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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of:	)	
	)	
CALVERT CLIFFS 3 NUCLEAR PROJECT, LLC AND UNISTAR NUCLEAR OPERATING SERVICES, LLC	)	Docket No. 52-016-COL
	)	
(Calvert Cliffs Nuclear Power Plant, Unit 3)	)	

DIRECT TESTIMONY OF UNISTAR WITNESSES DIMITRI LUTCHENKOV, STEFANO RATTI, AND SEPTIMUS VAN DER LINDEN

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I. INTRODUCTION

A. Dimitri Lutchenkov

Q1. Please state your full name.

A1. My name is Dimitri Lutchenkov ("DL").

Q2. By whom are you employed and what is your position?

A2. I am currently employed as the Director, Environmental Affairs and Special Projects, for UniStar Nuclear Energy, LLC ("UniStar"). In my position at UniStar I have responsibility for the environmental aspects of the Calvert Cliffs 3 licensing reviews, including preparation of the Environmental Report ("ER") and development of responses to NRC Staff Requests for Additional Information ("RAIs").

Q3. Please summarize your educational and professional qualifications.

A3. My professional and educational qualifications are summarized in the curriculum vitae attached to my declaration (Exh. APL000002). Briefly summarized, I earned a B.S. in mechanical engineering from the University of Maryland. I have over 30

years experience in developing energy projects. Since 2008, I have been employed as Director of Environmental Affairs at UniStar. Prior to that, I was employed as Project Director at Constellation Energy.

Q4. What is the purpose of your testimony?

A4. The purpose of my testimony is to provide my opinion on Contention 10C in this matter concerning the Calvert Cliffs 3 project, including the purpose and need for the new unit and the environmental impacts of alternatives. I also describe and evaluate the analysis performed by the NRC Staff in the FEIS related to the contention. In addition, I provide background information on the Calvert Cliffs 3 application and licensing reviews.

Q5. What documents or information have you reviewed to prepare your testimony?

A5. I have reviewed the discussion of energy alternatives in Section 9.3 of the DEIS and FEIS (Exhs. APL000050 and NRC00003A), including the NRC Staff's analysis of the potential for wind, solar, and a combination of energy alternatives to provide the 1600 MW(e) of <u>baseload</u> power that would meet UniStar's stated project purpose and need. I have also reviewed the filings and decisions in this proceeding that relate to Contention 10C.

B. <u>Stefano Ratti</u>

Q6. Please state your full name.

A6. My name is Stefano Ratti ("SR").

Q7. By whom are you employed and what is your position?

A7. (SR) I am the founder and owner of Chaberton Consulting.

Q8. Please summarize your educational and professional qualifications.

A8. (SR) My professional and educational qualifications are summarized in the curriculum vitae attached to my declaration (Exh. APL000003). Briefly summarized, I earned a degree in Energy Systems Engineering from Polytechnic University of Milan and a M.S. in Mechanical Engineering from the University of Illinois at Chicago. Prior to starting Chaberton Consulting, I was Vice President, Renewable Energy Business Group, at AREVA. While at AREVA, I was responsible for developing strategic renewable initiatives, including evaluation of potential acquisitions in the renewable energy sector and creation of renewable energy businesses in the United States.

Q9. What is the purpose of your testimony?

A9. (SR) The purpose of my testimony is to provide an assessment of the current state of wind and solar technologies in the United States. I provide an assessment of the key parameters involved in deployment of wind and solar with a focus on wind and solar projects in Maryland. I also evaluate the NRC's analysis of the combination of energy alternatives in the FEIS as they relate to wind and solar power.

Q10. What documents or information have you reviewed to prepare your testimony?

A10. (SR) I have reviewed the NRC Staff's Draft and Final Environmental Impact Statements for Calvert Cliffs 3 (Exhs. APL000050 and NRC00003A). I have also reviewed the filings and decisions in this proceeding that relate to Contention 10C. In addition, I have reviewed documents regarding the status of existing and planned wind and solar projects in Maryland and the region.

C. Septimus van der Linden

Q11. Please state your full name.

A11. My name is Septimus van der Linden ("SVDL")

Q12. By whom are you employed and what is your position?

A12. (SVDL) I am the founder, co-owner, and President of BRULIN Associates LLC.

Q13. Please summarize your educational and professional qualifications.

A13. (SVDL) My professional and educational qualifications are summarized in the curriculum vitae attached to my declaration (Exh. APL000004). During my previous employment with Curtiss/Wright Power Systems (13 years) and then with Alstom (19 years), I investigated compressed air energy storage systems ("CAES"). I worked for Brown Boveri Corporation (BBC) – Asea Brown Boveri ("ABB"), which built the first CAES plant in Huntorf, Germany, in 1976. BBC also developed a machinery product range for the U.S. market. I was tasked at BBC to support that effort with the Electric Power Research Institute ("EPRI"), utilities, and Architect/Engineers. I have been involved in the design and application aspects of CAES plant and technology in the U.S. and participated in many EPRI-lead workshops that led to construction of the first CAES plant in the U.S. at McIntosh, Alabama. I currently consult on CAES-related issues.

Q14. What is the purpose of your testimony?

A14. (SVDL) The purpose of my testimony is to provide an overview of CAES, including background information on CAES, the status of existing and planned CAES plants, and developments in CAES technology. I provide an assessment of the use of wind and solar, in conjunction with CAES, to provide baseload power in Maryland. I also

evaluate the NRC's analysis of the combination of energy alternatives in the FEIS as they relate to energy storage.

Q15. What documents or information have you reviewed to prepare your testimony?

A15. (SVDL) I have reviewed the NRC Staff's Draft and Final Environmental Impact Statements for Calvert Cliffs 3 (Exhs. APL000050 and NRC00003A). I have also reviewed the filings and decisions in this proceeding that relate to Contention 10C. In addition, I reviewed documents regarding the status of existing and planned CAES projects in the United States.

II. DISCUSSION

A. Need for Baseload Power

Q16. What is baseload power?

A16. (DL) Baseload power plants are intended to meet a region's continuous energy demand and typically produce energy at a constant rate. Baseload plants typically run continuously except during repairs or scheduled maintenance. Coal and nuclear power plants typically operate in a baseload manner. Natural gas combined-cycle generation plants may be used for baseload generation, but are often used as intermediate generation sources. Wind energy and solar energy are both considered intermittent energy sources, meaning that these sources may be uncontrollably variable or more intermittent in normal operational conditions compared to traditional baseload plants.

Q17. What is the region of interest?

A17. (DL) The region of interest is the State of Maryland.

Q18. What is the purpose and need for the proposed action?

A18. (DL) The purpose and need for the proposed NRC action (issuance of a combined license for Calvert Cliffs 3) is to provide for additional large baseload electrical generating capacity within the State of Maryland. Calvert Cliffs 3 will provide approximately 1600 MW(e) of baseload power in the region of interest. In 2009, the Maryland Public Service Commission ("MPSC") issued a Certificate of Public Convenience and Necessity ("CPCN") for a new nuclear unit at Calvert Cliffs. In issuing the CPCN, the MPSC took into account the effect of the proposed new unit on the stability and reliability of the electrical system. Subsequently, the MPSC issued a 2010 report showing a decrease in peak demand and utility forecasted energy sales in Maryland compared to its previous year's report, but continued to assert that there will still be a need for central power stations in Maryland.[1]

B. <u>Energy Alternatives</u>

Q19. Does NEPA require consideration of alternatives?

A19. (DL) Yes. However, NEPA does not require an applicant to look at every conceivable alternative. Rather, NEPA requires only consideration of feasible, non-speculative, reasonable alternatives.[2] According to NUREG-1555, Section 9.2.2, if the proposed project is intended to supply baseload power, a competitive alternative would also need to be capable of supplying baseload power. There are many possible combinations of energy alternatives that could satisfy a need for baseload power.

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1 FEIS at 1-9.

2 *See, e.g.*, NUREG-1555, Section 9.2.2 (Exh. NRC000008).

Q20. What energy alternatives did the NRC Staff consider in the FEIS?

A20. (DL) The FEIS considers the environmental impacts of discrete power generation sources, a combination of sources, and those power generation technologies that are technically reasonable and commercially viable for producing baseload power. FEIS at 9-7 (Exh. NRC00003A). The FEIS correctly notes that the three primary energy sources for generating baseload electric power in the United States are coal, natural gas, and nuclear energy. The FEIS considers the environmental impacts of those discrete power generation sources, as well as a combination of energy alternatives. The NRC Staff concludes in Section 9.2.3 of this FEIS that renewable energy alternatives, such as wind and solar, would not by themselves be reasonable alternatives to a new nuclear generating unit operated as a baseload power plant.

Q21. Do you agree with the NRC Staff's conclusions in the FEIS regarding the reasonable energy alternatives?

A21. (DL) Yes. I agree that coal and natural gas are reasonable alternatives to the proposed action (nuclear). And, I agree that coal and natural gas are not environmentally preferable to Calvert Cliffs 3.

The FEIS also considered a combination of energy alternatives consisting of the following: 1200 MW(e) of natural gas combined-cycle generating units at the Calvert Cliffs site; 25 MW(e) from hydropower; 75 MW(e) from solar power; 100 MW(e) from biomass sources, including municipal solid waste; 100 MW(e) from conservation and demand-side management programs (beyond current plans); and 100 MW(e) from wind power.[3] In light of the project goal of producing baseload

3 FEIS at 9-28 (Exh. NRC00003A).

power, I agree that a fossil energy source, most likely coal or natural gas, will be a significant contributor to any reasonable alternative energy combination. I also agree that this combination of alternatives is reasonable for the purpose of a NEPA discussion. And, as discussed further below, I agree with the NRC Staff conclusions that this combination of alternatives considered in the FEIS is not environmentally preferable to Calvert Cliff 3.

Q22. Briefly summarize the NRC Staff's assessment of the energy alternatives.

A22. (DL) For the natural gas alternative, the FEIS assumes that the plant would use combined-cycle combustion turbines.[4] Overall, the NRC Staff concluded that a 1600-MW(e) natural-gas fired plant would cause LARGE adverse impacts to historic and cultural resources, a SMALL to MODERATE beneficial impact on taxes and economy, SMALL to MODERATE impacts on air quality, and SMALL adverse impacts on land use, water use and quality, ecology, waste management, socioeconomics (except taxes and economy), human health, and environmental justice.[5] I generally agree with this assessment in the FEIS, which is based, in part, on the information presented by UniStar in the ER associated with the Calvert Cliffs 3 COL application.[6]

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4 *Id.* at 9-14.

5 *Id.* at Table 9-4.

6 Calvert Cliffs Power Plant Unit 3 COLA (Environmental Report), Rev. 7 – Chapter 09, Alternatives to the Proposed Action, Sections 9.1 and 9.2, December 20, 2010 (ADAMS Accession No. ML103620413) (Exh. APL000048).

According to the FEIS, the adverse environmental impacts of proposed Calvert Cliffs 3 (*i.e.*, the nuclear generation alternative) upon land use, air quality, water use and quality, waste management, human health, and environmental justice will be SMALL.[7] The NRC Staff concluded that impacts on historic and cultural resources will be LARGE and that the adverse environmental impacts of Unit 3 upon ecology will be MODERATE. The NRC Staff concluded that exposures from liquid pathways, gaseous pathways, or direct radiation from the station operation would be within the limits specified by NRC and EPA regulations.[8] Accordingly, human health impacts and environmental impacts from radiological effluents from Unit 3 would be SMALL.[9] Similarly, the risk-based radiological impacts of accidents at Unit 3 will be SMALL. I generally agree with this assessment in the FEIS, which is based, in part, on the information presented by UniStar in the ER associated with the Calvert Cliffs 3 COL application.

According to the FEIS, the environmental impacts associated with the construction and operation of the combination of energy alternatives are SMALL for water use and quality, human health, and environmental justice. The impacts are SMALL to MODERATE for air quality, waste management, and socioeconomics (except taxes and economy). The environmental impacts are MODERATE for land use and ecology and LARGE for historic and cultural resources. The impacts on

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7 *Id.* at Table 9-4.

8 *Id.* at 5-63 to 5-65 and Tables 5-10 and 5-11.

9 *Id*. at Table 5-20.

socioeconomics (taxes and economy) are SMALL to MODERATE beneficial.[10] The impacts of the combination of energy alternatives accounts for the proportional decrease in impacts, including air emissions, associated with a smaller natural gas facility relative to a 1600 MW(e) gas plant. I generally agree with this assessment in the FEIS, which is based, in part, on the information presented by UniStar in the ER associated with the Calvert Cliffs 3 COL application.

C. Wind Power

Q23. Please provide an overview of wind power technologies, both onshore and offshore.

A23. (SR) Wind power involves the conversion of wind energy into electricity through wind turbines. Most modern turbines are horizontal-axis, three bladed turbines. Wind turbines consist of four main components — rotor, transmission system, generator, and yaw and control systems — which are designed to work together to reliably convert the motion of the wind into electricity. These components are fixed onto or inside the nacelle, which is mounted on the tower. The nacelle rotates (or yaws) according to the wind direction.

Today's wind turbines typically range in size from 1 to 5 MW per turbine, although larger-size turbines are available and 10 MW turbines are under development. Offshore installations tend to be on the higher end of the turbine size spectrum, since there are fewer land-based transportation and construction constraints on the size of the blades, and blades are allowed to rotate faster, since noise is generally less of a concern. In general, there is no theoretical limit to the size of a wind farm, but an

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[10] *Id.* at Table 9-3

average onshore wind farm tends to be in the 50-150 MW range. Installations in the Appalachian region tend to be smaller than Great Plains installations, due to topographic constraints and the need to build wind farms on mountain ridges.

Over 90% of installed wind energy worldwide and 100% of domestic wind energy is generated through onshore wind turbines, which offer proven technologies and development processes and a significantly cheaper installed cost than offshore wind installations.

Offshore wind technology has evolved from onshore wind technology. Today, offshore wind technology has been proven for shallow waters (typically, less than 30- or 35-meter deep), with virtually all installations of offshore wind projects in this category. In shallow water, the substructure extends to the sea floor and includes monopoles, gravity bases, and suction buckets. For deeper water, more complicated technologies are necessary, such as jacket substructures and multi-pile foundations, which extend to the sea floor. At some depth, it is no longer economically advantageous to have a rigid structure fixed to the sea floor, and floating platforms may be required. However, these technologies are still in the early development stage and have not been proven at a commercial scale.[11]

Q24. What are the capacity factors for wind projects?

A24. (SR) Capacity factors for wind installations vary greatly depending on location, weather, and climate patterns. Capacity factors for onshore wind installations range

[11] National Renewable Energy Laboratory, "Large-Scale Offshore Wind Power in the United States – Assessment of Opportunities and Barriers," 2010 at 5 ("NREL 2010") (Exh. APL000007).

from 15% to 45%, with most of the installations between 25% and 35%.[12] Capacity factors are typically higher during the night hours, often in the 40%+ range, but then drop during the day (typically during periods of peak load), with daily capacity factors in the range of 25%.[13]

Offshore wind installations benefit from higher-than-average capacity factors, typically higher than 30%, and, in certain cases, as high as 45-50%.[14] For offshore wind installations off of the United States East Coast (New England and Mid-Atlantic), one can expect a capacity factor of around 35-40%.[15]

Q25. How much land does a wind installation require?

A25. (SR) Onshore wind farms are typically built over large areas. Spacing of wind turbines is necessary to minimize turbulence interference between turbines and varies depending on wind patterns and terrains. The distance between wind turbines (between turbine rows and between turbines within a row) is commonly described in terms of rotor diameters. For example, a 3-by-10 spacing means that the turbines are generally spaced 3 rotor diameters apart within rows, and the rows are spaced 10 rotor diameters apart. For a project using wind turbines with a 70-m (230 ft) rotor

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12 Department of Energy, Lawrence Berkley National Laboratory, "2009 Wind Technologies Market Report," 2009 (Exh. APL000008).

13 GE Energy Consulting, "The Effects of Integrating Wind Power on Transmission System Planning, Reliability, and Operations," Prepared for the New York State Energy Research and Development Authority, March 4, 2005 (Exh. APL000009).

14 NREL 2010 (Exh. APL000007).

15 University of Delaware's Center for Carbon-free Power Integration, College of Earth, Ocean, and Environment, "Maryland's Offshore Wind Power Potential," February 1, 2010 (Exh. APL000010).

diameter, this would mean spacing the turbines 210 m (690 ft) apart within a row, and 700 m (2,300 ft) apart between rows.[16] Spacings of 3-by-10 and 5-by-10 are fairly common and represent a good proxy for the amount of wind that can be harvested at a given location. A wind farm in open, flat terrain generally requires about 40 acres per megawatt of installed capacity. A wind plant on a ridgeline in hilly terrain will require much less space — as little as two acres per megawatt.

Offshore wind obviously does not require land, but it presents other issues in terms of the need to co-exist with marine life and activities, potential interference with shipping lines, and the need to lease concessions through the federal government in order to operate in public territory.

Q26. What are the costs associated with onshore wind power?

A26. (SR) Wind power costs include capital costs and operation and maintenance ("O&M") costs. Capital costs are best referred to in terms of dollars per kilowatt ("KW") of capacity installed. Until 2-3 years ago, a good rule of thumb for onshore wind power capital costs was that a turbine would cost approximately $1,500 per KW and a wind farm would have a total installed overnight[17] cost of $2,000 per KW.[18] However, in the last couple of years, prices for wind turbines have dropped due to oversupply. Today's wind turbine prices are approaching $1,000 per KW, with total

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16 New York State Energy Research & Development Authority, "Wind Power Project Site – Identification and Land Requirements," October 2005 (Exh. APL000011).

17 Unless otherwise stated, "installed cost" refers to overnight costs (*i.e.*, excludes costs for interest during construction).

18 Department of Energy, Lawrence Berkley National Laboratory, "2009 Wind Technologies Market Report," 2009 (Exh. APL000008).

installed wind farm costs falling to around $1,500 per KW.[19] However, on the East Coast, the currently accessible wind resources are located on mountain ridges in the Appalachian region, are typically smaller in size, and therefore are more expensive to harvest. East Coast installation costs are likely to be well above $1,500 per KW. For reference, the 2011 Long-Term Electricity Report ("LTER") for Maryland assumes installed cost for onshore wind farms at $2,200 per KW, decreasing to $1,800 per KW after 2011.[20] O&M costs are typically in the $10 to $15 per MWh range, but vary significantly depending on location, and wind farm scale (larger farms enjoy significant economies of scale). O&M costs include land rent, insurance, maintenance and spare parts, and owner's overhead. The LTER for Maryland assumes $11 per MWh for O&M.[21]

Q27. What about offshore wind power?

A27. (SR) Offshore wind farms are significantly more expensive than onshore farms. While there are some limited cost advantages for an offshore wind farm — most notably the fact that offshore rotors can be allowed to rotate faster, which implies lower torque and therefore lighter, less costly drive train components — these relatively small cost advantages are greatly overwhelmed by the additional costs associated with components resistant to corrosive salt waters, resilience to tropical and extra-tropical storms and waves, long distance electrical transmission on high-

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19 John Blau, "Oversupply Causes Drop in Wind Turbine Prices," October 10, 2011 (Exh. APL000013).

20 Exeter Associates, Inc., "Long-Term Electricity Report for Maryland," Prepared for the Maryland Department of Natural Resources, September 23, 2011 (Exh. APL000005).

21 *Id*.

voltage submarine cables, turbine maintenance at sea, and accommodation of maintenance personnel. Additionally, building an offshore wind farm requires development of necessary support infrastructure, including costs for customized vessels, port and harbor upgrades, new manufacturing facilities, and workforce training.

According to NREL, capital costs for offshore wind installations are estimated to be twice as high as land-based systems, with some of the extra cost being partially offset by higher capacity factors.[22] Another recent estimate from the Energy Information Administration puts the cost of offshore wind at 2.5 times that of onshore.[23]

Additionally, the projects in the United States that have been announced recently had estimated capital costs that are many times the typical cost of onshore wind farms:

- The Deepwater project in Rhode Island was announced in October 2011 with a price tag of $205 million for 30 MW, which is over $6,000 per KW, or more than four times as expensive as comparable onshore wind farms.[24]
- Estimates for the larger Cape Wind project have not been made public from the company, but it has been reported that the Massachusetts Attorney General's office estimated the project cost at $2.62 billion, which is also close to $6,000 per KW, and four times as expensive as comparable onshore wind farms.[25]

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22 NREL 2010 (Exh. APL000007).

23 Department of Energy, Energy Information Administration, DOE/EIA-0383, "Annual Energy Outlook 2011," Table 1, December 2010 (Exh. APL000014).

24 "Deepwater to build first U.S. offshore wind farm," Reuters, October 13, 2011 (Exh. APL000015).

25 "2 Mass. utilities make very different power deals," Associated Press, March 27, 2011 (Exh. APL000016).

- In August 2010, Duke Energy canceled plans to erect three demonstration wind turbines in North Carolina's Pamlico Sound, between the mainland and the state's Outer Banks. After a year of in-depth study and collaboration with the University of North Carolina at Chapel Hill, Duke Energy concluded that the fixed costs associated with permitting, design, and construction would render the small-scale project not economically viable. Cost estimates for the Pamlico Sound project exceeded $8,000 per KW.[26]

As was experienced with land-based wind systems over the past two decades, offshore wind costs would be expected to drop with greater experience, increased deployment, and improved technology. In the meantime, some manufacturers are designing larger wind turbines capable of generating more electricity per turbine. Several manufacturers are considering 10-MW turbine designs, and programs such as UpWind in the European Union are developing the tools to support these larger machines. The extent to which any of these efforts will be successful in reducing the high cost of offshore wind is, however, speculative at present.

Although there is no direct experience with offshore wind in the United States, O&M costs of offshore wind farms are also likely to be significantly higher than onshore wind farms, around $20 per MWh and above. For reference, the LTER for Maryland assumes an installed capital cost of $4,460 per KW and an O&M cost of $21 per MWh for offshore wind.[27]

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26 Duke Energy, "2010-2011 Sustainability Report," Another Strong Year for Renewables, 2011 (Exh. APL000017); Wind Energy News, "Duke Energy Axes North Carolina Offshore Wind Pilot," August 20, 2010 (Exh. APL000018).

27 LTER 2010 (Exh. APL000005).

Q28. What are the permitting issues and development times associated with onshore wind power?

A28. (SR) Depending upon the size and potential impact of the project, regulating bodies at the local, state, and federal levels may participate in the permitting process for wind farms.

For onshore wind, at the local level, the local planning commission, zoning board, city council, or county board of supervisors or commissioners, generally govern permitting. Many projects may also require some form of local grading or building permit to assure compliance with structural, mechanical, and electrical codes. At the state level, permits may be required from natural resource and environmental protection agencies, historic preservation offices, industrial development and regulation agencies, public utility commissions, and siting boards. Federal permitting authorities include federal land management agencies (such as the U.S. Forest Service), the Federal Aviation Administration ("FAA"), and the U.S. Fish and Wildlife Service.

Typical steps in permitting include pre-application, application review, decision making, and administrative and judicial review. Issues that might be addressed during the permitting process for onshore wind farms include land use, noise, impact on birds and other biological resources, visual impact, soil erosion, water quality, public health and safety, cultural and paleontological resources, socioeconomics, public service, and infrastructure, solid and hazardous wastes, and air quality and climate.

The length of time required to receive a permit varies from project to project, but onshore wind farms can be brought on line faster than most other types of power-generating facilities. The length of construction depends primarily upon the number of turbines to be erected, the terrain, and weather conditions. Under the best circumstances, this can all be accomplished within one to two years.[28]

Q29. Is permitting more difficult for offshore wind power projects?

A29. (SR) Yes, the permitting process for offshore wind farms is much more complex. There is limited experience in the United States and the only project that has received the required permits is the Cape Wind project off the coast of Massachusetts. The Cape Wind project was announced in 2001 and received its local and state permits in 2009 and most federal permits in 2010 and 2011, including those from the Department of the Interior ("DOI"), the FAA, the Mineral Management Service ("MMS") now called the Bureau of Ocean Energy Management ("BOEM"), the Environmental Protection Agency ("EPA"), and the U.S. Army Corps of Engineers. The permitting process has taken over ten years.

Given the significant amount of public controversy over the high costs and impact of offshore wind, as well as the number of local, state, and federal government agencies involved in permitting an offshore wind farm, it is likely that any offshore project in the United States will go through a similarly lengthy permitting process. This remains true even though the federal government, through the DOI's "Smart from the

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[28] National Wind Coordinating Committee, "Permitting of Wind Energy Facilities," August 2002 (Exh. APL000019).

Start" initiative, is taking steps to attempt to reduce the length of the permitting process, at least at the Federal level.

Q30. What are the estimated development times for wind power projects?

A30. (SR) The time needed to bring a wind farm to operation is dependent not only on the permitting process, but also on commercial considerations. Commercial development steps include negotiations of power purchase agreements ("PPA"), turbine supplier agreements, leases, utilities, construction contracts, and interconnection and transmission agreements. Delays involving any of these steps can significantly add to the time necessary to bring a project online. In addition, before power can be connected to the grid, there is, of course, the time needed to construct the project.

The commercial development of onshore wind farms is fairly well understood, with standardized contracts and fairly straightforward development and construction processes. On balance, one can expect an onshore wind farm to be online and generating electricity within 3 to 5 years from conception.

However, once again, offshore wind farms face a very different set of circumstances. In addition to the much longer permitting process, as previously discussed, offshore wind farms must develop a local supply chain structure, conduct a much more complicated negotiation of power contracts (due to very high impact to ratepayers), obtain leases from the federal government, and endure a longer construction timeline. Therefore, for offshore wind farms, one should expect overall development times in the 10-15 year range.

Q31. You mentioned a Department of Interior program. Can you please provide a brief overview of activities by Interior involving offshore wind?

A31. (SR) DOI launched the "Smart from the Start" Atlantic Outer Continental Shelf ("OCS") initiative in the fall of 2010.[29] The main objective of the initiative is to accelerate responsible renewable wind energy development on the Atlantic OCS by using appropriate designated areas, coordinated environmental studies, large-scale planning, and expedited approval processes. The program aims to:

- Simplify the approval process for individual proposed projects and eliminate unnecessary regulatory requirements;
- Implement a comprehensive, expedited leasing framework for Atlantic wind by identifying Wind Energy Areas ("WEA") in the Atlantic, organizing, financing and implementing the gathering of information from key agencies regarding the environmental and geophysical attributes and other uses of these WEAs, and assembling the information in a publicly available format; and
- Move, on a parallel (but separate) track, to process applications to build offshore transmission lines.

DOI has already taken several steps to implement the program.[30] For example, the Cape Wind project in Massachusetts signed the first lease with DOI in October 2010.[31] Nevertheless, even if this program addresses a number of the issues related to developing offshore wind farms, it does not necessarily ensure that future offshore

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29 Department of the Interior, "Frequently Asked Questions: 'Smart from the Start' Atlantic OCS Offshore Wind Initiative," 2010 (Exh. APL000020); Department of the Interior Press Release, "Salazar Launches 'Smart from the Start' Initiative to Speed Offshore Wind Energy Development off the Atlantic Coast," November 23, 2010 (Exh. APL000021).

30 Bureau of Ocean Energy Management, Regulation, and Enforcement, "Fact Sheet: Renewable Energy on the Outer Continental Shelf," 2011 (Exh. APL000022).

31 Department of the Interior Press Release, "Salazar Signs First U.S. Offshore Commercial Wind Energy Lease with Cape Wind Associates, LLC," December 6, 2010 (Exh. APL000023).

wind projects will be expedited owing to other state and local permitting requirements and regulatory approvals.

Q32. Please provide a brief summary of wind power potential in Maryland (offshore and onshore).

A32. (SR) A common way to look at wind power potential is to use "wind classes." Wind resources are classified in wind class from 1 to 7. Wind classes 1 and 2 are not suitable for power generation. Most onshore wind farms are located in class 3 and 4 areas, and offshore wind farms could go as high as class 5 and 6.[32] The vast majority of onshore wind potential in the United States is located in the so-called wind corridor, which is the area immediately to the east of the Rocky Mountains. On the East Coast, the only locations with higher-than-class 3 winds, which are suitable for some limited wind developments, are the ridge tops in the Appalachian region. In terms of potential power generation capacity for onshore wind, NREL estimates that there is 1,483 MW of onshore wind potential in the State of Maryland, which would generate approximately 500 MW(e) on average.[33]

A study by the University of Delaware estimated the potential for offshore wind off the coast of Maryland, using an existing NOAA buoy to measure wind speed and wind patterns, applying industry averages, and accounting for marine, avian, visual, shipping conflict, and military conflict areas. The results show that the overall

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[32] National Renewable Energy Laboratory, "United States Wind Resource Map," 2009 (Exh. APL000024).

[33] National Renewable Energy Laboratory, "Estimates of Windy Land Area and Wind Energy Potential, by State, for areas >= 30% Capacity Factor at 80 meters," Feb. 4, 2010 (Updated April 13, 2011 to add Alaska and Hawaii) (Exh. APL000025).

offshore wind potential is 14,625 MW of capacity in Maryland in shallow waters (*i.e.*, less than 35-meter deep, which allows for the use of proven technology), generating approximately 5,000 MW(e) on average.[34]

Q33. What is the status of legislative efforts to promote wind power in Maryland?

A33. (SR) The Maryland Offshore Wind Energy Act was introduced during the Maryland legislature's 2011 session, but it did not move forward. The bill would have required investor-owned electric utilities to purchase between 400 and 600 MW of nameplate wind capacity, equivalent to approximately 160-240 MW(e) on average. Each investor-owned electric utility would have been required to purchase a portion of the total offshore wind power proportional to their load share.[35]

At this point in time, it is not clear whether a similar bill will be reintroduced in 2012. Nor is it possible to assess the prospects for passing such a hypothetical bill. In a recent speech at the American Wind Energy Association's Offshore Wind Expo in Baltimore on October 11, 2011, Governor O'Malley did not provide any additional insight as to whether a new offshore wind bill would be re-introduced.[36]

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34 University of Delaware's Center for Carbon-free Power Integration, College of Earth, Ocean, and Environment, "Maryland's Offshore Wind Power Potential," February 1, 2010 (Exh. APL000010).

35 Maryland State Administration, "Maryland Offshore Wind Energy Act," 2011 (Exh. APL000027).

36 Statement of Gov. O'Malley to American Wind Energy Association, October 11, 2011 (Exh. APL000028).

Q34. Please describe the conclusions of the Maryland Department of Natural Resources' recent LTER for Maryland regarding wind power.

A34. (SR) In the LTER "Reference" case, the levels required by the Maryland Renewable Portfolio Standard ("RPS") are fully met every year with the lowest-cost available renewable energy source.[37] Tier 1 non-solar energy resources in PJM currently generate approximately 20,100 GWh of electricity per year, which is more than enough to supply the regional 2010 Tier 1 non-solar renewable energy requirements established in Maryland and those of the other PJM states with RPSs. Development of Tier 1 non-solar renewable resources is assumed to keep pace with demand so that the region's RPS requirements are fully met throughout the study period. It is also assumed that increasing renewable energy requirements in Maryland would be fully met through in-state renewable generation sources.

According to the model used for the report, the result is that 190 MW of onshore wind would be added over the next 10 years, equivalent to 57 MW(e) on average (30% capacity factor), and no offshore wind. The existing Roth Rock and Criterion projects (discussed further below) already account for 120 MW of additional onshore wind capacity, so there would only be an additional 70 MW installed beyond those two projects in the LTER reference case. The majority of the Maryland RPS would be satisfied through non-wind renewable sources, such as biomass and landfill gas.

The LTER for Maryland also considers a hypothetical "high renewable scenario." In this scenario, the scope of the Maryland RPS is expanded to require 30% renewable energy by 2030. Under this scenario, nothing changes until 2020 (190 MW of

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37 LTER (Exh. APL000005).

onshore wind, no offshore wind). However, between 2020 and 2030, this scenario results in the addition of 1,220 MW of onshore wind (366 MW(e)), along with 2,500 MW of offshore wind (1,000 MW(e) at a 40% capacity factor).[38] The underlying calculation is that 75% of the available onshore wind resources would be used up, and the remaining balance of unmet RPS quota would be filled out through the only remaining renewable resource (offshore wind). This scenario is, at best, speculative and would require significant changes in policy and project economics.

As discussed by others in this testimony, even assuming these onshore and offshore resources could be tapped, converting the energy to "baseload" power would require some form of storage system.

Q35. Please provide a brief overview of existing wind projects in Maryland or nearby region.

A35. (SR) There are currently two operating large-scale wind projects in Maryland with a total of 120 MW installed capacity (36 MW(e)). The first project is the 70 MW Criterion project in Western Maryland, which is owned by Constellation, and has been in operation since December 2010.[39] The Criterion Project was originally announced in 2002 and took 8 years of development to come on line. The second

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[38] The "MW(e)" values presented here and elsewhere in the testimony for wind power are average values based on a capacity factor of 30%.

[39] Constellation Energy, "Criterion Wind Project, Garret County, Maryland" (accessed October 20, 2011) (Exh. APL000029).

project is the 50 MW Roth Rock project, which is also in Western Maryland and is owned by Gestamp Wind North America.[40]

Outside of Maryland, there are other wind farms in the nearby region, including the following:

- Pennsylvania has 751 MW (225 MW(e)) of wind capacity currently on line, and an additional 177 MW (53 MW(e)) is under construction. Operating projects include: Locust Ridge, Armenia Mountain, Allegheny Ridge, North Allegheny, Waymart, Casselman, Bear Creek, Forward, Green Mountain, Lookout, Meyersdale, Mill Run, Stonycreek, and Somerset.[41]

- West Virginia has 431 MW (129 MW(e)) of wind capacity currently on line, and an additional 147 MW (44 MW(e)) is under construction. Operating projects include: Mount Storm, Beech Ridge, and Mountaineer.[42]

- Virginia has no operating project, but the Highland 38 MW (11 MW(e)) project is currently under construction.[43]

Overall, within the PJM region, most of the wind generation came from the wind-rich Midwest regions of PJM (Ohio, Michigan, Indiana, and Illinois).

No offshore wind projects are currently operational in Maryland or the mid-Atlantic region.

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40 Gestamp Wind, "Roth Rock," 2011 (Exh. APL000030).

41 American Wind Energy Association, "Wind Energy Facts: Pennsylvania," August 2011 (Exh. APL000031).

42 American Wind Energy Association, "Wind Energy Facts: West Virginia," August 2011 (Exh. APL000032).

43 American Wind Energy Association, "Wind Energy Facts: Virginia," August 2011 (Exh. APL000033); Highland New Wind Farm Development, LLC, "Our Vision" (accessed October 20, 2011) (Exh. APL000034).

Q36. Please provide a brief overview of planned wind projects in Maryland or the nearby region.

A36. (SR) Two onshore projects have gone through a significant number of development steps in Maryland:

- The Savage Mountain 40 MW project was originally proposed for Western Maryland in 2002, from US Windforce, and received permits to construct in 2003. However, the project was cancelled in 2010, due to its inability to secure a PPA.
- The Dan's Mountain 69.6 MW project, also developed by US Windforce, is apparently still under development in Western Maryland, and is currently going through the permitting process.[44]

Additionally, according to the PJM interconnection queue, there are over 600 MW of projects in Maryland that have applied for interconnection. However, queue numbers should not be construed as being representative of future installed capacity, since the majority of projects apply for interconnection early on, and most of the projects will never come to fruition. I am not aware that any of these projects have signed PPAs. Similarly, between Pennsylvania, West Virginia, and Virginia, there are more than 5,000 MW of wind projects in the queue. If all those projects came to fruition, that would represent harvesting 75% of the total wind potential in those states. But, once again, only a tiny fraction of these projects are likely to go forward.

With respect to offshore projects, Bluewater Wind is currently developing projects in Delaware, New York, New Jersey, Maryland, and New England. The Bluewater Delaware 450 MW project has been under development for over 5 years and is currently the most advanced project of the Bluewater portfolio. The project signed a final PPA in 2008 with Delmarva Power for 559,000 MWh of electricity (200 MW at

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44 US Windforce, "Dans Mountain" (accessed October 21, 2011) (Exh. APL000035).

~32% expected capacity factor), and has obtained exclusive rights to negotiate a lease with the federal government under the "Smart from the Start" program.[45] However, the Bluewater Delaware project is still very far from being operational. First, the permitting process still has several hurdles to overcome, and the Cape Wind project showed the complexity of getting such large offshore wind projects through the permitting process. Second, the revenue side of the project is still not resolved. The PPA signed with Delmarva Power covers only 200 MW of output, or 559,000 MWh, and 160,000 Renewable Energy Certificates ("REC"), with each REC accounting for 3.5 "regular" RECs, as legislated through Delaware Senate Bill No. 328.[46] When capacity payments are included, the PPA effectively provides approximately $150 per MWh, in 2011 dollars, for 559,000 MWh. That price is likely to fall short of what is needed to make the project economically viable, even considering federal incentives, unless the remaining 399,000 RECs can be sold at a very high price. Selling RECs at a high price does not appear likely in today's depressed REC market. So, in my opinion, the project is unlikely to move forward unless the PPA is significantly renegotiated or additional incentives are provided.

Furthermore, the estimated impact to consumers, provided in the 2008 analysis, is likely to be significantly underestimated.[47] Natural gas price projections, electricity

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45 Department of the Interior Press Release, "Interior Initiates Process for First "Smart from the Start" Lease for Commercial Wind Power Offshore Delaware," March 24, 2011 (Exh. APL000036).

46 New England Opportunities, Inc. et al., "Report on Final Power Purchase Agreement between Delmarva Power and Bluewater Wind Delaware LLC," July 3, 2008 (Exh. APL000037).

47 *See id*.

prices, and demand forecasts in the PPA were all based on, what we can see today with the benefit of hindsight, was the top of the market. In that respect, there is likely to be pressure to further reduce the impact on ratepayers associated with the PPA, while the opposite would be necessary to make the project successful.

The other Bluewater projects in Maryland, New York, and New Jersey are at the very early stages of development. Similarly, the Atlantic Wind Connection project, which has formed to build a DC line to allow 7000 MW of offshore wind to connect to the grid, has taken important steps (FERC approval, application for right-of-way, and commitments from strong financial partners), but it is also still very early in the development process.[48] These projects are all many years from completion.

Q37. What are your expectations regarding installed wind power capacity in Maryland over the next 10 years?

A37. (SR) My expectations are in line with what is outlined in the reference case of the LTER for Maryland. The LTER reference case is based on the current regulatory environment and RPS. I think this is the appropriate scenario to look at because an expansion of RPS requirements beyond the current RPS is highly speculative.

I expect wind power capacity to be added only to the extent that it is used to fulfill the RPS requirements and is the lowest-cost renewable option. Beyond the RPS requirements, I would expect no additional wind capacity to come on line, since, without receiving a REC, wind would not be competitive with natural gas in

48 David Roberts, "Answer to cheap power is blowing in offshore wind: Atlantic Wind Connection sees hundreds of miles of turbines making efficient energy," May 10, 2011 (Exh. APL000006).

Maryland. Incidentally, current incentives that improve wind power economics may disappear in the future.[49]

The LTER reference case shows 190 MW of additional capacity coming on line. In reality, 120 MW of that capacity has already come on line, through the Criterion and Roth Rock projects, which leaves an additional 70 MW of installed wind capacity to be expected over the next few years. This is equivalent to 21 MW(e) on average. In the unlikely, but plausible, case that all of the new renewable energy necessary to satisfy the RPS were to come from wind power, wind power would have to provide up to approximately 1.5 million MWh per year. That would approximately represent an additional 570 MW of wind power, or 170 MW(e) on average.

A final consideration is that renewable power generation is mostly driven by RPS compliance, which is defined as a percentage of the total electric load. Successful energy efficiency and energy conservation programs would therefore result in lower loads and proportionally lower amounts of renewable energy being installed.

Therefore, in my professional opinion, I expect approximately 21 MW(e) of wind power capacity to come on line in the next few years. Under optimistic (though speculative) conditions, up to 100 MW(e) is possible. Therefore, I consider the NRC Staff's use of 100 MW(e) from wind in the FEIS combination of alternatives to be reasonable.

[49] These incentives are discussed further in ¶46.

Q38. In your professional opinion, is the use of CAES in combination with wind turbines to generate 1600 MW(e) in Maryland reasonable in the next 10 years? What about 100 MW(e) or 400 MW(e)?

A38. (SR) As noted above, use of wind power to generate 400 MW(e) in Maryland is not foreseeable in the next 10 years, much less 1600 MW(e). On balance, assuming that the addition of a storage technology was technically and economically feasible,[50] it is plausible, but unlikely, that 100 MW(e) of wind energy could be available in Maryland as "baseload" in the next 10 years. I therefore consider the FEIS analysis of the combination of alternatives to be reasonable. However, 400 MW(e) or 1600 MW(e) of generation is not foreseeable, or even possible.[51]

D. Solar Power

Q39. Please provide a brief overview of solar power technologies.

A39. (SR) Solar power indicates the conversion of the energy from the sun into electricity. There are two main solar technology categories available for utility-scale plants. Each category has several commercially available technologies:

- Concentrated Solar Power ("CSP"), or "thermal solar", in which mirrors concentrate the solar power to heat up a fluid that drives a turbine or an engine. The primary CSP technologies are parabolic trough, power tower, linear Fresnel reflectors, and Stirling systems.

- Photovoltaic ("PV"), in which solar power is converted directly into electricity through the use of cells with semiconductors. The primary PV technologies are crystalline silicon and various types of thin-film (*e.g.*, cadmium-telluride or gallium-arsenide). In some applications, it is also

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50 A typical CAES system adds significant cost to a wind farm and would likely make wind non-competitive against other alternatives — that is, utilities would elect to pay the $40 per MWh RPS Alternative Compliance Payment ("ACP") rather than purchase wind power.

51 Additional wind power installed capacity is very unlikely to ever exceed 200 MW(e) under the current regulatory framework.

possible to concentrate the sun rays, before they hit the solar panel (Concentrated Photovoltaic, "CPV").

In general, CSP and CPV work only in dry sunny climates. In the United States, this means that only the Southwest is a viable option for these technologies. PV is more flexible and works well in diffuse light situations, which is often the case in the mid-Atlantic region. Therefore, for the purpose of my testimony, I will limit the discussion to solar PV technology.

Q40. What are the capacity factors for solar PV?

A40. (SR) Because solar PV power generates electricity only when the sun is shining, capacity factors are relatively low. This is exacerbated by evening, cloudy, and other low-light periods. Fixed tilt (at latitude) capacity factors are 14%-24% for Seattle to Phoenix, with most of the East Coast typically around 14-18%.[52] Tracking systems can increase the capacity factor significantly, but also add to the cost. For reference, the LTER for Maryland assumes a solar capacity factor of 15%, and the recently announced 17.1 MW solar plant in Emmitsburg, Maryland, also plans to operate with a capacity factor just under 15%.[53]

Q41. What are the land use implications of solar PV?

A41. (SR) Utility-scale solar plants use a significant amount of land, typically between 2.5 and 12.4 acres of land per MW installed, depending on local climate, panel

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52 Department of Energy, National Renewable Energy Laboratory, "2008 Solar Technologies Market Report," January 2010 (Exh. APL000039).

53 LTER (Exh. APL000005).

efficiency, and panel distribution.[54] Most utility-scale installations fall within the 4 to 8 acres per MW range. For reference, the Emmitsburg solar project uses 100 acres, or approximately 6 acres per MW.

Smaller solar projects, up to several hundred KW, can often be located on rooftops. Placement of solar panels on rooftops is common for residential and commercial installations. For these types of projects, land use requirements are minimal since the panels are placed on pre-existing structures.

Q42. Can you give a sense of the costs associated with solar PV installations?

A42. (SR) In 2010, the typical cost of utility-scale PV plants was approximately \$3,400 per KW, down from \$8,000 per KW in 2004.[55] Since then, there have been further price decreases, although some of those decreases may be due to a temporary supply/demand imbalance. Prices for solar panels, in particular, have decreased through 2011 and can now be found on the market for around \$1 per W. This equates to an installed cost for solar plants of less than \$3,000 per KW.[56] Thin-film solar plants tend to cost less than crystal silicon, but also have lower efficiency. For non-utility-scale installations, such as rooftops, the costs are significantly higher. Estimates from installers in Maryland for rooftop installations in September 2011

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54 *Id.*

55 Department of Energy Solar Energies Technology Program, "The Prospect for \$1/Watt Electricity from Solar," August 10, 2010 (Exh. APL000040).

56 \$3,400 per KW is roughly the cost that Constellation has estimated for the Emmitsburg solar project. *See* Constellation Energy – Emmitsburg Solar, "Constellation Energy to Develop Maryland's Largest Solar Photovoltaic Power System," 2011 (Exh. APL000041).

were around $6,000 per KW for a ~5 KW system. Larger commercial installations will fall somewhere in between the cost of utility-scale plants and residential rooftops. Annual O&M costs for PV systems are fairly low, typically accounting for less than 1% of the initial capital investments, or somewhere in the order of $10 to $15 per MWh.

Q43. Please provide a brief summary of solar power potential in Maryland.

A43. (SR) The raw potential for solar power is certainly high. At 6-7 acres per MW, it is just a question of how many acres can be devoted to solar power. If 10% of the land in Maryland were covered by solar panels, there would be 20,000 MW(e). However, such numbers are of little interest in the case of solar, because the economics of solar are such that building solar power plants makes economic sense only inasmuch as it is mandated through state standards and/or federal incentives are made available.

Q44. What is the effect of incentives on solar PV deployment?

A44. (SR) Without any state or federal incentive, solar would have a levelized cost of more than $200 per MWh for utility-scale power plants and $400-500 per MWh for rooftop installations. Even if the cost of solar power decreases dramatically, solar power will not be competitive with conventional power sources for the next decade at the very least. Therefore, the potential for solar power is limited to the demand generated by governmental mandates and future incentives, which are speculative at best.

To further illustrate the point, Maryland Solar Renewable Energy Certificates ("SREC") in 2011 have traded at around $200 per MWh.[57] At present, there is a

[57] SREC Trade, "SREC Market Prices," 2011 (Exh. APL000042).

strong incentive to build solar plants in Maryland, considering that the current Solar Alternative Compliance Payment ("SACP") is $400 per MWh. However, in the future, the amount of solar power that is likely to come on line will be capped by satisfaction of the solar carve-out in the RPS (2% by 2022) or at a lower level if the SACP becomes lower than the required economically-viable SREC price.

Q45. What is the status of legislative efforts to promote solar power in Maryland?

A45. (SR) To the best of my knowledge, there is currently no legislative effort underway to promote solar power in Maryland other than the 2% solar carve-out in the RPS, which is currently in effect. There are programs aimed at incentivizing renewable energy, such as the solar Sunburst Program (financed under the American Recovery and Reinvestment Act of 2009) and the Maryland Clean Energy Grant Program, which provides $ 500 per KW of solar power (DC) installed. There are also broader initiatives aimed at reducing greenhouse gas emissions, such as the Regional Greenhouse Gas Initiative ("RGGI"), and the Maryland Greenhouse Gas Reduction Act ("GGRA").

Q46. Are there federal incentives that could promote development of solar PV or wind power in Maryland?

A46. (SR) Renewable energy development over the last few years has been greatly supported through federal incentives, such as the Production Tax Credit ("PTC"), the Investment Tax Credit ("ITC"), which was initially made available only for solar, and the 1705 Loan Guarantee Program.[58] However, these incentives, which have greatly facilitated the development of renewable energy, are expiring. Given the very

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58 Many of these incentives are also available for wind generation projects.

difficult and unique fiscal and political conditions facing the United States, they may not be renewed.

The Section 45 PTC provides a $22 per MWh credit to qualifying facilities for the first 10 years of operation. It was initially enacted through the Energy Policy Act of 1992, and was renewed four times. However, it was allowed to sunset temporarily on three occasions, creating a stop-and-go situation that, for example, did not allow for the wind energy to gain momentum until 5-6 years ago. The PTC is slated to expire at the end of 2012, and there is significant uncertainty as to whether it will be renewed.

The 1603 Program was enacted under the American Recovery and Reinvestment Act ("ARRA") of 2009 and provides a rebate for 30% of the installed cost of a qualifying facility. However, it only applies to facilities that have initiated construction before the end of 2011 and is not expected to be renewed.

The 1705 Loan Guarantee Program was also enacted under ARRA and allows developers to reduce financing costs for projects that are "shovel-ready." The program expired on September 30, 2011, and I do not expect it to be renewed.

Solar power still enjoys additional incentives, most notably the Section 48 ITC, which provides a tax credit equal to 30% of the installed cost of qualifying facilities. The Section 48 ITC was enacted under the Energy Policy Act of 2005 and is not set to expire until 2016. Solar plants also qualify for various depreciation provisions in the U.S. Tax Code.

Q47. Are there different market forces at work when considering renewable energy development as opposed to traditional baseload generation?

A47. (SR) Effectively, there are two markets in the electricity industry: one for green energy and one for brown energy.[59] This is consistent with the overall approach of the LTER for Maryland, as well as my own experience developing renewable energy projects.

The two markets are not entirely separate, but they are fairly distinct. The green energy market is driven by RPS compliance — that is, renewable energy sources compete against each other. As long as REC prices do not exceed ACPs ($40 per MWh for non-solar Tier 1 resources in Maryland), green sources do not have to compete against brown energy. Once the green market is exhausted (*i.e.*, the RPS is satisfied), renewable energy sources would have to compete against brown sources without the advantage of REC payments. With few limited exceptions, renewable energy sources are almost always more expensive.

It is always possible for policymakers to create sub-markets by mandating them. Renewable energy as a whole is a mandated market, and solar in particular is mandated through carve-outs. To spur offshore wind developments in Maryland, it would be necessary to mandate a third green energy market (beyond non-solar Tier 1 resources and solar), or to provide equivalent special provisions (similar to what has been done in Delaware, where offshore wind RECs count for 3.5x), or expand the

59 This discussion applies equally to wind power, but is discussed here because of the specific carve-out for solar in the Maryland RPS. In Maryland, the green market is further split into the solar market and the non-solar market, because of the solar carve-out requirement in the RPS.

RPS to 30% to be satisfied with in-state resources and with a very high ACP. As discussed above, under the latter scenario, Maryland effectively would run out of available onshore wind and other renewable sources, and then would need to tap into offshore wind to meet the RPS. However, these scenarios all involve speculation. None could be considered reasonable at present.

Q48. Describe the conclusions of the Maryland Department of Natural Resources' recent LTER for Maryland regarding solar power.

A48. (SR) The LTER for Maryland estimates that future installed capacity of solar power will be closely linked to the levels required in the solar RPS carve-out (2% by 2022). The LTER reference case assumes that new solar power will be installed to meet the growing requirements for solar through 2018 and, up to that point, there will be availability of SRECs at prices below the SACP.[60] After 2018, the LTER reference case assumes that the additional requirements for solar power will not be met through new physical installations; rather, it is assumed that the utilities will elect to pay the SACP. This is driven by the fact that the SACP will decrease over time from $400 per MWh today to $150 per MWh in 2019, and, at that point, SRECs will not be available below that price level. In terms of installed capacity, the LTER reference case predicts that there will be 498 MW of new solar capacity installed in Maryland over the next 10 years, equivalent to approximately 75 MW(e) on average. This is consistent with the NRC Staff's use of 75 MW(e) in the combination of alternatives considered in the FEIS (though, as discussed below, this is not, by itself, "baseload" power).

60 This is true at present. SRECs are currently priced at ~$200 per MWh, while the SACP is $400 per MWh.

The high renewable scenario assumes that the entire 2% solar carve-out will be met through physical solar installations, and none through SACPs. The additional RPS requirements imposed under this scenario (30% by 2030) will be met through lower-cost renewables (onshore wind first, and then offshore wind). Thus, only limited new solar power installations are expected beyond 2020. In terms of installed capacity, the LTER high renewables scenario forecasts that there will be 785 MW of additional solar capacity by 2020 (approximately 120 MW(e)), 1068 MW by 2022 (160 MW(e)), and 1158 MW by 2030 (174 MW(e)). This scenario is, at best, speculative.

Q49. Please provide a brief overview of existing and projected utility-scale solar projects in Maryland or the nearby region.

A49. (SR) In Maryland, the only utility-scale operating project is the 2.2 MW University of Maryland Eastern Shore plant. There is also a large commercial installation (1.8 MW) on McCormick's Hunt Valley Distribution Center. There are however, some larger projects that are expected to come on line over the next couple of years including the 17.4 MW Constellation Energy project in Emmitsburg, a 5.5 MW Southern Maryland Electric Cooperative project in Hughesville, and a 20.0 MW Maryland Solar LLC project close to Hagerstown.

According to the Solar Energy Industries Association, the surrounding states also have some solar projects in construction or development, including the following:

- Pennsylvania: 6 MW in operation, 1 MW in construction, and 52 MW in development

- Delaware: 10 MW in operation (Dover Sun Park)[61]

Q50. What are your expectations regarding installed solar power capacity in Maryland over the next 10 years?

A50. (SR) My expectations are generally in line with the LTER reference case scenario, which estimates approximately 75 MW(e) of new solar installed capacity by 2020. It is plausible, though unlikely, that SRECs will remain competitive against ACPs beyond 2018 considering the decline of solar panel prices, the potential for technological breakthroughs, and the possibility that federal incentives will be extended. If so, all of the solar 2% carve-out would be met through physical installations in Maryland and would amount to 160 MW(e) of new solar power over the next 10 years. It is highly unlikely that there will be any solar power installation beyond the 160 MW(e) level in the absence of a significant policy shift, which is highly speculative.

Q51. In your professional opinion, is generation of 1600 MW(e) in Maryland reasonably foreseeable? What about 75 MW(e) or 300 MW(e) of solar power, in conjunction with CAES, as baseload?

A51. (SR) 1600 MW(e) of solar power in Maryland is simply not possible in that time frame. As I noted previously, increases in installed solar capacities are likely to be driven by Maryland's RPS. In my professional opinion, installation of the equivalent of 75 MW(e) baseload (assuming that energy storage is technically and economically feasible) is a reasonable assumption. This is broadly in line with the values assumed in the NRC Staff's combination of energy alternatives. Installation of the equivalent

61 Solar Energy Industries Association, "Utility-Scale Solar Projects in the United States Operating, Under Construction, or Under Development," October 14, 20114 (Exh. APL000043).

of 300 MW(e) of baseload solar is highly unlikely in the next 10-15 years.[62] On balance, the NRC Staff assumption of 75 MW(e) of solar power in the FEIS analysis of a combination of alternatives is reasonable.

E. CAES Systems

Q52. Please provide a brief overview of CAES technologies?

A52. (SVDL) The basic objective of utility-scale storage of electricity is to store excess energy or energy with low production costs produced during off-demand periods and to use this energy at a later date to generate power during periods of higher demand. CAES is analogous to pumped hydro storage ("PHS") where electricity is converted to a stored energy form as high pressure compressed air or water elevated from a lower reservoir to a higher reservoir. Recovery from compressed air is accomplished by expanding the high pressure air with Expander Turbines, which requires energy input (fuel) to heat the air, and the resulting mechanical power drives a generator to produce electric power. For PHS, the water volume at the higher elevation is released to drive a hydro turbine, coupled with a generator at the lower elevation. No additional fuel is required.[63] Both PHS and CAES can only deliver power to the extent that the storage facility can deliver; after that, recharging is necessary.

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62 Assuming a CAES plant could be developed, this hypothetical scenario could be met if, as discussed in ¶50, all of the solar 2% carve-out was met through physical installations in Maryland, generating 160 MW(e) of solar power. However, as I also explained, this is unlikely to occur and would not be a reasonable assumption for the FEIS combination of alternatives.

63 Because pumped hydropower plants require no additional fossil fuel and have a level of efficiency of up to 80%, they are much more efficient than CAES power plants. However, pumped hydropower plants generally implicate the considerable environmental impact of the reservoir and downstream basin and are costly to develop. *See* American

Air is compressible, which means that it can be stored at higher pressure (1000 psi to 1500+ psi). Underground cavities are suitable for the large volumes required by compressed air storage. While these volumes are much less than that required by PHS, they are still quite substantial and require proper geological characteristics, as discussed later in my testimony. The best candidates for CAES storage are solution-mined salt caverns (lower cost), though natural deep saline aquifer structures and abandoned mines may be suitable to a lesser degree.

Q53. What is the general purpose of a CAES plant?

A53. (SVDL) CAES is not a continuous base load power plant. CAES can, however, provide baseload over a specified daily dispatch based on the energy storage volume of a given reservoir. This storage reservoir, when drawn down, must be recharged by drawing power from other energy sources.

As already mentioned, there are basically only two proven methods available for the feasible storage of bulk energy on a utility scale in the foreseeable future: pumped hydro and larger CAES power plants. Small CAES plants cannot be considered "bulk energy storage," which generally involves plants rated in hundreds of MW-hrs. But, small CAES plants can play a role in smoothing wind energy distribution (absorption) during low load morning demand and to sustain green energy delivery during peak demand cycles.

Wind Energy Association, "Wind Power and Energy Storage," 2011, at 4 (Exh. APL000038).

CAES can contribute valuable benefits to a grid system through load management (shifting) regulation, spinning reserve, rapid ramp capabilities. CAES plants can also be used to meet daily demand cycle variations (keep base load plant at best performance levels) and to match renewable energy to capacity, shaping, and firm values. CAES extends the value chain of renewable energy in providing the ancillary services that wind and solar cannot, by themselves, provide as energy sources. While CAES is therefore a useful asset to a utility portfolio and can supplement baseload generation by reducing the variability of renewable energy, it is not a steady 24/7 baseload facility and does not meet the purpose of Calvert Cliffs 3 as articulated in the FEIS.

Q54. How does CAES work?

A54. (SVDL) A CAES power plant splits a conventional industrial gas turbine into a compressor unit for compressing the combustion air and an expansion turbine to generate mechanical power to drive a generator. The basic concept in CAES is the Brayton cycle (gas turbine).[64] The compression cycle is separated from the turbine expansion cycle. Compression of air in a high power density gas turbine absorbs 60% or more of the Power Turbine output, so that almost 2/3 of the fuel energy input is required to drive the compressor. By separating the compression cycle, lower cost power (*e.g.*, off-peak power or excess baseload) or excess wind energy can be utilized to drive the compression cycle. This makes it possible to restrict the use of valuable

64 Septimus van der Linden: "APS (American Physics Society) Energy Study Working Group-Study on Electricity Storage," August 14th, 2006 (Exh. APL000044).

fossil fuels to heating the pre-compressed air only. This substantially reduces the amount of fossil fuel used and the resulting CO_2 emissions.

When low cost or excess energy is available, the motor/compression unit compresses air into the storage medium (*e.g.*, underground storage). The heat of compression requires cooling of the air before being injected into storage. When the compressed air is released, the stored compressed air is fed into the combustion chamber together with natural gas. The heated compressed air expands in the turbine to drive the generator.[65]

Q55. What is the rated output potential for CAES technology?

A55. (SVDL) The plant ratings are expressed in MW for bulk energy storage. However, the actual output is generally expressed in MW-hours per daily dispatch, as determined by the cavern or reservoir storage. For example, a 15 MW system capable of running 4 hours will deliver 60 MW-hours. The basic unit sizes for CAES, starting at 15 MW, are determined by available gas turbine sizes in the market. Individual units could be rated up to 450 MW. Thus, depending on the storage volume, it is theoretically possible to have a CAES plant with significant energy storage. For example, the Norton Project in Ohio had a planned capacity of 2700 MW, defined by a 338 million cubic feet limestone cavern.

65 Septimus van der Linden, "Review of CAES Systems Development and current Innovations that could bring commercialization to fruition," EESAT 2007 (Exh. APL000045).

Q56. Please provide brief overview of existing CAES projects.

A56. (SVDL) There are currently only two operating CAES plants. The plant in Huntorf, Germany, operated by E.ON Kraftwerke, was commissioned in 1977-78 by NWK. It was the first CAES power plant in the world. It is designed for turbine operations with 290 MW for 2 hours or compressor operations with 60 MW for 8 hours. The compressed air is stored in two salt caverns with a capacity of 5.3 million cubic feet per cavern. The second CAES plant began operations at the beginning of 1991 in McIntosh, Alabama. This unit is based on the reheat turbine concept (as in Huntorf, Germany). This plant has a generating capacity of 110 MW over 26 hours; the air is stored in a single cavern with a volume of 19.6 million cubic feet.[66]

The two existing operating CAES plants have operated as intended with a high degree of reliability. While similar in cycle concept (reheat high pressure and low pressure combustors), they differed in mission. The Huntorf unit was intended as a back-up to a nuclear plant and was designed for a short fast high-power response (290 MW in 6 minutes) as well as short duration peak-lopping demand. Huntorf does not incorporate a recuperator to preheat the cavern air before entering the HP combustor. The smaller 110 MW unit at McIntosh is recuperated, resulting in lower fuel consumption. The McIntosh facility provides power for longer duration (26 hrs at 100 MW) to balance power demand for the Power South generation portfolio.

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66 Septimus van der Linden, "Bulk Energy Storage Potential in the USA, Current Developments & Future Prospects," 17th International Conference on Efficiency, Costs, Optimization, of Simulation and Environmental Impact of Energy Process Systems, ECOS 2004 (Exh. APL000046).

Q57. Please provide a brief overview of other proposed or planned CAES projects in the United States.

A57. (SVDL) The CAES projects in the United States that have been announced publicly include the following:

- Two DOE-funded CAES projects: (1) a 150 MW salt cavern air storage plant in New York; and (2) a 300 MW project using a depleted gas field for air storage in California;
- Norton Energy Storage, which has a 2700 MW potential, in Ohio. This project was initiated 12 years ago, but there has been no firm decision to proceed;
- Magnum Western Energy Hub in Utah is evaluating a potential 300 MW CAES plant that would include natural gas and liquefied natural gas storage in the same salt dome;
- Apex Energy Texas is assessing a possible 150 MW CAES plant, though no storage facility has been selected to date.
- Iowa Stored Energy Project ("ISEP") is a 270 MW CAES plant with aquifer storage. Although developed for several years, the project was terminated due to porosity limitations in the aquifer sandstone.

Q58. Are there any utility-scale CAES projects under development in Maryland?

A58. (SVDL) To the best of my knowledge, there are no utility-scale CAES projects under development in Maryland.

Q59. What is the amount of storage needed for a CAES plant with underground storage?

A59. (SVDL) For a CAES plant using existing technology, the storage volume is determined by size and hours of operation. For example, the McIntosh facility stores 130 MW-hrs/million cubic feet in cavern with a volume size of 20 million cubic feet. Importantly, the cavern can only be drawn down to about half of the stored capacity to avoid large pressure fluctuations that would damage the salt cavern walls.

A nominal 100 MW CAES system requires 769,230 cubic feet to get 100 MW-hours. To simplify the example, 750,000 cubic feet (based on a higher pressure cavern of 1250 psi vs. 1050 psi at McIntosh) equals 7.5 million cubic feet for 10 hours of operation and no reserve capacity. This means that a full recharge is necessary overnight using much larger (MW rated) compressor units. To extend the discharge another 10 hours (for a total of 20 hours) the cavern volume would need to be increased to 15 million cubic feet.

Q60. Please describe the use of solution-mined caverns for CAES projects and the potential for their use in Maryland.

A60. (SVDL) The storage of natural gas in depleted oil and gas reservoirs, in aquifer formations, or in man-made salt caverns, has been standard practice for many decades in the United States. In Germany and France, over 20% of annual consumption is stored underground. And, some 100 new natural gas storage caverns are currently being constructed in Northern Germany.

Natural reservoirs dominate in terms of amount of gas stored underground world-wide. However, the current enlargements in storage capacities in Europe are concentrated on salt caverns because these storages are much more flexible, having much higher injection and withdrawal rates, and the flexibility to handle frequent cycles.[67] The installation of caverns is dependent on the availability of suitable salt formations. Significant quantities of brine are produced during solution mining. Thus, the ability to dispose the large volumes of brine in an environmentally-

67 Fritz Crotogino et al., "Grid Scale Energy Storage in Salt Caverns," 2011 (Exh. APL000047).

compatible manner is a limitation on CAES siting. For example, the brine could be used as a feed stock at a chemical plant or discharged to the ocean.

An overview of the McIntosh salt cavern gives a sense of issues involved in developing a solution-mined cavern for high pressure air storage (as would be required by a 110 MW CAES power plant). The top of this solution-mined salt cavern is located 1,500 feet underground. The bottom of the cavern is 2,500 feet underground. The air storage volume is 19.6 million cubic feet (usually quoted as 20 million) — 200 ft in diameter and 1,000 feet tall. The cavern walls do not move due to the pressure changes and have the strength 50 times that of the maximum pressure produced for the CAES plant. At full charge, the cavern pressure is 1,100 psig, at full discharge the pressure is 650 psig, the Delta P is the working volume. The air is withdrawn at a rate of 340 lbs/sec (as fast as a wide bodied jet engine) or 1,224,000 lbs/hr delivering 110,000 kW. The air recharging system is designed to compress for 1.7 hrs per hour of generation.

There are no known salt domes or strata salt deposits in Maryland. Thus, salt caverns are not available to support a bulk energy storage CAES plant in Maryland.

Q61. Please describe the use of natural reservoirs for CAES projects and the potential for their use in Maryland.

A61. (SVDL) In addition to salt caverns, natural reservoirs could be used for CAES. One issue with the use of natural reservoirs, such as aquifers or depleted gas fields, is the potential for oxygen in the air to react with the minerals and the microorganisms present in these natural reservoirs. This can result in a loss of oxygen as well as the blockage of the fine pores in the reservoir rocks by the reaction products. To avoid

this, caverns are used for energy storage primarily in those regions that have suitable salt formations available. The geological map of the United States identifies potential for siting CAES power plants with suitable storage strata.[68] Maryland would have limited potential with granitic plutonic and sedimentary volcanic rock formations.

Hard rock caverns are used to store hydrocarbon fuels and are potentially the most abundant storage media in the United States.[69] In a hard rock cavern CAES plant, a vertical shaft connects the underground chamber with a surface lake. As air is injected into the chamber, the column of water is pushed up; as air is released, the water fills the void (the same principle as pneumatic/hydraulic accumulator). Hard rock caverns are more expensive to use for CAES, though modern techniques for shaft and cavern excavations have progressed significantly in the past 20 years. To keep the costs at a manageable level, the cavern must be small and the air in the cavern must be maintained at a constant pressure by means of a water compensation system. A water-compensated rock cavern can store about five times as much energy as an uncompensated cavern of the same volume. To the best of my knowledge, there are no hard rock storage sites under consideration for CAES in Maryland. Thus, hard rock storage as the medium for CAES in Maryland is very unlikely for the foreseeable future.

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68 Septimus van der Linden, "Bulk Energy Storage Potential in the USA, Current Developments & Future Prospects," 17th International Conference on Efficiency, Costs, Optimization, of Simulation and Environmental Impact of Energy Process Systems, ECOS 2004, at 30 (Exh. APL000046).

69 Septimus van der Linden, "Hard Rock Caverns-Limestone and Other," March 2011 (Exh. APL000049).

Aquifer storage also has been studied for decades for possible air storage. Dating back to 1982, comprehensive studies on the feasibility of aquifer-based CAES systems were prepared by the Public Service Company of Indiana and Sargent and Lundy Engineers for EPRI. Based on those studies and current investigations, deep saline aquifers with a retaining dome were found to be best suited for CAES.[70] In aquifer storage systems, the retaining dome that secures the air bubble "inverted saucer" (or cap rock) must be of adequate thickness and strength to be impermeable and prevent air loss or blowout. The rock — usually shale, siltstone, or dense carbonate — must be thick enough to prevent fracturing and have low permeability. The rock must also have large capillary forces in order to prevent air from migrating through the media. As a general rule, the pressure of injection is not allowed to exceed the discovery pressure of the formation in order to avoid cap rock fracture — a sufficiently high threshold pressure is needed to ensure that air will not migrate through pore spaces in the cap rock in response to pressure fluctuations during CAES operation. The parameters of porosity, permeability, and thickness will impact different aspects of CAES operation, including reservoir capacity, compressed air deliverability, and the required operating pressures of the turbo-machinery.

Unlike a salt cavern storage or hard rock cavern, multiple wells are required to accept injection and withdrawal of air delivered by the compressor and required by the CAES plant. For a hypothetical 135 MW CAES plant, 400 lbs/sec or approx 3.0 lbs/sec/MW would be required, based on the deliverability of the reservoir. The

70 Jürgen Kepplinger et al., "Present Trends in Compressed Air Energy and Hydrogen Storage in Germany," SMRI Fall Technical Conference, October 3-4, 2011, at 9 (Figure 3.3). (Exh. APL000051).

number of wells needed and the porosity determine the land use needed to support such a CAES facility. The 270-MW Iowa Storage Energy Project ("ISEP") at Dallas, Iowa, was the first project to investigate and consider a well-defined reservoir structure. After developing several exploratory boreholes, the permeability of the sandstone was determined to be such that injection and withdrawal rates would not support the 800 lbs/sec flow for the planned facility. As a result, only a much smaller CAES project was technically possible. At the reduced size, the project could not be economically justified. As a result, the project was subsequently terminated.[71]

To the best of my knowledge, there are no aquifer storage sites under consideration for CAES in Maryland. Thus, aquifer storage as the medium for CAES in Maryland is very unlikely for the foreseeable future.

Q62. Are there other storage systems for CAES projects that could be used in Maryland?

A62. (SVDL) EPRI and others have performed studies on pipe and pressure vessel storage. For above ground pipe and pressure vessels, there were no major advantages other than the fact that shop-fabricated pressure vessels of 8 to 12 ft diameter had shorter installation times and lower installation costs.

The most cost-effective system would be buried pipeline using transmission right of way and other available space at existing sites. Construction of natural gas pipelines is well-established and 42-inch, 48-inch, or 60-inch welded pipe delivered in 80 ft lengths could be cost effective. For example, a 42" pipe (1515 psia) can store +/-

[71] Iowa Store Energy Park Press Release, "Iowa Stored Energy Park Project Terminated," July 28, 2011 (Exh. APL000052).

5.8428 lbs/air in one cubic foot of pipe. One foot length equals 7.817 cubic feet, where as a 60' pipe will store 2.445 times per foot length. Buried pipe CAES projects would probably favor the readily-produced and easily-transportable 42-inch pipe, though the full economics of pipe and installation costs would have to be developed based on current gas pipeline costs. Storing at 1000 psig would increase the required pipe length for the same output by a factor of 1.623.

By using a gas turbine in the 5 MW class, a 15.2 MW CAES plant could be achieved. Using pipe storage capable of storing 27.6 MWh, the CAES plant could deliver 30.4 MW-hours during 2 hours of operation. A larger gas turbine could increase CAES plant size to 18.5 MW. To increase the output beyond 30.4 MWh requires additional air storage volume. Considering the higher costs of large battery systems, an additional 5 hours of storage generally would be considered economic for dispersed storage systems. That said, the economics will always be site-specific and related to local storage costs for buried pipe storage (*e.g.*, cost of using transmission line real estate to accommodate the buried pipe).

To the best of my knowledge, there are currently no pipe-storage systems under development in Maryland.

Q63. Can you please describe some of the potential new CAES technologies under development?

A63. (SVDL) The Intervenors' filings mentioned two companies that are working on CAES technologies (SustainX and General Compression). The CAES technologies at these companies involve two concepts that are still in the early phases of development. Based on publications and presentations at energy storage workshops

and conferences, the objective of these companies is to create distributed energy storage systems (similar to battery storage), but at a lower cost (*i.e.*, the goal is to fill the market niche that currently is filled by high-cost battery storage).

SustainX has funding to develop and demonstrate a 1 MW CAES system as a hedge against battery cycle life, cost, and the need to recycle batteries that have reached the end of life. The SustainX system is an isothermal compression and expansion concept. Scaling the technology to larger sizes (*i.e.*, above 2 MW) is theoretically possible, but is unlikely to ever serve the bulk energy storage market due to the limitations on time of storage (*e.g.*, limited to a few hours). The nameplate rating cannot be sustained for long periods and should be best described in MW-hours. Thus, SustainX technology is unlikely to support the bulk energy storage systems needed to generate baseload power, as described in the FEIS.

General Compression has also attracted funding for their near-isothermal compression and expansion system. General Compression's approach would need to rely on cavern-type air storage to compete in the bulk energy storage market. In the General Compression approach, the compressor is motor driven and also serves as the expander when the stored air is released. The concept is to use units of 2 MW ratings and install the units as modular, factory-packaged systems up to the limit of the storage system. High production rates and assembly line construction could yield relatively lower costs. However, these could be offset by increased field labor and interconnects costs, as well as by the costs of storage capacity development. Phillips-Conoco signed a support agreement to deploy the first units; however, the time table was not revealed and system development has been ongoing for several years.

Commercialization of either concept, after satisfactory demonstration of proof of concept and scale up economics, would still be 3 to 5 years away. And, as noted above, the primary limitations on the use of these technologies in bulk energy storage systems are the MWh rating for SustainX (*i.e.*, limited to only a few hours worth of stored energy) and the overall storage requirements for large MW General Compression facilities (*i.e.*, very large number of smaller systems must be used together).

Q64. Are there other energy storage technologies under development?

A64. (SVDL) Conversion of renewable energy, such as wind and solar, to hydrogen is another method that could be used to store energy on a bulk basis. In Germany, where salt caverns are abundant for storage, hydrogen can be blended and piped into natural gas pipe supply systems or used directly for power generation.[72] However, hydrogen generation requires huge offshore wind generation, in addition to storage facilities. As discussed in more detail in Mr. Ratti's testimony, this is not a reasonably foreseeable option in Maryland for the next 10 years or longer.

Bulk storage adiabatic CAES systems are still in the early development phase. Thermal Energy Storage ("TES") could store the heat of compression for use in the expansion cycle, which would then require no fuel usage and would have minimal emissions. However, air storage caverns are still necessary. A conceptual demonstration plant of 200 MW, known as "Adelle," is being contemplated in

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[72] Jürgen Kepplinger et al., "Present Trends in Compressed Air Energy and Hydrogen Storage in Germany," SMRI Fall Technical Conference, October 3-4, 2011 (Exh. APL000051).

Germany.[73] However, even if the TES component proves successful in Germany, this technology would have no application in Maryland due to the lack of large volume air storage.

Q65. Please discuss some of the major permitting issues and anticipated timelines for developing CAES projects.

A65. (SVDL) The permitting issues for CAES projects are similar to those for fossil fuel fired plants. The use of natural gas to support a CAES plant would be similar to any gas turbine combined cycle plant in terms of land use footprint and water use. The storage facility itself will have additional permitting requirements, including permits to drill wells in the designated aquifer and disposal of solution-mined brine. These aspects of permitting (without significant public opposition) would take at least three years. Another three years would be needed to purchase, construct, and commission the plant. Smaller pipe storage systems could be realized in approximately five years. However, technical and safety issues related to high pressure buried piping or above ground pipelines could cause permitting delays.

Q66. In your professional opinion, is the use of CAES in combination with wind turbines to generate 1600 MW of continuous base load power to the Maryland grid reasonably foreseeable in the next 10 years or longer?

A66. (SVDL) No. First, large scale storage facilities would need to be explored and developed. Permitting requirements for exploratory reservoir boreholes would be another impediment, as well as the actual field development (assuming suitable aquifers were determined to exist, acreage required was available, and the requisite

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[73] Chris Bullough et al., "Advanced Adiabatic Compressed Air Energy Storage for the Integration of Wind Energy," Proceedings of the European Wind Energy Conference, November 2004 (Exh. APL000053).

boreholes could be installed to deliver the required airflow to a large CAES power plant). In addition, large wind installed capacity would be required, even optimistically assuming a 40% capacity factor for offshore wind. Of course, you can only recover what you can store on a daily input basis.

Q67. In your professional opinion, is the use of CAES in combination with solar energy to generate 1600 MW of continuous base load power to the Maryland grid reasonably foreseeable in the next 10 years or longer?

A67. (SVDL) No, this is not reasonable foreseeable. CAES can only facilitate bringing solar energy, when available, to a steady state of supply during the day. Otherwise, the required storage volume for continued power supply is huge and, in any event, not available in Maryland.

Q68. In your professional opinion, is the use of CAES in combination with wind turbines to generate 100 MW of continuous base load power to the Maryland grid reasonably foreseeable in the next 10 years? What about 400 MW?

A68. (SVDL) Assuming that storage is available, it could be possible to generate 100 MW(e) of "baseload" wind energy – but only if enough wind energy can be delivered such that sufficient energy could be stored for use. The additional storage would allow the CAES plant to continue to generate 100 MW(e) for continuous baseload when the wind was not blowing.[74] In addition, Technical Paper Presentation IMEC-

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74 Septimus van der Linden, "Integrating Wind Turbine Generators (WTGs) with GT-CAES (Compressed Air Energy Storage) stabilizes power delivery with the inherent benefits of Bulk Energy Storage," IMECE 2007-41853, November 2007 (Exh. APL000054); Septimus van der Linden, Technical Paper Presentation, IMECE 2007-41853, "Integrating Wind Turbine Generators (WTGs) with GT-CAES (Compressed Air Energy Storage) stabilizes power delivery with the inherent benefits of Bulk Energy Storage," November 2007 (Exh. APL000026).

41853 graphically illustrates (in slides 51 to 54) wind energy storage issues.[75] However, given the current state of CAES development, this is unlikely to occur in the next decade or two.

For 400 MW(e) the wind resource would need to be close to 1600 MW installed capacity, and in addition to large cavern or reservoir storage facilities.[76] This is unlikely to be available in Maryland for a decade or two. And, of course, this discussion is at best speculative at present, because there are no known geological structures to support CAES in Maryland.

Q69. In your professional opinion, is the use of CAES in combination with solar energy to generate 75 MW of continuous base load power to the Maryland grid reasonably foreseeable in the next 10 years? What about 300 MW?

A69. (SVDL) As with wind energy, this is theoretically possible, but unlikely. In order to produce excess energy for storage, the number of solar arrays would have to be more than double (assuming there is 12 hours of sunshine to support 12 hours of nighttime generation with CAES). And, this does not consider the capital investment and large acreage needed to generate 75 MW(e). The same limitations are applicable to a larger 300 MW(e) facility. So, in my opinion, this is not a reasonable possibility in the next 10 years.

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75 *See* Septimus van der Linden, Technical Paper Presentation, IMECE 2007-41853, "Integrating Wind Turbine Generators (WTGs) with GT-CAES (Compressed Air Energy Storage) stabilizes power delivery with the inherent benefits of Bulk Energy Storage," November 2007 (Exh. APL000026).

76 Ridge Energy Storage & Grid Services L.P., "The Economic Impact of CAES on Wind in TX, OK, and NM, Final Report," Prepared for: Texas State Energy Conservation Office, June 27, 2005 (Exh. APL000012).

F. Assessment of Environmental Impacts of Reasonable Energy Alternatives

Q70. Please summarize the environmental impacts of the combination of energy alternatives.

A70. (DL) As noted above, the environmental impacts associated with the construction and operation of the combination of energy alternatives are SMALL for water use and quality, human health, and environmental justice. The impacts are SMALL to MODERATE for air quality, waste management, and socioeconomics (except taxes and economy). The environmental impacts are MODERATE for land use and ecology and LARGE for historic and cultural resources. The impacts on socioeconomics (taxes and economy) are SMALL to MODERATE beneficial.[77] I agree with the NRC Staff conclusions in the FEIS, which are based, in part, on information presented in the Environmental Report for the COL application.

Q71. Are the NRC Staff's conclusions sensitive to changes in the relative contribution of renewable energy alternatives to the overall combination of alternatives?

A71. (DL) No. Even if wind contribution (with storage) was quadrupled to 400 MW(e) of baseload power, the combination alternative would still require 900 MW(e) from natural gas.[78] While this would proportionally decrease the air emissions associated with the natural gas component of the combination of energy alternatives, it would not change the overall impact categorizations. With a fourfold increase in the contribution of wind, the impact categorizations would not change, except (1) for onshore wind, impacts to land use and ecology might become LARGE; and (2) for offshore wind, increased impacts to aquatic ecology are likely (*i.e.*, could change

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77 FEIS at Table 9-3.

78 FEIS at 9-28.

from MODERATE to MODERATE to LARGE). A combination of alternatives that includes a significant increase in wind production, in conjunction with energy storage, is not clearly preferable to construction of a new baseload nuclear power generating plant located within UniStar's region of interest.

(DL) Even if solar contribution (with storage) was quadrupled to 300 MW(e) of baseload power, with a 300 MW(e) CAES plant, the combination alternative would still require 1000 MW(e) from natural gas. While this would proportionally decrease the air emissions associated with the natural gas component of the combination of energy alternatives, it would not change the overall impact categorizations. With a fourfold increase in the contribution of solar, the impact categorizations would not change except that land use impacts could increase from MODERATE to MODERATE to LARGE due to the low energy density of solar radiation relative to other common energy sources. Even if photovoltaics could be deployed on rooftops and sufficient storage mechanisms were available in conjunction with the photovoltaics to produce baseload power, the environmental impacts of the combination of alternatives still would not change appreciably. A combination of alternatives that includes a significant increase in solar production, in conjunction with energy storage, is not clearly preferable to construction of a new baseload nuclear power generating plant located within UniStar's region of interest.

Q72. As discussed above, the NRC Staff included a sensitivity analysis in the FEIS discussion of a combination of energy alternatives. Is a quadrupling of the contribution of wind or solar to the combination of alternatives reasonable?

A72. (SR) As I explained previously, on balance, assuming that the addition of a storage technology was technically and economically feasible, it is plausible, but unlikely,

that 100 MW(e) of "baseload" wind energy could be available in Maryland in the next 10 years. However, an assumption that the amount of baseload-equivalent wind power would be four times that assumed in the FEIS (400 MW versus 100 MW) in the next 10 years is not reasonable.

(SR) With respect to solar, in my professional opinion, installation of the equivalent of 75 MW(e) baseload (assuming that energy storage is technically and economically feasible) is plausible (if unlikely) and therefore reasonable. However, installation of the equivalent of 300 MW(e) of baseload solar (quadruple the amount assumed in the FEIS) in the next 10 years is not a reasonable assumption.

(SR) In addition, if the contribution of wind or solar is assumed to be four times as much as in the FEIS combination, the additional wind or solar likely will displace some of the 100 MW(e) of biomass and the 25 MW(e) of hydropower in the FEIS combination. As a result, the 900 MW(e) or 1000 MW(e) "remaining" contribution from natural gas in the wind and solar sensitivity case is likely under-stated.

(SVDL) A 300 MW CAES plant, in conjunction with solar, or a 400 MW CAES plant, in conjunction with wind, capable of producing power that roughly approximates baseload would be larger than any CAES plant in existence in the world at present. Moreover, no storage media (*e.g.*, salt domes, caverns, deep aquifer) are known to exist in Maryland and, even if they were present, would take many years of development to commission for operation. Thus, an alternative involving a much greater contribution of wind or solar, in conjunction with CAES, is not reasonably foreseeable.

III. CONCLUSIONS

Q73. What are your overall conclusions regarding the reasonableness of the NRC Staff's assumption of 100 MW(e) of wind power, in conjunction with energy storage, as baseload power in the FEIS combination of alternatives?

A73. (SR) On balance, assuming that the addition of a storage technology was technically and economically feasible, it is plausible, but unlikely, that 100 MW(e) of "baseload" wind energy could be available in Maryland in the next 10 years. The use of 100 MW(e) of wind energy in the FEIS is reasonable.

(SVDL) Assuming that sufficient wind energy over and above the 100 MW can be delivered on a continuous basis such that another 100 MW could be stored for use in a CAES plant, it is technologically plausible to create 100 MW of "baseload" wind power. However, given the current state of CAES development and the lack of any known storage resources in Maryland, this is not reasonably foreseeable. Thus, the FEIS combination of energy alternatives is speculative, at least to the extent that it relies on the availability of CAES.

Q74. What are your overall conclusions regarding the reasonableness of the NRC Staff's assumption of 75 MW(e) of solar power, in conjunction with energy storage, as baseload power in the FEIS combination of alternatives?

A74. (SR) As I noted previously, increases in installed solar capacities are likely to be driven by Maryland's RPS. In my professional opinion, installation of the equivalent of 75 MW(e) "baseload" solar (assuming that energy storage is technically and economically feasible) is plausible and therefore reasonable. The use of 75 MW(e) of solar energy in the FEIS is therefore reasonable. However, generation of greater amounts of "baseload" solar is unlikely to occur in the next 10-15 years.

(SVDL) Assuming that enough solar energy can be delivered on a continuous basis such that sufficient energy can be stored in a CAES plant, it is technologically plausible to create 75 MW of "baseload" solar power. However, given the current state of CAES development and the lack of any known storage resources in Maryland, this is very unlikely to occur in the foreseeable future. Thus, the FEIS combination of energy alternatives is speculative, as least to the extent that it relies on the availability of CAES.

Q75. What are your overall conclusions regarding the assessment of energy alternatives in the FEIS?

A75. (DL) I agree with the NRC Staff's conclusions. The combination of energy alternatives considered in the FEIS is reasonable based on based on evaluations of technologically and economically achievable generation technologies in the region of interest. Based on the assessment of the environmental impacts of a range of reasonable energy alternatives, combinations involving wind and solar power with storage, supplemented with natural gas, are not environmentally preferable to Calvert Cliffs 3 — even considering the potential for significant increases in the contributions of wind and solar. Any dispute over the specific mix of wind or solar used in the combination of alternatives is not one that would affect the outcome of the NEPA analysis.