Canyon is likely to go up. This renders the Diablo Canyon's contribution to output uncertain.

21. While the merit order effect has an important impact once renewables are deployed, it is not the primary cause of the underlying deployment. If renewable resources were at a severe cost disadvantage, it is unlikely they would have gained sufficient market share to so dramatically affect market clearing prices. Declining total (levelized) costs are the ultimate driver of change. Figure 11 combines the results of the two most recent estimates of levelized cost of electricity from Lazard. [18]

21. Combining the rising cost of operating aging reactors and the declining cost of alternatives yields a supply curve for low carbon resources in which nuclear reactors, **old and new**, are far from the least cost resources.

22. I have included three additional estimates of nuclear costs, because Lazard continues to use a construction period of just under six years -- the U.S. average was ten and the reactors currently under construction are well past six. I include two other estimates of the cost of power from new nuclear reactors. The official cost of the U.K. Hinkley reactor provides an estimate that reflects the higher cost projections of current technologies. I then include my estimate of the long-run cost of Small Modular Reactors, which have recently received a lot of attention.[19] Finally, I include an estimate of the cost of power from aging reactors for the mid-term based on the most costly (Ginna) and least costly (Byron) estimates for the at-risk

[18] Cooper, EPA comment.
[19] Cooper, EPA comment.

reactors that incorporate the underlying cost escalation assumed by Credit Suisse in its study of aging reactors.[20]

23. Figure 12 delivers a message that has been clear to energy analysts for quite some time. There are a number of alternatives that are likely to be competitive with natural gas-fired generation. Many alternatives are likely to be considerably less costly than nuclear, even in a low-carbon environment. Efficiency and wind are already less costly than aging reactors. Solar is likely to join that club in the near future, as are several other technologies that play a smaller role in the resource debate (biomass, geothermal, microturbines). Unabated gas is much less costly, while gas with carbon capture and storage is competitive with new nuclear. The EPA's Clean Power Rule focuses its attention on gas, efficiency, and non-hydro renewables, which are clearly lower in cost that nuclear.

24. In Tables 8.1 and 8.2, PG&E presents renewal of the Diablo Canyon operating license as having "small" environmental impacts. I do not think this characterization is consistent with the large socioeconomic costs of storing and disposing of spent reactor fuel. In fact, these costs are high enough to tip the balance against licensing or re-licensing nuclear reactors.

25. On December 16, 2013, I prepared a declaration for submission by SLOMFP and other organizations in the NRC's Waste Confidence Proceeding. 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. 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

[20] Eggers, et al., 2013. I show 2023, the mid-point of the current period for the EPA Clean Power rule.

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. A copy of my December 16, 2013 declaration is attached as Attachment 3.

Under penalty of perjury, 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.

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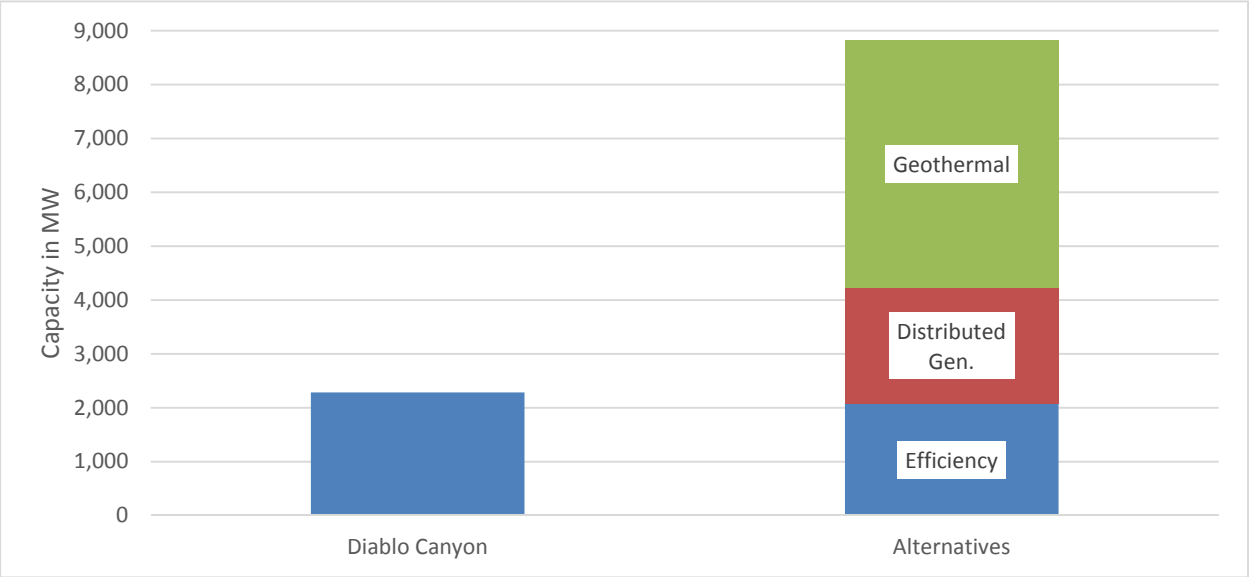
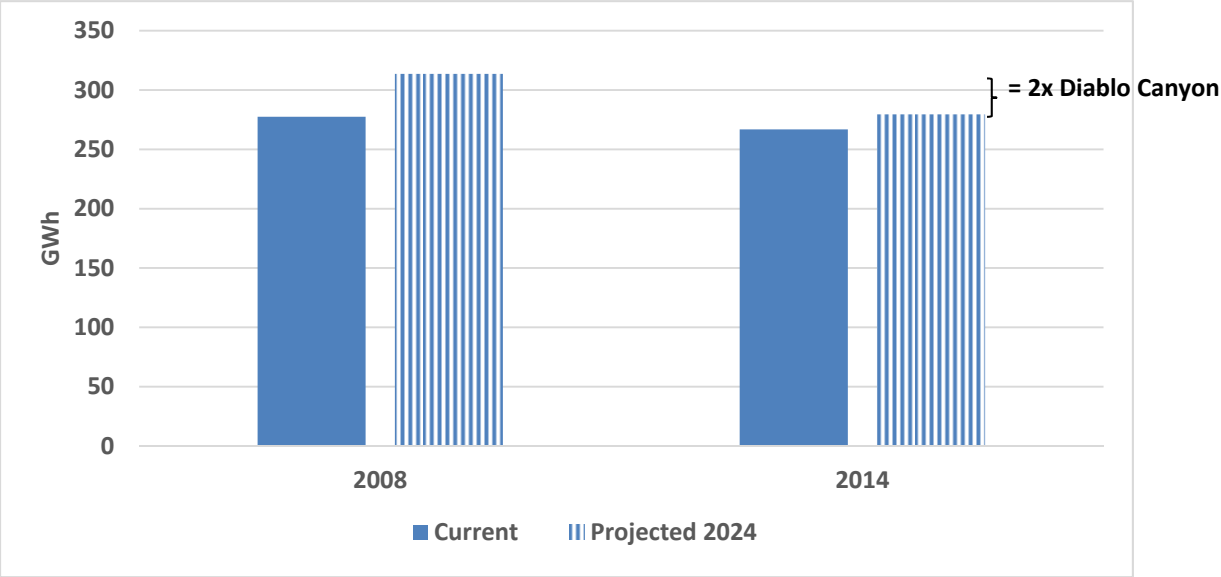
Mark Cooper
Date: April 6, 2015

FIGURE 1:
ALTERNATIVE POTENTIAL IS FOUR TIME DIABLO CANYON CAPACITY



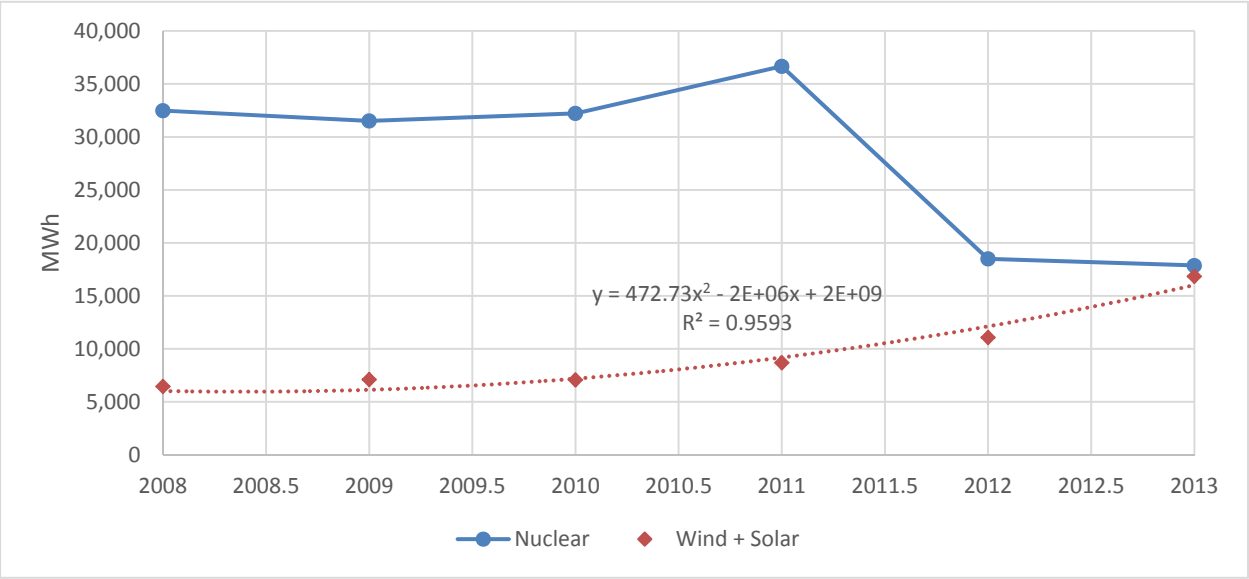
Diablo Canyon Amended Environmental Report pp. 7.2-6, 7.2-11, 7.2-12

FIGURE 2:
DECLINING DEMAND REDUCES THE NEED FOR DIABLO CANYON CAPACITY



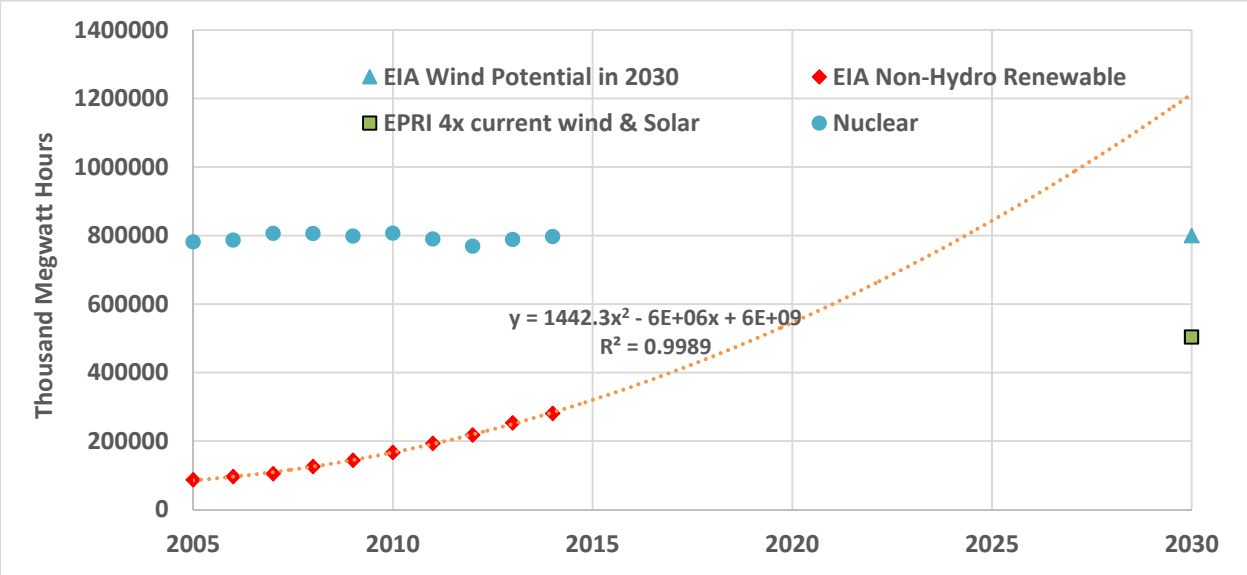
Diablo Canyon Amended Environmental Report, p. 7.2-1

FIGURE 3:
CALIFORNIA GENERATION



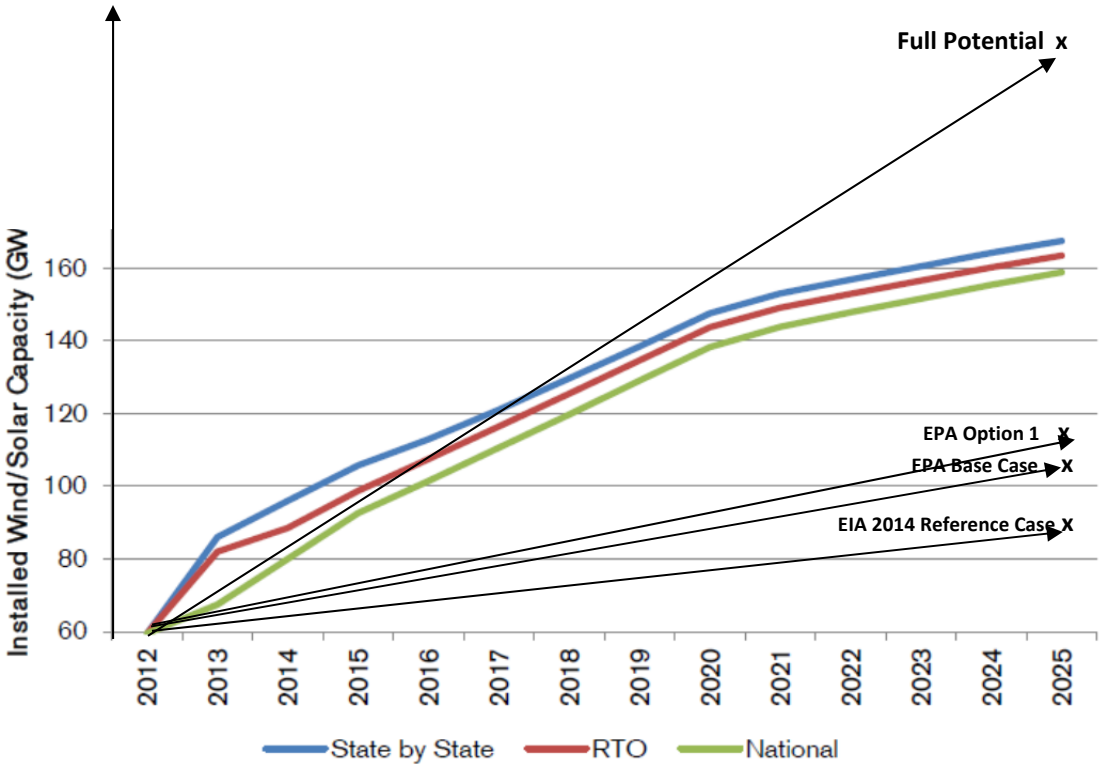
http://www.energy.ca.gov/renewables/tracking_progress/documents/installed_capacity.pdf

FIGURE 4:
NATIONAL PROJECTIONS OF LOW CARBON RESOURCE POTENTIAL



EPRI 4X current wind and solar cited at Diablo Canyon Amended Environmental Report, p. 7.2-2; Nuclear and EIA Non, from EI A electricity data;

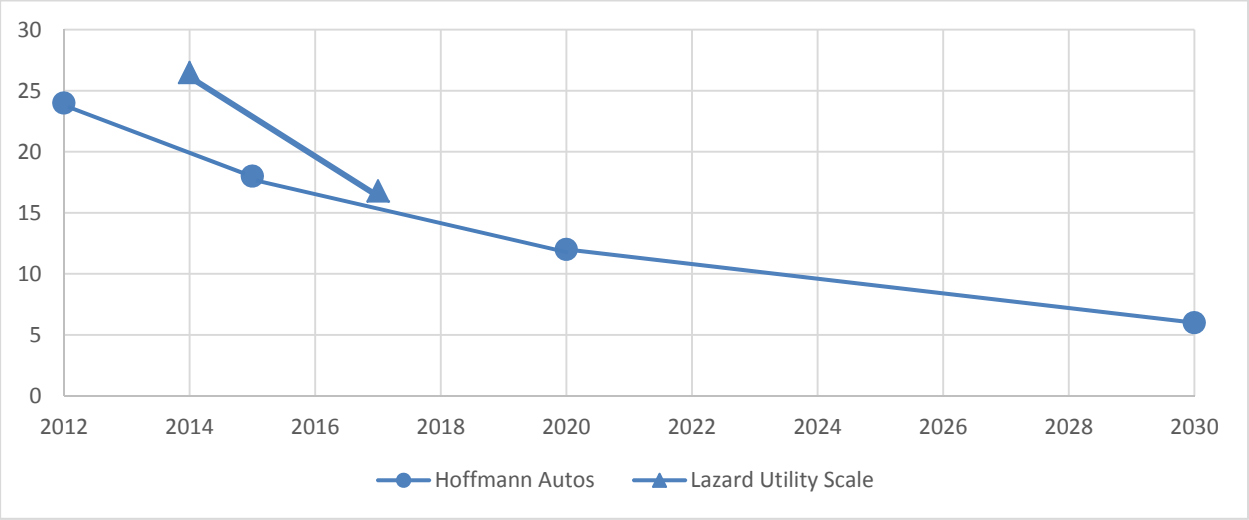
FIGURE 5:
CREDIT SUISSE PROJECTION OF RENEWABLE GROWTH COMPARED TO EPA OPTION 1 AND EIA 2014 REFERENCE CASE



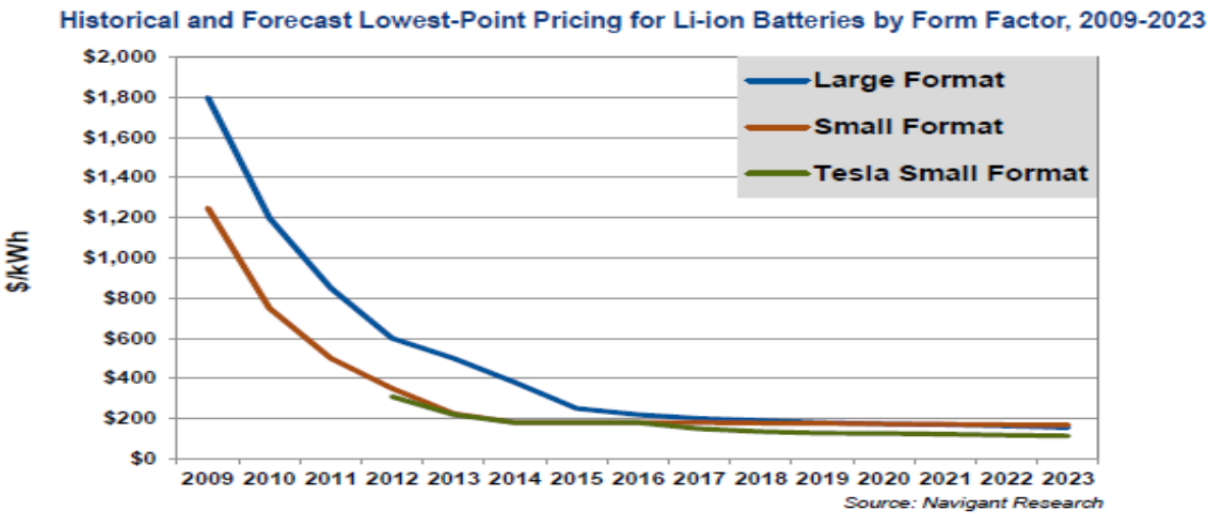
Source: Dan Eggers, Kevin Cole, Matthew Davis, *The Transformational Impact of Renewables,* Credit Suisse, December 20,2013, p. 18., EPA, *Regulatory Impact Analysis,* 2004, Table 3-11, Energy Information Administration, *Annual Energy Outlook, 2014,* Table A-16. See Comment of Mark Cooper, In the Matter of Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Before the Environmental Protection Agency, RIN 2060-AR33, November 24, 2014, pp. 145-150.

FIGURE 6:
COST OF BATTERIES, CENTS/KWH

Utility Scale

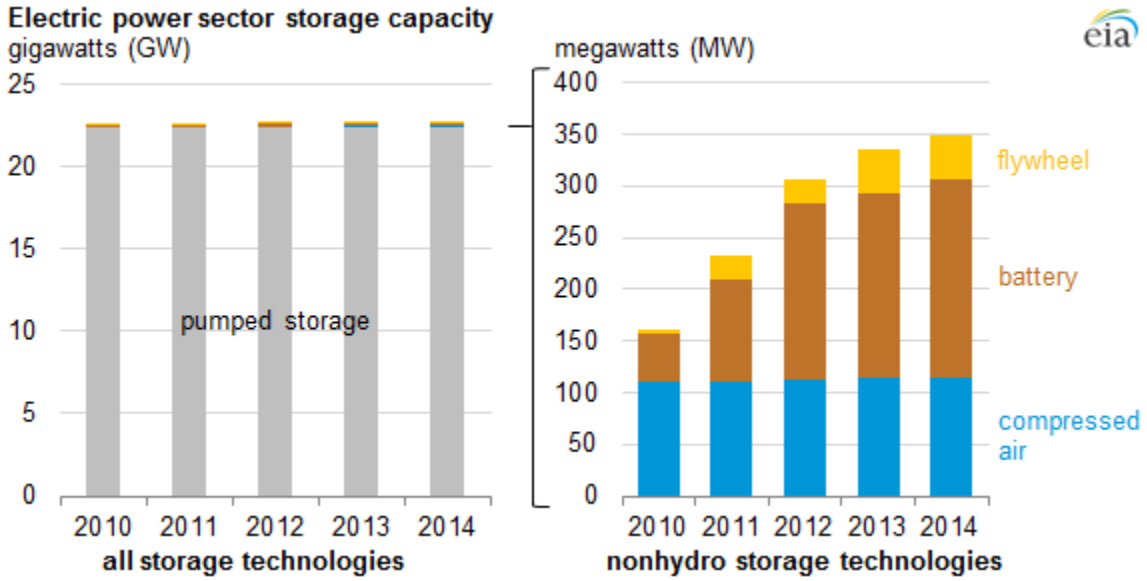


Source: ***Lazard's Levelized Cost of Energy Analysis – Version 8.0,*** **Wilfred Hoffman, as reported in Fuhs, Michael, 2014, "Forecast 2030: stored electricity at $0.05/kWh," *PV World,* September 29.**



Source: Sam Jaffee, 2014, *The Lithium Ion Battery Market Supply and Demand,* ARPA E RANGE Conference, January 28, p. 8.

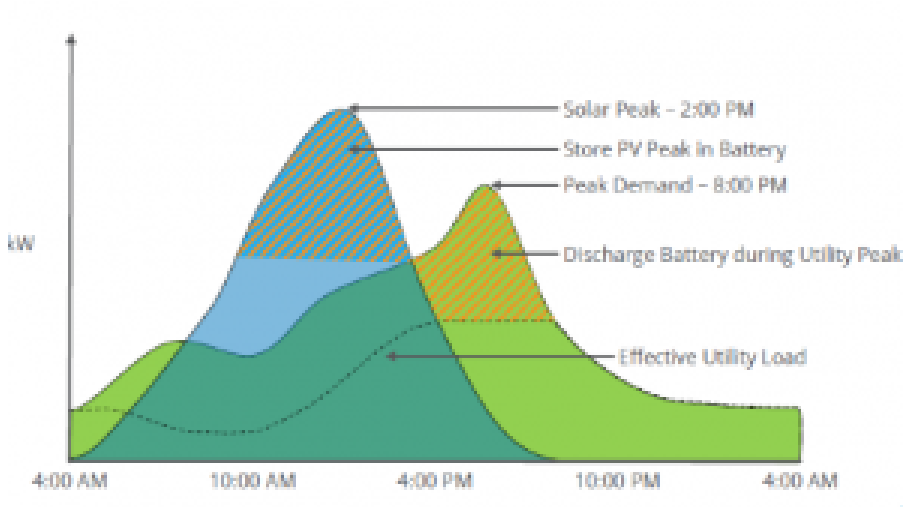
FIGURE 7
BATTERY STORAGE IS EXPANDING RAPIDLY, OTHER STORAGE TECHNOLOGIES ARE STATIC



EIA, Nonhydro electricity storage increasing as new policies are implemented, Energy Today, APRIL 3, 2015

HTTP://WWW.EIA.GOV/TODAYINENERGY/DETAIL.CFM?ID=20652

FIGURE 8
THEORETICAL LOAD CURVE REDUCTION WITH STORAGE



Source: Deutsche Bank, cited in Sophie Vorrath, Energy storage to reach cost 'holy grail', mass adoption in 5 years, *Renew Economy,* 3 March 2015

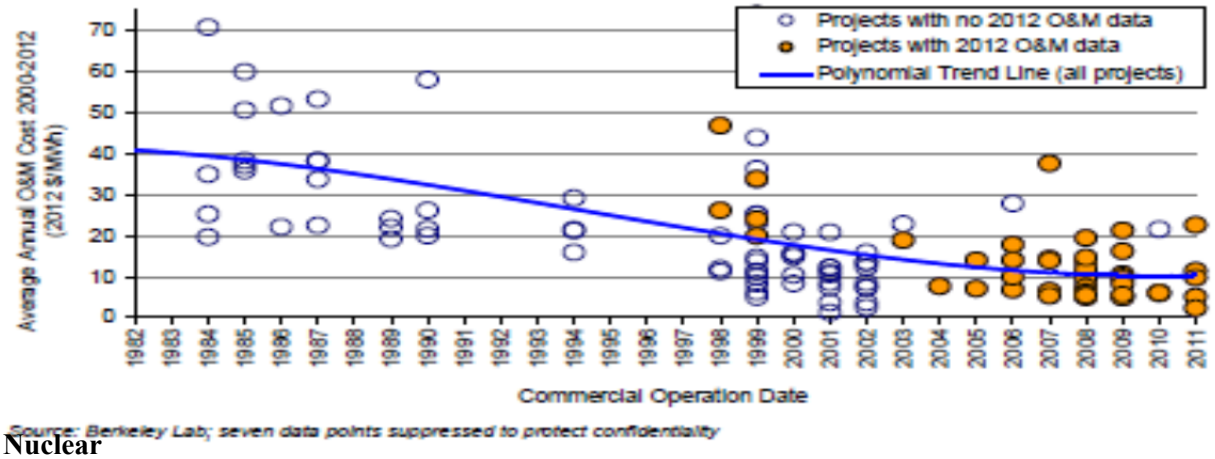
FIGURE 9
MEASURES TO MANAGE AN INTELLIGENT, DECENTRALIZED ELECTRICITY SECTOR AND REDUCE PEAK LOAD

Lovins	**Regulatory Analysis Project**	**Clean Coalition**
Efficiency	Target efficiency to peak reduction	
Forecasting		
Demand response	Aggressive Demand Response	Demand Response
	Manage water heater loads to reduce peak	
	Target fixed cost recovery to ramping hours	
Diversify supply	Retire must run base load	Curtail Base load
Technology		Import/Export
Geography	Integrated power transactions,	
	Target solar to peak supply (west orientation)	Curtail renewables
Dispatchable renewables	Solar thermal with storage	
Distributed storage	Utility storage in strategic locations; Air conditioning with storage	Storage

Source: Amory Lovins, *An initial critique of Dr. Charles R. Frank, Jr.'s working paper "The Net Benefits of Low and No-Carbon Electricity Technologies," summarized in the Economist as "Free exchange: Sun, Wind and Drain,* Rocky Mountain Institute, August 7, 2014. Jim Lazar, *Teaching the "Duck" to Fly*, Regulatory Analysis Project, January 2014. Clean Coalition, *Flattening the Duck,* December 16, 2013.

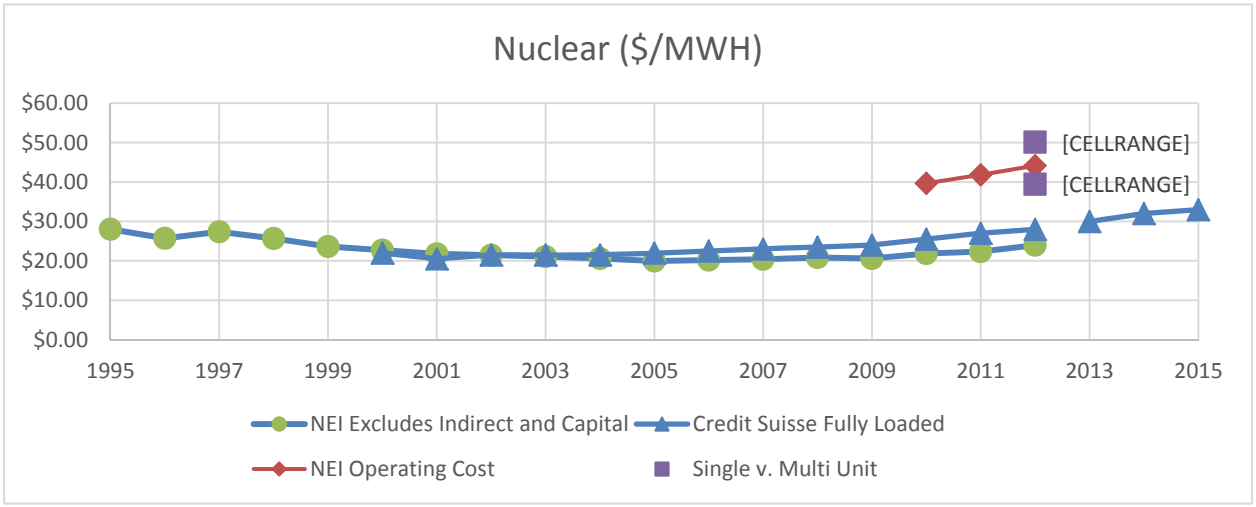
FIGURE 10:
AVERAGE O&M COASTS ($/MWH)

Wind



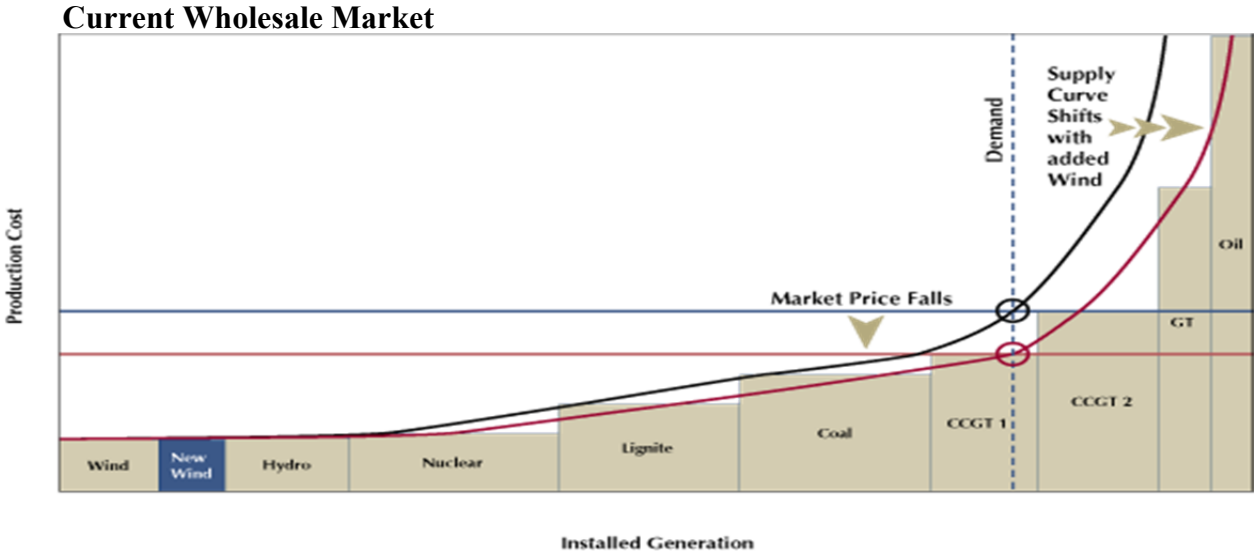
Source: Berkeley Lab; seven data points suppressed to protect confidentiality

Nuclear



Source: NEI Operating Cost (Nuclear Street News Team. "NEI Lays Out the State of Nuclear Power." Nuclearstreet.com. February 26, 2014); NEI Excludes Indirect (Nuclear Energy Institute, Operating Costs, http://www.nei.org/Knowledge-Center/Nuclear-Statistics/Costs-Fuel,-Operation,-Waste-Disposal-Life-Cycle/US-Electricity-Production-Costs-and-Components); Credit Suisse, *Nuclear… The Middle Age Dilemma?, Facing Declining Performance, Higher Costs, Inevitable Mortality,* February 19, 2013, p. 9.

FIGURE 11:
MERIT ORDER EFFECT OF ADDING NEW WIND CAPACITY ON PEAK PRICES



Source: Doug Vine and Timothy Juliant, 2014, *Climate Solutions: The Role of Nuclear Power,* Center for Climate and Energy Solutions, April, p. 6, with authors additions.

FIGURE 12:
RETIREMENT RISK FACTORS OF THE NUCLEAR FLEET

Reactor/ Capacity (MW)	Economic Factors							Operational Factors			Safety Issues	
	Cost	Small	Old	Stand Alone	Merchant	20yr<w/o Ext.	25yrw< w/ Ext.	Broken	Reliability	Long term Outage	Multiple Safety Issues	Fukushima Retrofit
RETIRED, 2013												
Kewaunee	X	X	X	X	X						X	
Crystal River	X		O					X		O	X	
San Onofre					X	X		X		O	X	
AT RISK												
Ft. Calhoun	X	X	X	X			O	X		O	X	
Oyster Creek	X	X	X	X	X		O			X		X
Ginna	X	X	X		X		O				X	
Point Beach	X	X	X		X		O					
Perry	X	X		X	X	X					X	
Susquehanna	X			X	X				X			X
Davis-Besse	X		O	X	X		O		X	X	X	
Nine Mile Point	X		X		X		O			X	X	X
Quad Cities	X			X	X		O					X
Dresden	X		X		X		O					X
Millstone	X		O	X	X		O				X	
Pilgrim	X	X	X		X	X	O			X	X	X
Clinton	X			X	X	X						
South Texas	X			X	X	X				X		
Commanche Peak	X			X	X	X						
Three Mile Island	X		X	X	X		O			X		
Palisades	X		X		X		O			X	X	
Fitzpatrick	X		O	X	X		O			X		X
Sequoyah	X				X	X				X		

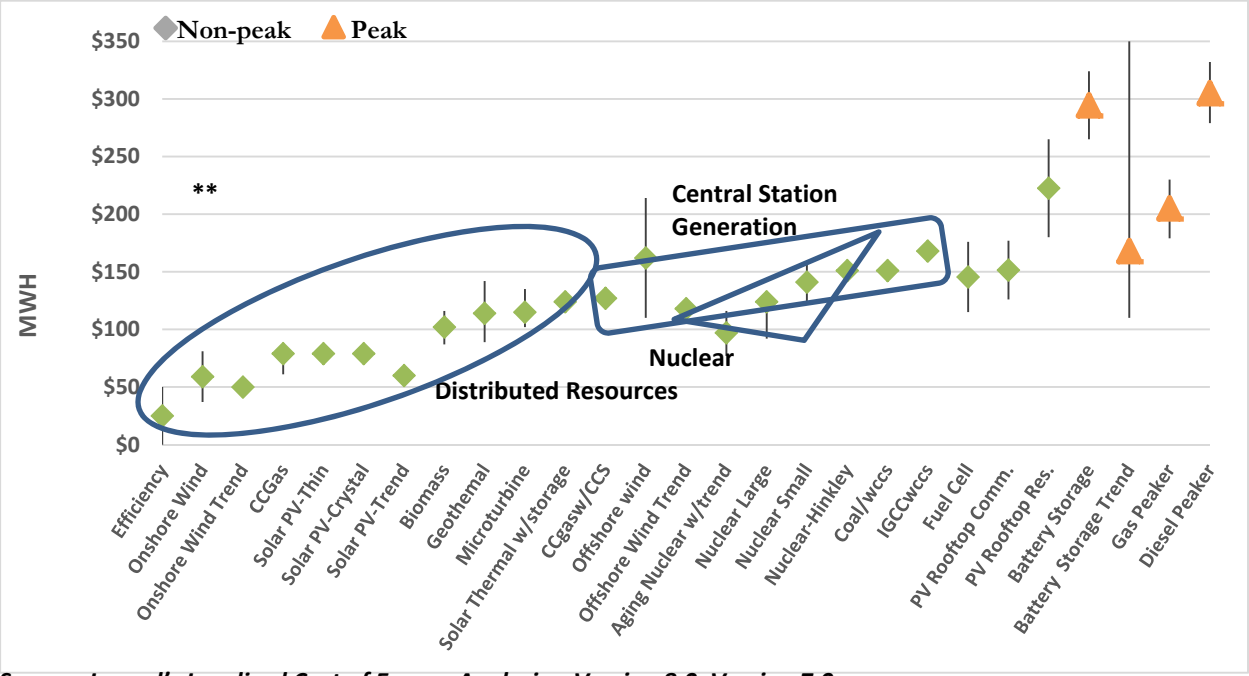
Hope Creek	X			X	X							X
Seabrook	X				X	X			X			
Indian Point	X		X		X		O			X		
Duane Arnold	X		O		X		O				X	X
Calvert Cliff	X		O		X		O			X	X	
Vt. Yankee	X	X	X		X		O					X
Browns Ferry			X				O		X	X	X	
Monticello	X	X	X			X	O				X	
Prairie Island	X	X	X				O				X	
Turkey Point	X	X	X			X	O			X	X	
Robinson	X		X			X						
Wolf Creek	X			X					X		X	
Fermi	X		X	X		X				X		
Diablo Canyon	**X**			**X**		**X**					**X**	
Cooper	X		X	X			O				X	
Callaway	X			X		X					X	
Cook	X		O				O		X		X	
LaSalle	X				X	X						X
Limerick	X				X	X						X

Sources and Notes: Credit Suisse, *Nuclear… The Middle Age Dilemma?, Facing Declining Performance, Higher Costs, Inevitable Mortality,* February 19, 2013; UBS Investment Research, *In Search of Washington's Latest Realities (DC Field Trip Takeaways*), February 20, 2013; Platts, January 9, 2013, "Some Merchant Nuclear Reactors Could Face Early Retirement: UBS," reporting on a UBS report for shareholders; Moody's, *Low Gas Prices and Weak Demand are Masking US Nuclear Plant Reliability Issues,* Special Comment, November 8, 2012.; David Lochbaum, *Walking a Nuclear Tightrope: Unlearned Lessons of Year-Plus Reactor Outages,* September 2006, "*The NRC and Nuclear Power Plant Safety in 2011,* 2012, and UCS Tracker); NRC Reactor pages.

Operational Factors: Broken/reliability (Moody's for broken and reliability); Long Term Outages (Lochbaum, supplemented by Moody's, o-current, x=past); Near Miss (Lochbaum 2012); Fukushima Retrofit (UBS, Field Trip, 2013)

Economic Factors: Cost, Wholesale markets (Credit Suisse) Age (Moody's and NRC reactor pages with oldest unit X=as old or older than Kewaunee, i.e. 1974 or earlier commissioning, O= Commissioned 1975-1979, i.e. other pre-TMI); Small (Moody's and NRC Reactor pages, less than 700 MW at commissioning); Stand Alone (Moody's and NRC Reactor pages); Short License (Credit Suisse and NRC Reactor pages).

FIGURE 13:
LEVELIZED COST (LCOE) OF LOW CARBON OPTIONS WITH TRENDS



Source: ***Lazard's Levelized Cost of Energy Analysis – Version 8.0, Version 7.0.***