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GRID-SCALE ENERGY STORAGE

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

TO

RECEIVE TESTIMONY ON THE ROLE OF GRID-SCALE ENERGY STORAGE IN MEETING OUR ENERGY AND CLIMATE GOALS

DECEMBER 10, 2009

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GRID-SCALE ENERGY STORAGE

THURSDAY, DECEMBER 10, 2009

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 10:01 a.m. in room SD–366, Dirksen Senate Office Building, Hon. Jeff Bingaman, chairman, presiding.

OPENING STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

The CHAIRMAN. OK. Why don't we go ahead and get started?

Thank you all for being here. We have had several hearings in this committee on the topic of energy storage, but those hearings were primarily focused on energy storage technologies for the transportation sector.

This morning, we are turning our attention to the role of energy storage for the grid. Let me just initially indicate there has been a lot of interest here in the committee on it. Senator Wyden has urged that we have this hearing. Senator Udall has urged that we have this hearing. I appreciate them and Senator Corker all being here. I know Senator Murkowski is on her way as well and will be here shortly.

We are told that grid-scale energy storage technologies have the potential to transform our grid, enabling energy to be delivered exactly when it is needed, regardless of when it was produced, and providing a new toolbox of capabilities for managing the grid. These capabilities will allow us to run our grid more efficiently and reliably and provide better power to customers.

They will allow us to maximize the capacity of our existing generation and transmission and distribution assets, reducing the need to build more, and we are also learning that energy storage technologies will be instrumental in achieving large amounts of renewable generation on the grid by acting as shock absorber for fluctuations in power and providing firm dispatchable energy.

The Recovery Act that was passed by Congress only 10 months ago has been instrumental in jumpstarting the development of these grid-scale energy storage technologies. The Department of Energy's Office of Electricity last week announced funding for 16 utility-scale energy storage demonstration projects aimed at proving out the technical feasibility benefits and business case for these technologies.

My own State is participating in two of those demonstration grants to demonstrate the use of flow batteries for firming up re-

newable power. I also know that the Department of Energy is pursuing several breakthrough grid storage projects through ARPA-E and through the Office of Science.

These efforts are positioning our country as a world leader in grid-scale energy storage research and development, ensuring that the capabilities of these technologies are used to our best advantage and swiftly deployed on the grid where it makes sense to do so and where it will help us to meet our clean energy goals, but will also ensure that we remain leaders in this area.

So I look forward to hearing from our witnesses. We have two distinguished panels today—first, a panel of Government officials who can tell us the state of policy and action in the executive branch and then a second panel of experts as well.

Let me defer to Senator Murkowski for any comments she has.

STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

Senator MURKOWSKI. Thank you, Mr. Chairman.

Good morning. Welcome to our witnesses, and I appreciate the opportunity this morning to continue our series of very informative discussions. The topic this morning, grid-scale energy storage has the potential to transform the way that we generate and receive electricity.

Energy storage capability has already changed the way that we live. If you look at those of us around here with our BlackBerrys and our cell phones. I think we recognize how frustrating it is when we forget to charge it up, and make sure that we have it functioning at full capacity every day. But it is easy to forget that it wasn't too long ago that we actually had pay phones here in the Dirksen building. My kids don't even know what a pay phone is.

For about a half a century now, our Nation's power delivery system has operated by carefully balancing in real time generation and load, and we have been using the just-in-time delivery system for immediate generation and delivery. That is all about to change. It has to, because we are changing the way that we use the grid.

As we seek to lower our emissions, we have an ever-increasing amount of renewables and distributed generation that are coming online. We are also moving toward the electrification of our transportation sector. Integrating variable resources like wind and solar has challenged our grid operators by often producing too much energy when it is not needed or not enough energy when it is needed. We need to make our grid smarter and change how we manage and control the delivery of electric power.

Cost-effective grid-scale energy storage is part of the solution to these energy challenges. Energy storage can firm up intermittent renewable energy sources and promises to improve the efficiency, the reliability, as well as the security of delivering energy.

Just as we need a diverse energy supply, we need a wide array of energy storage technologies, everything from pumped hydro, flywheels, and batteries to compressed air energy storage. Even plug-in vehicles can play an important role in shifting load to off-peak hours.

Coming from Alaska, I can certainly appreciate that pumped hydro has been the energy storage workhorse, providing the most

storage capacity that can deliver power during peak demands. It often doesn't get the credit that it deserves. Today, in addition to learning about the emerging technologies, I would like to hear a little bit more about increased opportunities for this effective and proven resource.

As you note, Mr. Chairman, we have got an impressive panel of witnesses today. I welcome you, Chairman Wellinghoff, and Dr. Koonin, back to the committee and look forward to the testimony that we will hear. I again look forward to helping establish the path forward on the development of policies that will support the development, the deployment, and the regulation of grid-scale energy storage systems.

Thank you.

The CHAIRMAN. I know there is a lot of interest here by members. Let me just allow each member to make any statement they would like to at this point.

Senator Wyden, did you want to make a statement?

STATEMENT OF HON. RON WYDEN, U.S. SENATOR FROM OREGON

Senator WYDEN. I did, Mr. Chairman. Thank you for your thoughtfulness. I know we have got witnesses we want to go on to.

I think this is an extraordinarily important topic because I don't think the people of this country, nor those of us in public office recognize that we are wasting so much of our treasure trove, this extraordinary array of renewable energy resources. We want to have carbon-free wind turbines and solar cells and, in my part of the country, wave and tidal energy. Yet we fritter away so much of this extraordinary resource because we have not set in place, as Senator Murkowski notes, the full array of storage technologies that would allow us to capture the full potential of these renewable resources.

There is something pretty bizarre, even by the standards of the Beltway, of throwing away the economic value, for example, of renewable energy because the wind is blowing or the tide is changing at 3 in the morning when demand is low.

So what we have got to do is figure out a way to not devalue, for example, the full potential of renewable energy, which is what you do because we can't sell it when prices are highest. We shouldn't end up spending more integrating it with nonstorage technologies, which is what Senator Murkowski talked about, and I think we can do this in a bipartisan way.

Earlier this year, Senator Menendez, Senator Collins, and I introduced legislation—S. 1091, the Storage Act—to provide tax incentives to deploy storage energy technologies. I note we have got a number of colleagues from both the Energy and Finance Committees. Senator Shaheen, Senator Dorgan, Senator Kerry, recently Congressman Thompson from California recently introduced the legislation. I think we can move forward in the storage area in a bipartisan way.

Our bill provides a 20 percent investment tax credit for grid-connected energy storage systems. It is technology neutral so that all of the various technologies—pumped hydro, compressed air, batteries, flywheels, and new technologies—all of them would have a

chance to compete in an open marketplace. The bill provides incentives for businesses and homeowners to install their own energy storage systems to store renewable or off-peak energy, including plug-in vehicles.

So I think the point is, as we move forward, and I believe this can be done in a bipartisan way to build a clean energy economy, let us make sure we do it in a way that is smart and not wasteful.

A key part of that equation is what you and Senator Murkowski are examining today, and I very much appreciate your holding the hearing.

The CHAIRMAN. Very good.

Senator Corker, did you have any comments you would like to make?

Senator CORKER. I think you know the answer to that. I look forward to hearing from the witnesses.

Thank you.

The CHAIRMAN. All right. Senator Udall, how about you?

STATEMENT OF HON. MARK UDALL, U.S. SENATOR FROM COLORADO

Senator UDALL. Thank you, Mr. Chairman.

If I might, I have a longer statement I would like to ask unanimous consent to include in the record.

The CHAIRMAN. We will do that.

Senator UDALL. Let me make a few brief comments. I want to thank you and the ranking member for holding this hearing.

I would like to associate myself with Senator Wyden's remarks. I know that these topics can seem dry. But to use a phrase that has been in the parlance this year, this could very well be a game-changer.

In the 2009 National Electricity Delivery Forum here in DC, participants were asked what will be the most transformative technology for the electricity industry. The answer, the most frequent answer was energy storage technologies, including plug-in hybrids. It wasn't an integrated smart grid, as important as that is, or transmission superhighways.

I am glad that the chairman of the FERC is here because I want to hear his thoughts on regulatory issues. I have come to understand that the technologies are almost more advanced than the regulatory questions that we have to answer, that there are a lot of disincentives in the systems right now to using storage technologies.

Then I am also pleased to see the Under Secretary here, and I am keen to hear about the Recovery Act storage projects and where we stand with those.

But again, Mr. Chairman and Ranking Member Murkowski, thank you for holding this important hearing.

[The prepared statement of Senator Mark Udall follows:]

PREPARED STATEMENT OF HON. MARK UDALL, U.S. SENATOR FROM COLORADO

Thank you Mr. Chairman. I appreciate your agreeing to hold this hearing and of course all the hard work of your staff. I requested it to draw attention to what the federal government is doing to advance storage technologies as well as what regulatory changes might be appropriate for storage facilities on the electrical grid.

I recognize that these topics may seem dry, but what we are talking about today is potentially game-changing. If we find a way to store the power generated from the sun and the wind, really all energy resources, then we can transform the energy industry forever.

At the 2009 National Electricity Delivery Forum here in DC earlier this year, participants were asked, "What will be the most transformative technology for the electricity industry?" The most frequent response was "Energy storage technologies, including plug-in hybrids." It scored higher than every other technology, including "An integrated Smart Grid" and "Transmission superhighways."

Energy storage can address problems that are already occurring that impact our economy and security. Power interruptions cost the United States economy roughly $80 billion per year. And these power outages do not have to last long. Two-thirds of those losses came from interruptions lasting less than five minutes. Storage can help reduce those outages, increase our economic productivity, and save consumers and businesses money.

I am glad that Chairman Wellinghoff is here to talk with us about regulatory issues related to energy storage. I am especially interested to hear his thoughts on how best to structure cost recovery for storage projects to account for all the benefits that storage provides to the electrical grid.

I am also pleased to see Undersecretary Koonin here to talk about what the Department of Energy is doing to advance energy storage technology, including the recently announced Recovery Act funding for storage projects. Getting those initial projects built and operating will provide extremely valuable experience for future investments.

It just seems to me that energy storage is poised to help us no matter what our energy supply mix is going forward—wind, solar, nuclear, natural gas, or coal with carbon capture and sequestration. Whether it is making the electrical grid more reliable, deferring new line construction, or reducing transmission and distribution congestion—energy storage has a role to play. Or maybe the goal is reducing carbon emissions, meeting peak demand, or integrating greater amounts of renewable energy—energy storage can help us face those challenges as well.

I look forward to today's testimony to hear ways of partnering together to solve these challenges. I also look forward to hearing ideas of how to effectively bring energy storage technologies to the marketplace.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Shaheen.

Senator SHAHEEN. Thank you, Mr. Chairman. I will reserve my comments for the questioning period.

The CHAIRMAN. Very good.

Let me introduce the first panel. It is Dr. Steven Koonin, who is the Under Secretary for Science in the Department of Energy. Thank you for being here.

The Honorable Jon Wellinghoff, who is chairman of the Federal Energy Regulatory Commission. Thank you for being here.

Dr. Koonin, did you want to start and take 6 or 8 minutes, whatever time you need to make the points you think we need to understand? Then I am sure we will have questions.

STATEMENT OF STEVEN KOONIN, UNDER SECRETARY FOR SCIENCE, DEPARTMENT OF ENERGY

Mr. KOONIN. Sure. Thank you.

Chairman Bingaman, Ranking Member Murkowski, members of the committee, I appreciate the opportunity to discuss grid-scale electric storage with you this morning.

Electricity is the cleanest and most convenient form of energy available for residential and commercial use. For that reason, it continues to grow significantly relative to other forms of energy in those sectors. Challenges in generating and using electricity stem from the great variation of demand during the day, which can double from early morning to late afternoon.

Since flowing electricity is perishable in that unused current cannot easily be stored for later use, generators must successively be turned on during the day as demand increases and then idled again in the evening. Grid assets are, thus, idle roughly half the time, and the system must be designed for a rarely achieved peak demand.

Indeed, our power system operates at only about 40 percent of its capacity. Yet it continues to require additional resources as demand grows.

A broader deployment of energy storage technologies well integrated into the grid would smooth the daily load cycle and allow our current infrastructure to be used much more efficiently. Storage on shorter timescales could provide for frequency regulation, peak shaving, and regional balancing. Reduced losses, improved power quality, increased capacity factors, and deferred capital investment would all result.

Grid-scale storage would enable a more complete exportation of the intermittent wind and solar generation that we aspire to increase. The optimal grid-scale energy storage technology would be rapidly charged and discharged with small losses of energy, durable over many cycles, physically compact, and significantly less expensive than the generation capacity that it supplements.

Unfortunately, we are not yet close to that ideal in part because of fundamental physical obstacles. The simplest and most common grid-scale storage technology is to raise or lower water. The challenge for such pumped hydro systems is that gravity is pretty feeble.

Raising 1 cubic foot of water by a typical 300 feet stores less than 1/100 of a kilowatt hour. So, to do this at scale, you need a suitable topography, and you also need a lot of water.

Another possibility is underground storage of compressed air for which appropriate geology probably exists in much of the Nation. Although this technology has been demonstrated for decades, 1 cubic foot of air at a typical 150 atmospheres still stores only 2/10 of a kilowatt hour of energy. So, again, you need a lot of air.

A cubic foot of batteries can store 100 times more energy than that in its electrons and ions, although at roughly 100 times the cost currently.

All of these technologies should be compared to the 1 kilowatt hour of chemical energy contained in a cubic foot of natural gas, which costs just a penny and weighs essentially nothing. Of course, that chemical energy in the gas is extracted irreversibly and with a carbon footprint.

So despite the challenges and current high cost, storage technologies can be of value in managing the grid. So what do we need to do in order to realize more effectively the potential for storage in managing the grid?

First, because utilities are appropriately cautious, we need to better demonstrate the potential of existing technologies. Department of Energy demonstrations under the Recovery Act are boosting such activities 50-fold and encompassing the complete range of technologies and scales from a single battery project in Pennsylvania to a 300-megawatt compressed air project in California.

These projects will provide much more operational experience and define best practices, and these will facilitate greater storage deployment efforts nationwide. They will also help us better quantify the economic dimension of the storage issue.

Second, we should be pursuing basic research to enable the next generation of storage solutions. Material science to synthesize and understand novel nanoscale materials tailored to specific electrochemical properties is the highest priority here. An out-of-the-box aspiration would be the reversible storage of electrical energy in chemical bonds.

You know, right now, we can use electrical energy to electrolyze water and produce hydrogen, compress and store that hydrogen, and then convert that hydrogen back into electricity using a fuel cell, for example. However, it is terribly inefficient currently and consequently uneconomic.

Research to do that electricity to chemistry back to electricity transformation would be truly game-changing. Such work would lead to low-cost storage devices with higher energy densities, cycle lifetimes, and reliabilities.

Then, finally, we need a deeper and more integrated systems-based understanding of grid structure and dynamics. Storage, demand management, peaking generation, real-time analytics, and real-time grid control are all tools that can be deployed to create a better grid. Understanding the synergies among them and their optimal deployment through data collection, analysis, and deployment is a task that we are only beginning to attend to through programs underway in the Department of Energy.

You know, as a theoretical physicist, I have been looking carefully for the last months for a theory of the grid, a simple, synthetic framework that you can use to get your arms around the concept, and I am sad to say I haven't yet found it. So, I look forward to helping perhaps stimulate programs to develop that so we can better understand how to integrate storage peaking generation, transmission grid management, demand management into a much more efficient system than we have currently.

With that, thanks for your attention.

[The prepared statement of Mr. Koonin follows:]

PREPARED STATEMENT OF STEVEN KOONIN, UNDER SECRETARY FOR SCIENCE, DEPARTMENT OF ENERGY

Thank you, Chairman Bingaman and members of the Committee, for this opportunity to testify before you on grid-scale energy storage and its role in achieving U.S. energy and climate goals.

Enhancing our national energy storage capability is an important tool to improve electric grid reliability and resiliency. Adequate deployment of storage technologies can materially reduce power fluctuations, enhance system flexibility, and enable greater integration of variable generation renewable energy resources such as wind and solar power. Each of these is critical for achieving the Nation's clean energy goals. Energy storage can also help stabilize the price spikes that occur during times of peak demand, and can delay or potentially avoid the need to construct capital intensive facilities and infrastructure that use conventional fuels and produce greenhouse gases.

The core function of energy storage is to bridge the gap that exists between the characteristics of the generation and load technologies within our electrical system. While some have identified this gap as a challenge inherent only to variable generation renewable energy technologies such as wind and solar, gaps and mismatches in characteristics exist throughout the grid that stress our infrastructure; these areas would benefit from the system flexibility that could be introduced with deploy-

ment of grid scale energy storage technologies. Power quality disturbances resulting from voltage and frequency fluctuation are but one indication of the stresses that exist in today's grid that could be ameliorated by increased energy storage. However, the functional requirements of energy storage for power conditioning are necessarily different than the functional requirements of energy storage for load shifting or variable generation firming, and it is therefore no surprise that different applications require different storage technologies.

It is important to recognize that despite the large number of existing energy storage technologies, there are only a limited number of known fundamental phenomena that can be exploited to store energy; currently these phenomena include gravity, electron movement and storage, mechanical conversion, chemical manipulation of materials, and thermal storage. The conversion process between energy states that enables storage also defines the characteristics of each storage technology, as well as the applications for which the technology is best suited. Gravity storage via pumped water, where each acre foot of water pumped contains more than 1 kilowatt-hour of potential energy for each foot of elevation increase[1], has the potential to store great amounts of energy and is well suited for large energy applications such as load leveling. Yet the requirement that water be moved limits the short time response capability of the technology. Conversely, mechanical kinetic energy storage via flywheels is particularly well suited to the short term requirements of power conditioning; and while flywheel systems can achieve very high energy densities[2], the physical constraints on flywheel size limit energy storage for extended activities such as peak shifting. Given the variety of conversion processes involved, it is critical that energy storage technologies be matched to potential applications.

The power requirements for energy storage range from of a few watts for personal electronics, up to 100 kilowatts for hybrid vehicles, tens of megawatts for ships, and hundreds of megawatts for electric utility applications. The duration requirements for these same applications covers a similarly broad range, from sub-second for power quality and voltage regulation to hours or even a day when peak shaving and load leveling. Among the most important requirements for stationary utility storage, which ranges from half a megawatt to hundreds of megawatts, are storage technologies that are low-cost and have a high cycle life, meaning a large number of charge and discharge cycles. High reliability, efficiency, environmental acceptability, and safety are also important. Unlike requirements for electric vehicles where energy density for conventional fuels is held as the benchmark against which storage technologies are compared, energy density and footprint are less important for utility storage.

Grid-scale energy storage received a significant boost through the American Recovery and Reinvestment Act. On Nov. 24, 2009, the Department announced it would award grants totaling $185 million to 16 energy storage demonstration projects[3]. This investment will substantially accelerate the development and deployment of utility-scale storage technologies, enhancing their market readiness in the U.S.

The Department of Energy's Office of Electricity Delivery and Energy Reliability has the lead within the Department for energy storage research, development, analysis, and demonstrations associated with the electric grid. The program works with numerous utilities to ensure that projects reflect the industry's needs, and close collaboration with the states has resulted in many jointly funded demonstration projects. In addition, the Office of Science selected six Energy Frontier Research Centers in the area of energy storage[4] to perform fundamental research relevant to battery technology. The Advanced Research Projects Agency-Energy (ARPA-E) has also selected six energy storage projects[5] as part of its first solicitation for breakthrough technologies. In fact, one project in the first ARPA-E tranche that has cap-

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[1] Potential energy is calculated to the theoretical limit and does not include efficiency losses from conversion between energy states. The theoretical potential energy for an acre foot of water is 1.02 kilowatt-hours per foot of elevation increase.

[2] Castelvecchi, D. (2007). Spinning into control. Science News, vol. 171, pp. 312-313.

[3] Project list available at http://www.energy.gov/news2009/documents2009/SG_Demo_Project_List_11.24.09.pdf.

[4] Center for Electrical Energy Storage Center for Electrocatalysis, Transport Phenomena and Materials for Innovative Energy Storage Energy Materials Center at Cornell Northeastern Chemical Energy Storage Center Center for Science of Precision Multifunctional Nanostructures for Electrical Energy Storage Heterogeneous Functional Materials Center

[5] High-Amperage Energy Storage Device-Energy Storage for the Neighborhood Planar Na-beta Batteries for Renewable Integration and Grid Applications Low Cost, High Energy and Power Density, Nanotube-Enhanced Ultracapacitors Metal-Air Ionic Liquid (MAIL) Batteries Silicone Coated Nanofiber Paper as a Lithium-Ion Anode High Energy Density Lithium Batteries

tured people's imagination is a storage technology, the liquid metal battery, so it is possible that storage is an area where truly creative thinking is possible.

GRID RELIABILITY AND FREQUENCY REGULATION

Reliability and power quality have become a necessity for the modern digital society because digital equipment is extremely vulnerable to short outages and even small voltage fluctuations. Studies have shown that momentary outages, lasting less than 5 minutes, cost the U.S. some $52 billion annually[6]. Energy storage with high frequency characteristics and response rate enables seamless continuity of power supply for a range of customers. One system of valve regulated lead-acid batteries, that was developed with Department of Energy funding, can protect energy intensive and highly sensitive facilities like microchip plants with 10 megawatts or more for 30 seconds, after which a back-up diesel generator can provide the necessary power. Similar systems are widely used for high tech manufacturing, financial institutions, and server farms. On a larger scale, a single 27 megawatt nickel cadmium battery safeguards the transmission line from Anchorage to Fairbanks by giving voltage support, preventing outages, and providing reactive power locally.

The need for frequency regulation arises because generation and demand are almost always out of synch. The resultant grid system is one which regional operators are required to balance by adjusting the frequency. Current management involves sending periodic signals that allow participating fossil fuel generators to increase or decrease production and reset the frequency. Fast storage performs this function considerably better. Studies have shown that regulating frequency by battery or flywheel storage is at least twice as effective and has a 70 percent reduced carbon footprint compared to use of fossil fuel generation[7]. Technical feasibility was shown by flywheel demonstrations funded by the Department jointly with state agencies in California and New York. Currently there are six 1 megawatt demonstration units operating on the grid, and through the Loan Guarantee Program the Department has entered into a conditional commitment for the development and deployment of a twenty megawatt flywheel energy storage facility in New York[8]. Meanwhile, under the guidance of the Federal Energy Regulatory Commission grid operators are developing new control signals, tariffs, and market rules to allow frequency regulation by fast storage to be deployed in a cost effective manner. With increased deployment of variable generation renewable energy assets, the need for frequency regulation on the grid will increase considerably.

ASSET UTILIZATION AND RENEWABLE INTEGRATION

It is well known that generation, transmission, and distribution are not efficiently utilized. Assets such as substations and transmission lines have to be sized for peak demand with ample capacity to spare for a hot day. One quarter of a facility's capacity is devoted to maintaining service during a 5 percent peak period. The goal of energy storage is to supply this peak load from energy stored during periods of least demand, thereby allowing for more complete and cost effective utilization of grid assets.

In particular, substation load can easily outgrow the original unit target size. Instead of an immediate and costly upgrade, installation of energy storage can be more economical and flexible, and is therefore finding favor with utilities. The first application in the U.S. was sponsored by the Department of Energy and American Electric Power in 2006 at a substation in West Virginia. The substation had been reaching its capacity limit and an upgrade was needed quickly to handle the overload during peak periods. Instead, energy storage was installed, so that energy is stored at night when the substation is not stressed and electricity is less expensive, and then released over a 6-hour period during peak load times. The system, using a sodium sulfur battery, has performed well and installation of storage will defer substation upgrades by 5 to 6 years. Seven more megawatts have since been deployed in similar installations at several utilities. Other utilities are planning to test flow batteries or lead-carbon batteries in efforts to defer substation upgrades.

While energy storage is important for reliability and efficiency of the grid, it is expected to become increasingly important for complementing and buffering increas-

[6] Hamachi-LaCommare, Eto. Understanding the Cost of Power Interruptions to U.S. Electricity Customers. Lawrence Berkeley National Laboratory (2004).

[7] Makarov, Ma, Lu, and Nguyen. PNNL Report #17632: Assessing the Value of Regulation Resources Based on Their Time Response Characteristics, Pacific Northwest National Laboratory (June 2008) Fioravanti and Enslin. KEMA Report #BPCC.0003.001: Emissions Comparison for a 20MW Flywheel-based Frequency Regulation Plant (2007)

[8] $43 million conditional commitment for a loan guarantee to Beacon Power (http://www.lgprogram.energy.gov/press/070209.pdf)

ing amounts of variable generation. Variability of wind and solar generation comes in three different time scales. Short term fluctuations of seconds or minutes are similar to the fluctuations created by load variability, and these fluctuations can be handled effectively by fast storage facilities placed on the grid for frequency regulation. Ramping over the course of hours—as sometimes occurs with wind generation—is an important issue for utilities, and energy storage can be used to address this challenge. With energy storage equivalent to a one hour reserve, the number of gas turbines required for ramp control could be reduced, thereby improving the economics of wind energy generation.

Another challenge results from the wind patterns that occur in areas where strong nighttime winds are common. Because night load is small when compared to daytime load, in such a scenario renewable resources can have a larger share of the generation mix during the night than during the day, resulting in periods when the value of continued generation of wind energy is challenged. In West Texas, for example, over nine hundred 15 minute intervals of negative pricing occurred during one month in 2008, and a number of wind developers in the area are beginning to realize that energy storage might lead to economic advantages and better utilization of wind energy.

Although interest is increasing, the United States has only a few megawatt-sized demonstrations of storage for the integration of renewable resources. In Japan, by contrast, a 34 megawatt/7 hour sodium-sulfur storage facility has been constructed in conjunction with a 51 megawatt wind farm. All excess night time generation is absorbed by the battery, resulting in completely dispatchable wind power during the day. While Japan encourages construction of energy storage associated directly with wind development, storage in the United States is viewed as a grid requirement which might be placed anywhere within a region. One hundred megawatt battery farms have been proposed domestically, but none has yet been constructed. An alternative approach which has been suggested is the introduction of community energy storage. Relatively small storage units of some 25 kilowatts would serve a cluster of 4-to-5 residences to provide emergency backup or to serve as a platform for installed photovoltaics. Individual units would also be aggregated into a centrally dispatchable fleet. This would provide the utility with a sizable resource for ramping, spinning or stand-by reserve, or other ancillary services.

For yet larger amounts of energy, compressed air energy storage (CAES) can be used. For this technology, air is compressed off peak and stored in salt domes, man made caverns, or deep aquifers. When extra energy is required during peak periods, air is released and fed directly into natural gas combustion turbines, eliminating the need for a compressor. While the current technology does not eliminate the need for fuel, it increases the efficiency of the turbines substantially, thereby reducing the carbon intensity of the generated electricity. There is also ongoing research into the use of adiabatic CAES technology, which does not require combustion of fossil fuels as the stored energy is converted back into electricity[9]. There are two CAES units in existence—one in Germany (290 megawatts) and one in Alabama (110 megawatts), and both facilities use salt domes formed by solution mining. CAES units could be used to take advantage of day-night power pricing arbitrage or as spinning reserve. Most proposed new plants intend to charge entirely with available wind energy, resulting in a very favorable carbon footprint. Besides producing electricity during peak periods, the plants can also provide system flexibility by absorbing excess energy whenever a wind increase occurs. This would eliminate the need for fossil fuel standby peaking plants.

Currently the best form of energy storage to handle really large quantities of energy is pumped hydro. Using reversible turbines, water is pumped into an upper reservoir during periods of inexpensive night power and released during periods of peak load to generate electricity. Some 20 gigawatts of pumped storage hydro plants are in use by utilities in the United States, which amounts to about 2.5 percent of the total U.S. electrical capacity. Europe has about 32 gigawatts of pumped hydro, or 10 percent of capacity, and Japan has as much as 15 percent which results in a very resilient grid capable of absorbing substantial amounts of renewable energy[10].

An impressive 440 megawatt pumped storage hydro plant in Missouri is scheduled for completion in 2010, and an additional 15 gigawatts of pumped hydro are either planned or in the permitting stage in the United States. Further new con-

[9] Bullough, Gatzen, Jakiel, Koller, Nowi, and Zunft. Advanced Adiabatic Compressed Air Energy Storage for the Integration of Wind Energy. EWEC 2004, London UK.

[10] 22% of generation capacity in Japan was attributed to renewable energy technologies during 2007, including hydropower (source: World Energy Outlook 2009, IEA).

struction is hampered, however, by environmental concerns, the current price of cement and steel, and a very lengthy permitting process extending over many years.

GRID-SCALE ENERGY STORAGE DEMONSTRATIONS UNDER THE AMERICAN RECOVERY AND REINVESTMENT ACT

The American Recovery and Reinvestment Act of 2009 provided unprecedented opportunity to accelerate the deployment of grid scale energy storage. On November 24, 2009, Secretary Chu announced the selection of 16 energy storage demonstration projects in conjunction with selection of Smart Grid demonstration projects[11]. The selected energy storage projects ranged over the entire spectrum of grid applications and will enhance grid reliability and efficiency, enable community energy storage options, and allow for greater use of renewable energy resources. Technologies include advanced batteries, flywheels, and compressed air energy storage. The selected awards total $185 million in Recovery Act funding but represent a total project value of $770 million based on substantial recipient cost sharing of between 50 to 80 percent of total project cost. The awards fall into five areas:

- Peak Reduction and Wind Farm Integration—three projects were selected with a federal cost of $61 million. The selected projects are intended to demonstrate the potential for battery storage to improve asset utilization, allowing better use of night time wind energy and grid integration of intermittent resources, thus increasing their share of the generation mix. These demonstrations in California and Texas will fund battery facilities in the 8 to 25 megawatt scale, a magnitude larger than current installations.
- Frequency Regulation Services for Stabilization of the Power Load—one project was selected for an award of $24 million. Electricity generation and load are never exactly synchronized. To balance them, regional system operators slightly shift the load frequency, by either increasing or decreasing power production. Using fast storage devices for these adjustments is twice as effective as using fossil fuel plants. A 20 megawatt flywheel system to be located in Illinois is ten times larger than existing demonstration units.
- Distributed Energy/Community Storage—five projects were selected totaling $20 million, which will allow utilities to experiment with smaller scale storage. Distributed energy storage strengthens and buffers the grid and allows utilities to deal effectively with load fluctuations or renewable generation. Utilities can use storage to provide peaking power during periods of high demand. The selected projects include a 3 megawatt installation in Pennsylvania to provide up to four hours of peak shaving, backup storage for a photovoltaic system in New Mexico, and aggregation of smaller systems into a community energy storage effort in Michigan.
- Compressed Air Energy Storage (CAES)—two projects for grants totaling $54 million have been selected. A 150 megawatt CAES facility will be constructed in New York State using an existing salt cavern. The plant will have sufficient storage to allow full operation in support of the transmission system and market needs and support some 3,800 megawatts of wind planned in the area. A second CAES project will be sited in California. The 300 megawatt plant, using a saline porous rock formation, is situated next to a transmission line receiving power from an expected 4,000 megawatts of new wind. Together, the two new plants will double the world's CAES capacity and provide invaluable experience for developing a fleet of such plants throughout the U.S.
- Promising, emerging technologies—five projects were selected for grants totaling $25 million. These new storage technologies are in their initial stage of development. Funding is intended to bring them to the prototype stage and ready for the market place. Among the projects are a Lithium-Ion battery with nanostructured polymer electrolyte, an iron-chromium based flow battery, and an isothermal compressed air technology that needs no extra fuel.

Successful implementation of these Recovery Act projects will depend not only on the diligence of the utilities and entrepreneurs involved, but also on the readiness of public utility commissions and regional system operators to accept the new technologies. As the new projects develop, they will be carefully monitored and fully integrated into the existing energy storage program at the Department of Energy. Results will provide a basis for analytical studies and economic modeling on the role of storage in a more sustainable electric grid.

[11] Project list available at http://www.energy.gov/news2009/documents2009/SG__Demo__Project__List__11.24.09.pdf

BARRIERS TO DEPLOYMENT

Technological barriers to improved energy storage systems range from gaps in fundamental knowledge to operational limitations in current technology. The Department of Energy's Office of Science has the lead for fundamental research to develop new concepts and approaches for energy storage necessary to meet the long-term needs of our nation. Significant advances in our understanding of basic physical and chemical properties of electrical energy storage are needed, and recent developments in nanoscience are opening promising scientific avenues that require further exploration. Fundamental research provides continually developing insights which enable the pursuit of new energy storage technologies to address the operational weaknesses of today's technologies, including: rate of system charge and discharge, safety hazards from over-charging or discharging, environmental hazards from toxic materials, and short lifetimes.

Widespread deployment of energy storage systems is impeded by the lack of uniform standards identifying operational parameters across applications. These and other issues, including additional regulatory and market barriers, have been identified previously[12].

The final barrier to deployment is economics. Current costs are too high to allow reasonable rates of return for investors in most applications, which can range from $1500/kW to $4500/kW depending on the technology. Although systems are beginning to enter the market at $2200-$2500/kW for high value applications, additional cost reduction is necessary to increase penetration; cost targets are application specific. Some cost reduction will be achieved through economies of scale as production numbers increase, but much will have to come from improved systems. Novel materials and components for energy storage applications, from batteries to flywheels, must be developed to enable long system lifetimes while using low cost base materials and inexpensive manufacturing processes.

CONCLUSIONS

Energy storage offers a diverse portfolio of technologies for a wide spectrum of applications. It allows us to optimize operation of the grid to make the most of our resources. Energy storage can:

- Provide power quality and reliability;
- Provide voltage and frequency regulation;
- Smooth integration of variable generation renewable energy technologies into the grid;
- Allow better asset utilization for generation and transmission;
- Provide relief to customers and utilities during peak load periods; and
- Provide spinning reserve and energy management to make renewable energy technologies more dispatchable.

Our basic research is leading fundamental scientific advances needed for leadership in developing the next generation energy storage technologies, and advances in energy storage are an international interest. Besides the U.S., the European Union, Canada, Australia, and Japan have sizable storage efforts. China recently initiated a substantial storage program focused on flow batteries.

Other emerging technologies have the potential of enhancing or augmenting storage. Smart grid concepts, for example, could link storage to demand response and enable aggregation of distributed storage. Plug-in hybrids and, perhaps eventuallybattery electric vehicles, add a whole new dimension by linking transportation to energy management. Utilities are increasingly becoming involved in energy storage, and states like California and New York continue to work with the Department in funding new projects. Recovery Act funding is supporting frequency regulation and wind integration projects on a commercial scale. The investment community is becoming interested in providing venture capital for companies developing new technologies and in funding ambitious large scale projects. Industry appears poised to move from single megawatt scale applications to utility grade projects in the hundreds of megawatts. The eventual goal is to make energy storage ubiquitous and thus to contribute to the development of a greener and more resilient grid.

This concludes my statement. Thank you for the opportunity to testify, and I look forward to answering any questions you and your colleagues may have.

The CHAIRMAN. Thank you very much.

[12] Electric Advisory Committee report—Bottling Electricity: Storage as a Strategic Tool for Managing Variability and Capacity Concerns in the Modern Grid—December 2008. (http://www.oe.energy.gov/DocumentsandMedia/final-energy-storage__12-16-08.pdf)

Chairman Wellinghoff, go right ahead.

STATEMENT OF JON WELLINGHOFF, CHAIRMAN, FEDERAL ENERGY REGULATORY COMMISSION

Mr. WELLINGHOFF. Thank you, Chairman Bingaman, Ranking Member Murkowski, and members of the committee. I appreciate the opportunity to speak here today.

My testimony addresses regulatory and technical issues related to the integration of energy storage into the electricity grid. Mr. Chairman, I would request that my full testimony be entered into the record, and I will summarize it here.

The CHAIRMAN. It will, and the full testimony of all witnesses will be included in the record.

Mr. WELLINGHOFF. Thank you.

The proliferation and adoption of renewable energy standards promise the Nation greater fuel diversity and lower emissions. But those goals cannot be achieved unless we also can ensure that new energy resources are integrated into the transmission system in a manner consistent with the reliable operation of the grid.

Integrating large amounts of new locationally dispersed energy resources will require system operators to alter traditional assumptions and balance load and resources in a way that accounts for the variable nature for renewable energy resources such as wind and solar. Storage can provide energy when these renewable resources cannot do so directly. Storage can do this by providing what is called regulation service, which is an essential service that supports the reliable operation of the grid.

The need for regulation service can dramatically increase the amount of variable renewable resources, and relevant to our discussion here today, it has been demonstrated that distributed resources, such as storage, providing regulation services are faster, generally cheaper, and have lower carbon footprint than the traditional power plant provided ancillary regulation services.

To date, the most used bulk electricity storage technology has been pumped hydro electric technology. But other storage technologies, such as the closed-loop pumped storage, flywheels, and grid-scale batteries, could provide substantial value to the electric grid. Even the batteries onboard electric vehicles or hybrid plug-in electric vehicles can provide regulation service to the grid and serve as mobile distributed storage.

With storage technologies at various stages of development, the commission already has had several opportunities to address grid-scale storage. For example, the commission recently accepted a proposal by the New York Independent System Operator, NYISO, to integrate energy storage devices into its day-ahead and real-time regulation services markets.

In the Midwest ISO market, FERC currently is considering the proposal to better accommodate stored energy resources.

In New England, in the New England ISO, they have recently sought to extend a pilot project that pays new storage technologies for regulation service based upon the speed of its response.

In the mid-Atlantic ISO, PJM, it has allowed a storage device, which includes battery power from three electric cars, to enter into

the frequency regulation market with no tariff or technical manual revisions.

In California, the California Independent System Operator has identified storage as one technology solution to facilitate renewable integration.

But I don't think we should stop there. We at FERC should look at industry-wide methods to remove regulatory barriers to the adoption of storage technology. In October, I provided Congress with the commission's strategic plan for fiscal years 2009 through 2014, which it reflects my intention to pursue market reforms that will allow renewable resources to compete in jurisdictional markets.

There are two main elements of this effort. First, the unique characteristics of storage technologies could require different market bidding parameters and telemetry requirements for providing energy and ancillary services than those established based on characteristics of traditional generators. Furthermore, the potential integration and synergies of renewable resources, storage, and demand response resources call for new ways to operate the electric system to take advantage of these resources for cost-effective, reliable, cleaner, and more efficiently produced electricity.

But some transmission tariffs may not yet allow storage technologies to either enter wholesale markets in a manner comparable to generation or be used as a substitute or complement to transmission investment.

Second, a key element of comparable tariff treatment is compensation. Some storage technologies appear to be able to provide near instantaneous response to regulation signals in a manner that is also more accurate than conventional resources, such as combustion turbine generators.

Most existing tariffs or markets do not compensate resources for superior speed or accuracy of regulation response. But such payments may be appropriate as system operators gain experience with the capabilities of storage technologies.

In conclusion, at FERC, our challenge as regulators is to remove barriers that impede the vast potential of energy storage to support our national energy goals. FERC can strive to ensure that regulatory barriers are removed, and compensation and tariff treatment are appropriately gauged to match the value of the services the storage can provide.

Thank you. I would be happy to answer any questions.

[The prepared statement of Mr. Wellinghoff follows:]

PREPARED STATEMENT OF JON WELLINGHOFF, CHAIRMAN, FEDERAL ENERGY REGULATORY COMMISSION

I. INTRODUCTION

Chairman Bingaman, Ranking Member Murkowski, and members of the Committee, thank you for the opportunity to speak here today. My name is Jon Wellinghoff, and I am the Chairman of the Federal Energy Regulatory Commission (FERC or Commission). My testimony addresses regulatory and technical issues related to the integration of energy storage into the electricity grid. I will begin my testimony by briefly describing the need for energy storage technology and then discuss some of the technical and regulatory issues that arise when integrating storage into the grid. I will conclude by discussing FERC's role in removing barriers to the development of grid-scale storage.

With the proliferation and adoption of renewable energy standards, the nation is showing itself increasingly committed to achieving climate change goals and a future in which clean, affordable, sustainable, and reliable energy is the everyday norm. Thirty states have adopted policies requiring fuel diversity and encouraging a move to lower-emissions energy sources, and Congress is considering a national renewable energy portfolio standard.

But greater fuel diversity and lower emissions cannot be achieved unless we ensure that the new energy resources are integrated into the transmission system in a manner consistent with reliable operation of the grid. With these concerns in mind, we at the Federal Energy Regulatory Commission are exploring our statutory authority to find ways to ensure that the reliable integration of these new energy resources reflects consumer decisions in the marketplace for electricity and meets policy goals.

One critical strategy for integrating new energy resources involves matching load and resource variations through the intelligent deployment of demand response and other distributed resources such as energy storage.

II. USE OF STORAGE

For the most part, electricity must be produced just in time to be consumed. Energy storage offers the ability to "warehouse" electrons for consumption later or to balance the variability of some renewable resources. It alters the traditional assumption of a linear electrical network, which assumes that centralized generators send electrons through transmission and distribution systems to instantaneously match need.

Integrating large amounts of new, locationally-dispersed energy resources into the grid will require system operators to alter traditional assumptions and balance load and resources in a way that accounts for the variable nature of renewable energy resources such as wind and solar power. Storage of renewable power can provide energy when these renewable resources cannot do so directly. For example, storage can be charged or filled off-peak by renewable energy and later provide a source of power during peak demand periods or periods when the sun or wind is not available, either through direct injection of energy into the grid or by enabling demand response.

And storage can do more than just balance the variable nature of solar and wind resources. The Energy Advisory Committee on Storage, convened by the Energy Policy Act of 2005, found that storage can: improve grid optimization for bulk power production via energy arbitrage; defer the need for investments in transmission and distribution infrastructure to meet peak loads; provide backup power to buildings; and provide ancillary services directly to the grid or market operators. My testimony will focus on the ability of storage to provide ancillary services, since that is the function most frequently addressed by FERC, and the function that may be of the most value to the integration of variable resources such as wind and solar.

Ancillary services help support the reliable operation of the grid. One such ancillary service is regulation service, which resources like storage can efficiently provide. Regulation service is the micro load-following service that increases generation supply when demand or load increases, and decreases supply when demand decreases. Regulation must be provided constantly, and it is one of the most expensive services on the grid.

Ancillary services like regulation service are essential to keep the system balanced and prevent it from cascading into a blackout. The need for regulation services can dramatically increase as the amount of variable renewable resources is increased. And it turns out that local storage is among the best means to ensure we can reliably integrate renewable energy resources into the grid.

Regulation service is usually provided by combustion turbine gas-fired generators. But while such generators can generally follow the minute-by-minute variations in load to keep the system in overall balance, the frequency excursions that are the subject of Regulation service actually occur on even shorter time intervals. Indeed, it has been demonstrated that distributed resources such as storage are more efficient than central station fast response natural gas fired generators at matching load variations and providing ancillary services needed to ensure grid reliability.[1] They are faster, generally cheaper, and have a lower carbon footprint than the traditional power-plant-provided ancillary service.

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[1] See, e.g., http://www.beaconpower.com/files/PNNL—Report—Assessing—Value—Regulation—Resources—June%202008.pdf at 26 ("Experiments also showed that an average 1 MW of flywheel regulation capacity can substitute for about 2 MW of the traditional regulation mix . . .").

III. STORAGE TECHNOLOGIES

To date, the most used bulk electricity storage technology has been pumped storage hydroelectric technology. Presently, there are 24 pumped storage projects around the nation with an installed capacity of over 19,500 MW. But new storage technologies are under development, and in some cases being deployed, that could provide substantial value to the electric grid. Building on experience with existing technology, closed-loop pumped storage uses two reservoirs that are "closed" to natural aquatic ecosystems. Other than initial filling and occasional topping off to offset evaporation or leakage losses, no natural river or stream would be used. This allows operational flexibility not available with a traditional pumped storage hydropower system, which uses natural rivers and reservoirs and must regulate flow to avoid harming local ecosystems. Currently, the Commission has issued preliminary permits for pumped storage—both traditional and closed-loop—totaling over 27,000 MW of capacity. Over one-quarter of this capacity is closed-loop.

A newer technology for providing storage for the electric grid is the flywheel, which works by accelerating a cylindrical assembly called a rotor (or flywheel) to a very high speed with low friction components, and maintaining the energy in the system as rotational energy. The energy is converted back by slowing down the flywheel. Flywheels have been successfully piloted in the U.S., and their speed is particularly useful for regulation service. For example, for the past year, ISO-NE has been conducting a pilot program to test how alternative technologies such as flywheels are able to provide regulation service.

Another promising storage technology is the grid-scale battery, which works like a giant consumer electronics battery. The battery takes energy in, and then with some small conversion losses, releases it later. Batteries for MW-scale storage have had successful pilots domestically for several applications. Like flywheels, batteries can respond more quickly and accurately than traditional generators to signals to increase or decrease the injection of energy into the grid when load changes. They can respond for short or long (multi-hour) periods of time, depending on the size and the controls of the battery. They can thus provide a variety of ancillary services or serve to defer the need for alternative transmission or distribution line investments.

The batteries onboard electric vehicles likewise can provide services to the grid. For purposes of this discussion, an electric vehicle is one that requires periodic re-charging of its propulsion battery from the electric grid. It may or may not also be a "hybrid," additionally capable of re-charging with a fuel-driven generator or by other mechanical means.

In the future, electric vehicles can provide ancillary services, like regulation service, to the grid and serve as mobile distributed storage. The evolving nature of electric vehicles' role and their market penetration curve create a unique set of challenges for integrating electric vehicles into electric markets as a grid service provider.

Although you may not think that a single electric vehicle could be providing an important ancillary service to the grid, researchers at the University of Delaware proved just that with a car that they parked outside of FERC headquarters that was providing regulation service to the PJM grid. More to the point here, the same researchers believe that, using this technology, parked electric cars connected and aggregated in large numbers in places like parking garages could be made available as energy storage to support grid operations, including balancing the variability of renewable resources such as wind and solar.

Each of these storage technologies—closed-loop pump storage, flywheels, batteries, and electric vehicles—are at various stages of development. Flywheels and chemical batteries have recently achieved technology maturity, and are well on the road to full scale implementation both here and abroad. Unlike flywheels and batteries, electric vehicles will not be commercially available for another year or two. Though there are several thousand electric vehicles on the road in the U.S. and abroad today, mass commercialization is expected to begin in 2010, and the U.S. has set a goal of having at least 1 million on the road by 2015.

IV. TARIFF ACTIVITIES ALREADY UNDERWAY

With storage technologies at various stages of deployment, the Commission already has had several opportunities to address grid-scale storage in regions operated by regional transmission organization or independent system operators, or RTOs and ISOs.

The Commission recently accepted a proposal by the New York Independent System Operator (NYISO) to integrate energy storage devices into its day-ahead and real-time regulation service markets. (127 FERC § 61,135). There we recognized that energy storage devices can help integrate wind resources, and that their inte-

gration in the regulation service market should help NYISO meet or exceed NERC control performance criteria. The Commission specifically pointed to the very fast response times of storage resources as a benefit to NYISO.

FERC currently is considering a proposal to better accommodate stored energy resources in the Midwest ISO markets. The Midwest ISO tariff revisions would allow short-term energy storage devices to enter, in a limited fashion, the frequency regulation market.

In the Northeast, ISO New England (ISO-NE) has recently sought to extend a pilot project for testing the ability of different storage technologies to participate in the regulation market. The pilot pays storage based on the speed of its response.

In the Mid-Atlantic, PJM Interconnection (PJM) has allowed a storage device to enter into the frequency regulation market with no tariff or technical manual revisions. AES installed a 1 MW battery at PJM headquarters to provide frequency regulation. PJM bundles that battery with the batteries of three electric cars, each of which purchase electricity at retail rates. The batteries then sell into the frequency regulation market. PJM has stated that it expects larger batteries to be able to enter other ancillary service markets or energy markets without significant tariff revisions.

Other areas of the country are examining the potential of demand response and other distributed resources to reliably integrate renewable energy resources into the grid. For example, this summer, the CAISO issued a white paper that identified storage as one technology solution to facilitate renewable integration.

V. FERC EFFORTS

Beyond the case-specific applications just described, we at FERC are already looking at methods to remove regulatory barriers to the adoption of storage technology. In October, I provided Congress with the Commission's Strategic Plan for FY2009-2014 and committed to take additional steps to address possible barriers to development of renewable resources, including the implementation of tools like storage to support reliable integration of renewable resources. And earlier this year, the Commission adopted a policy statement on the smart grid, which included storage as a key functionality of the smart grid. It is the Commission's expectation that this policy statement, which seeks greater interoperability and functionality of smart grid technologies through the adoption of standards, will help accelerate the development and promulgation of newer storage technologies.

And FERC will continue to monitor the development of storage technologies to ensure that they receive tariff treatment comparable to other resources and receive compensation commensurate with the value of the services they provide to wholesale markets and the grid.

Regarding compensation, some storage technologies appear able to provide a nearly instantaneous response to regulation signals, in a manner that is also more accurate than conventional resources. These two characteristics can reduce the size, and hence overall expense, of the regulation market. Most existing tariffs or markets do not compensate resources for superior speed or accuracy of regulation response, but such payment may be appropriate in the future as system operators gain experience with the capabilities of storage technologies. In the meantime however, the unique characteristics of storage technologies could require different market bidding parameters and telemetry requirements for providing energy and ancillary services than those established based on the characteristics of traditional generators. Furthermore, the potential interaction and synergies of renewable resources, storage and demand response resources call for new ways to operate the electric system to take advantage of these resources for cost-effective, reliable, cleaner and more efficiently produced electricity. This would ensure that consumers have access to the lowest cost resources needed to provide electricity service.

As for transmission tariffs, some tariffs may not yet allow storage technologies to enter wholesale markets in a manner comparable to generation or to use storage as a substitute, or complement, to transmission investment. FERC will monitor these developments and, when appropriate, ensure best practices for development and use of storage for all of its various purposes.

VI. CONCLUSION

In conclusion, at FERC, our challenge as regulators is to remove barriers that impede the vast potential of energy storage to support our national energy goals. With the appropriate compensation and tariff treatment, storage resources will have the opportunity to proliferate. While energy storage offers ample benefits just in improving grid operation and efficiency, it can also make integration of renewable energy resources not only reliable, but efficient and cost-effective as well. Fully opening

wholesale electric markets to resources like storage will make it easier to meet renewable energy standards by efficiently matching renewable energy resources and demand resources with distributed storage resources to smooth variations in resource output. In this way, these resources can complement each other to ensure a stable and reliable grid. FERC can strive to ensure that regulatory barriers are removed and compensation and tariff treatment are appropriately gauged to match the value of the services that storage provides.

The CHAIRMAN. Thank you both very much.

Let me start with a few questions. Dr. Koonin, I should understand this subject better to be asking questions about it. But at any rate, I remember a couple of years ago getting a briefing at Los Alamos National Laboratory on the issue of the research, basic research they were doing on the subject of capacitors and the belief that at least the folks briefing me had that capacitors have substantial capability to help us with storage issues in the future.

I don't know if you have a view on that subject, if that is something you are trying to support, that type of research in the department?

Mr. KOONIN. We are supporting work on super and ultra capacitors. Capacitors are, in many ways, complementary to batteries. Like batteries, you can move the energy in and out very quickly, capacitors even more quickly than batteries. So, they are useful for delivering energy in a short time, a surge, if you like.

Their drawback is that we currently can't store very much energy in them. So, in vehicles, for example, they are fine for boosting power when you need it, but not for long-term power storage and quite complementary to batteries.

The CHAIRMAN. OK. Let me ask an obvious question. You indicated that by virtue of the funding that you have in the Recovery Act, you have been able to increase the expenditures of the Department of Energy on storage by 50 times. What happens now that the Recovery Act is going to be over with?

I mean, is this something that we can maintain a focus on and maintain funding for, this kind of research and development in this area, or does this fall back to a second-tier pursuit?

Mr. KOONIN. You know, the array of projects that we have lined up right now, and hopefully will begin delivering on soon, I think nicely spans an array of technologies and applications, and we need to get experience in operating these, deploying them, understanding how to use them. They need to be well instrumented so that we collect appropriate data to inform our path going forward.

Then it really becomes a question of can we have gotten far enough down the road so that it becomes attractive for a utility to pick it up, and we move toward full-scale commercial deployment? So I am a bit agnostic at the moment as to how much more demonstration we need to do. I would like to see how this first round goes.

The CHAIRMAN. OK. I know the subject of our hearing is grid-scale energy storage, but one of the issues that we have dealt with now for many years is the whole issue of centralized generation versus distributed generation. It would seem to me that there is an obvious analogy between centralized storage and distributed storage. I don't know either you, Chairman Wellinghoff, or Dr. Koonin, if you have thought through which of these focuses makes the most sense?

Mr. WELLINGHOFF. Mr. Chairman, if I may? I think we certainly need to look at the economics of both. When you teed up this hearing as grid-scale storage, I tell you that I gave it a very broad definition. I believe that distributed storage can be grid-scale in the sense that things like plug-in hybrid and plug-in electric vehicles I think can significantly contribute to storage on the grid, as well as other technologies.

There are companies out there, for example, right now that are doing significant ice storage that can be used to shave peaks and effectively store energy from off-peak times and use that cooling to cool our homes and businesses in the Southwest and other areas of the country.

But that doesn't mean that we should ignore in any way larger centralized storage. Like pumped hydro, as Senator Murkowski indicated, is a very not only viable, but very proven storage technology that is here today. Although we need to understand, again, relative economics and look at relative costs and benefits.

For example, one statistic I heard the other day is that there is more storage available in all the electric hot water heaters in the United States than there is pumped hydro storage currently. So I thought that was a pretty interesting statistic.

So, again, it is a matter of looking at cost benefits and relative economics and determining what are the most viable things to start with.

The CHAIRMAN. Dr. Koonin, did you have a comment on that?

Mr. KOONIN. Yes, I do. You know, there are sometimes unanticipated systems issues that are well worth being aware of, and let me just take the plug-in hybrid example that looks so attractive as we try to merge transportation and power.

I would just add a couple of cautions that we probably need to think through as we go down that road. One is what is the impact of the grid ebb and flow into the battery in terms of its battery performance and lifetime beyond what you would get in an ordinary drive cycle?

The second is if we are talking battery vehicles, we shouldn't leave the battery vehicles high and dry. If you drain my battery during the afternoon to manage the peak, I may have a hard time getting home late in the afternoon.

Then, finally, if the net effect of integration of PHEVs into the grid is to turn liquid fuel into electricity for the grid, that would be, I think, quite foolish because we have, in fact, worked very hard to get oil out of the power sector over the last 30 years.

So, these are all interesting systems management issues that we need to be thinking about as we look to distributed storage, for example, and PHEVs.

The CHAIRMAN. Thank you very much.

Senator Murkowski.

Senator MURKOWSKI. Thank you, Mr. Chairman.

Dr. Koonin, I have been expressing concern about our reliance as a Nation on other countries, particularly China, with regards to the rare earth minerals and recognizing that it is these rare earth minerals that we need for purposes of our battery technologies, for the magnets that are used in the electric motors.

Are there alternatives that currently exist to utilizing the rare earth minerals for batteries and for the permanent magnets?

Mr. KOONIN. Yes. So the rare earths—I agree that we don't want to become addicted to imported rare earths in the same way that we have for oil. For the batteries, the rare earths are not an issue. Some of the precious metals or transition metals are an issue, but not for the rare earths. The rare earths——

Senator MURKOWSKI. An issue for the batteries is——

Mr. KOONIN. The transition metals are. But the rare earths are not. The rare earths are an issue for electric motor technologies. There, you know, I have a great faith both in supply curves and in technology to help us around that problem. There are resources for rare earths in the U.S. They are not quite as economically attractive as what we have in China, but with sufficient impetus, we could be tapping into those resources.

Second, the technology may be able to come into help with the rare earths. We don't need necessarily, for example, bulk rare earth materials, but we might be able to get by with just surface coatings on our——

Senator MURKOWSKI. So we are looking to these alternatives to——

Mr. KOONIN. We are starting to look very seriously at those.

Senator MURKOWSKI. Let me ask you, Commissioner Wellinghoff, you have mentioned that it is important to remove the regulatory barriers. Whether it is regulatory barriers or just regulatory uncertainty, how much does this hinder the development of energy storage technologies? How big of a contributing factor is that to what we are dealing with right now?

Mr. WELLINGHOFF. Certainly to the extent that these technologies want to scale and start into commercial operation, they are going to want to know that there is a revenue stream to support them. So, for example, flywheel storage technology is currently being paid under a tariff in New York, which is a good thing.

Ultimately, they have some certainty that they know they can provide regulation service into the New York grid and get a sufficient revenue stream to support a business model. In the PJM area, right now battery technology is getting paid to support the grid, and again, they know under a tariff they have a revenue stream to do that.

So what we are trying to do is encourage the ISOs and RTOs that are under our jurisdiction to formulate these tariffs that will compensate storage technologies in a way that they can develop a business model that can be sustainable that ultimately can grow that business. I think it is very important to have that regulatory certainty to make sure that those industries will grow.

Senator MURKOWSKI. When we were having the discussion here in the committee with our energy bill and the discussion about renewable electricity standard, you came before us and testified in support of a 25 percent RES. I understand that the FERC is underway with a study that looks to determine exactly how effective the grid is in its ability to integrate renewable resources. Can you give me any update or status on that study and what we might expect?

You have spoken to this in the past, but do we know at this point in time what percentage of renewables we believe that the grid, as it exists today, can reasonably accommodate?

Mr. WELLINGHOFF. I don't think we have that number. I can't give you an update, per se, from our study. I hope that our results will be out in March or April.

I will tell you that I got a briefing yesterday, however, on a very interesting study that is funded by DOE through NREL called EWITS that did look at a 20 percent renewable level in the grid and looked at how that would be accommodated. They seemed to believe that it could be accommodated.

We would like to validate that with the study that we are doing at FERC looking at regulation and frequency response in the grid and how that may be balanced. But these are things that I think we need to look at.

I had an opportunity to speak to a number of European legislators this last weekend, and they are looking at levels of renewables in their grid of 15 to 20 percent or more and are managing it currently in places like Spain, where they actually—at times of the day actually have over 50 percent of their total load supplied by wind energy.

So we need to learn from these examples. But storage is going to play a very critical role there because, ultimately, the storage will be necessary to balance out the variations that we see if we are going to be meeting these higher levels of 20, 25 percent and more.

The CHAIRMAN. Senator Wyden.

Senator WYDEN. Thank you, Mr. Chairman.

Thank you both.

Dr. Koonin, I want to make sure I understand what you were saying to Chairman Bingaman because your answer, I will tell you, troubles me. He asked you what is going to happen next, and you essentially said our position is wait and see.

I mean, wait and see is not the kind of activist strategy that I think this country needs to tap the full potential for these energy storage technologies. I don't see this as primarily a question of just spending money. I am certainly not advocating going out and spending money on dubious ideas. But I do want to see a game plan for tapping the full potential.

If what happens now is your agency, in effect, waits to see what happens, as I think you were saying to Chairman Bingaman, we could be waiting around for years and years and have a lot of foot-dragging when we really want a research game plan and activist strategy for tapping the full potential.

I don't think you would do that in the physics area, which I know you know lots about as well. So let me give you a chance to go at this area once again in terms of how we are actually going to get the kind of activist research plan that the country needs.

Mr. KOONIN. So what I have come to understand about energy after 5 or 6 years' worth of experience is that what we really need are well-chosen, consistent policies that move aggressively toward the goals that we are after. In science, you always look to assess what you have learned in order to let you move confidently and quickly to the next steps.

So I think we need to balance. I agree that there is an urgency, but we also need to make sure that we are making the right steps, the right technology choices, making the technology accessible for the utilities in the sense of giving them confidence to deploy.

I would hope that the round that we have got underway will do that and let us see what happens. I understand the urgency, but at the same time, we must learn from what we are doing.

Senator WYDEN. I am all for learning. It is just I see a lot of "wait and see" here, and what I want is something that is much more aggressive because I think waiting and seeing is a prescription in this town for a lot more delay, and I don't think the country can afford it.

Can you get us a document that describes what your research blueprint is and incorporates your ideas about trying to evaluate these projects? When could we see that?

Mr. KOONIN. I would be happy to get that for you. We can certainly do that as quickly as we can. I would be happy to get——

Senator WYDEN. Months? Is that in 60 days?

Mr. KOONIN. Yes. We can do that.

Senator WYDEN. Great. OK. Your research blueprint for tapping the full potential of storage technology, and that is very helpful.

Mr. KOONIN. Very good.

Senator WYDEN. One question for you, Mr. Wellinghoff. You essentially described the agency getting into it, in effect, when others bring it to you, these independent—the ISOs. We looked at the strategic plan, which essentially describes FERC's priorities, and energy storage is not mentioned in the strategic plan. Can you all go back and amend the strategic plan and lay out for us what the priorities would be for the agency?

Mr. WELLINGHOFF. We would be happy to go through the strategic plan and probably point out for you aspects of it that relate to storage that may not specifically say the word "storage." But certainly to the extent that we are, in that strategic plan, I think very clear about trying to integrate resources on the demand side into markets, storage is a big part of that, in my mind.

So it wasn't any intent to leave out storage from that strategic plan. It was subsumed by things like demand-side resources, which would include storage, energy efficiency, demand response, photovoltaics, distributed generation. All those things we need to figure out how to better integrate into the grid, how to make sure that they are paid their economic value for being integrated in the grid, and it was all intended as part of our strategic plan.

Senator WYDEN. Then have staff fill us in on the parts of the document that show us that this is going to be a major priority for the agency because that is what I——

Mr. WELLINGHOFF. We will do that. We will give you a response that shows that.

Senator WYDEN. We will look forward to working with both of you.

Thank you, Mr. Chairman.

Mr. WELLINGHOFF. Be happy to do that, Senator.

The CHAIRMAN. Thank you.

Senator Corker.

Senator CORKER. Mr. Chairman, thank you. Thank you for this hearing and the testimony of our witnesses.

My hometown community benefits right now from hydro storage, and I look forward to the day in the future when the batteries that are inside vehicles, which also are being produced in Tennessee, I might add, are used as storage at night. Base load power being used at night, lesser expensive, whether it is nuclear or other, nuclear power ultimately powering vehicles and, at the same time, during the day using that storage to lessen the load on the grid. That is an exciting development that I hope happens, and I appreciate my colleagues pursuing that.

I do want to ask Chairman Wellinghoff about a related grid issue. I offered an amendment during our energy debate that wanted to make sure that when we make these allocations of the cost of the grid, that people that are actually having to pay for that receive a benefit, and it did not go beyond that.

The original bill did not define benefits from the standpoint of allocation. I offered an amendment that passed—Senator Wyden and others supported it, it was bipartisan—that made sure we were talking about reliability and economic benefits, which doesn't really move beyond existing policy as it relates to the grid.

In the event we do want to shift costs for the grid to people who are not receiving a benefit, it seems to me that those of us in Congress should decide that and not FERC. I know there has been comments about the fact that, well, something happening some other place because it is environmentally good benefits mankind. So everybody should pay for it. But I think all of us are wanting to make sure that our constituents are paying for the power that they are receiving.

I am not anti-renewable and very excited about many of the developments that are taking place in our country. I know Governors from Senator Shaheen's area and Governors from Senator Wyden's area were very concerned that the bill that was before us didn't have those defined elements, and therefore, I added it in, which, again, is just current practice.

I wanted to ask the chairman, since you have had some choice comments about that in other settings, I wondered if you had some concern about your ability to implement current policy as it relates to that?

Mr. WELLINGHOFF. We have concern about the issue of precisely quantifying benefits because we have to be sure that—and I certainly agree with you that with respect to allocation of costs and transmission that we should, in fact, do that in a way that somehow fairly spreads the benefits and costs.

Senator CORKER. You mean fairly allocate when you say "spread?"

Mr. WELLINGHOFF. Yes.

Senator CORKER. That word concerns me. I assume you mean making sure that those who are receiving benefit pay for it. Is that what you are saying?

Mr. WELLINGHOFF. Yes, I am.

Senator CORKER. OK.

Mr. WELLINGHOFF. However, my concern, I guess, is precisely quantifying it, in that your problem is you can have benefits today

for one set of customers or one set of transmission customers or rate payers and those benefits will change next year because the nature of the grid will change. So the problem is it is a moving target. If we are required to precisely quantify it, at one point in time, we are going to be wrong.

So that is my main concern, I think, Senator, with your——

Senator CORKER. I thought you would say that, and I wanted you to know my amendment did not require you to be precise. As a matter of fact, it was current—the 7th Circuit had a ruling recently——

Mr. WELLINGHOFF. Right.

Senator CORKER [continuing]. That said you had, and they said we do not suggest the commission has to calculate benefits to the last penny. You seemed to like that because your response was that it leaves the door open for you to be able to analyze who benefits from that. Nothing about our amendment said it had to be precise.

As a matter of fact, I would say it is very much in keeping with the 7th Circuit ruling that you seem to support. So I just want to say that your responses to the 7th Circuit seemed to indicate you felt like you could, to a reasonable degree, determine whether people were benefiting from certain grid expenditures or not. Is that true?

Mr. WELLINGHOFF. Yes. That is correct. I did not read your amendment to be necessarily consistent with the 7th Circuit, and if you are indicating that it is, that is, I think, something that the 7th Circuit decision does provide us that flexibility, I think, because it does very specifically say that quantification of benefits does not have to be precise. It gives quite a range in that 7th Circuit decision.

Senator CORKER. I think what we would like to do, and the reason I am bringing this up—I know it is something that Senator Bingaman and I and others will be working on at some point before it goes to the floor. I think our concern is that having some grid going to some remote area in North Dakota, which is going to have no benefit for anybody up here, that we end up, our constituents end up paying for that. I think that is what we are trying to keep from happening.

Mr. WELLINGHOFF. Certainly.

Senator CORKER. What I would love to do is work with you to see if there is a way that we might end up with some language that would keep it that way. I don't want folks in Tennessee paying for some transmission grid to some mesa someplace that has no benefit.

I will say in closing. I know my time is up, and the chairman is always generous. There have been comments made by associates and folks who have been concerned about this amendment that we should know that, look, this benefits all of mankind, and everybody should pay for this.

I don't think that is an appropriate way of looking at reliability and economic benefit, and I just hope that you can work with us to form more closely if our amendment is not—if you can't work with that, I don't know why you couldn't because the 7th Circuit ruling that you applauded just said the same thing.

But I would love to work with you and Chairman Bingaman and others who might want to work on this to ensure that we don't spread these costs around to mankind, but that people actually are receiving a benefit pay for it.

Mr. WELLINGHOFF. Senator, I would be happy to do that. Thank you very much.

Senator CORKER. Great. Thank you.

The CHAIRMAN. Senator Udall.

Senator UDALL. Thank you, Mr. Chairman.

Welcome again. Let me start, Chairman Wellinghoff, with you and build some specificity into the line of questioning that Senator Corker just directed your way.

Cost structures for storage activities—are there any other cost structures that you think should be considered that would provide storage facilities with compensation for all or at least several of the different values they add to the grid?

Mr. WELLINGHOFF. Senator Udall, primarily in my testimony, I was referring to cost compensation in organized wholesale markets. There certainly needs to be some type of cost structures that would primarily be in the purview of State regulatory commissions in those areas where we don't have organized wholesale markets with respect to those utilities in those jurisdictions incorporating storage into their operations.

So that would be something that individual utilities and State commissions would have to work through as to how to recover costs for those storage investments, whether it be through expensing or rate basing those costs. But it would, again, primarily be within the purview of the State jurisdictions.

Senator UDALL. Thank you for that insight.

I wanted to pursue this line of questioning. As I understand, interruptions to our power systems cost us about $80 billion annually. They don't have to last for a very long time. Two-thirds of the losses come from interruptions that are less than 5 minutes. That is astounding to me, and this seems to be a real opportunity for storage because storage can help reduce those outages, increases productivity, and saves consumers money because those replacement electrons are very, very expensive.

Could each of you talk about the source of those outages and to what extent storage could help alleviate them? Let me start with you, Chairman.

Mr. WELLINGHOFF. My understanding is that the large majority of those outages—and I don't have a specific percentage figure, but it is probably much higher than 50 percent. It may be as high as 80 percent of those outages are at the distribution level.

So to the extent that we can incorporate in storage and other distributed resources at the distribution level—distributed generation, photovoltaics, et cetera—and certainly storage, we can probably reduce substantially the amount of those outages. But again, those are going to be primarily within the purview of State commissions to work with State utilities at the distribution level to build up those systems, make those grids at the distribution level smarter and also more responsive with incorporating storage.

Mr. KOONIN. I am not enough of an expert to comment on the source of the grid outages, but I can just note that extreme distrib-

uted storage at the household level, for example, at current battery costs seems quite feasible. At $500 a kilowatt hour for batteries, as we have with lithium ion batteries, for example, you could easily store 10 kilowatt hours in a house and use that to handle outages as long as 10 or 20 hours.

So I think uninterruptible power supply seems perfectively feasible if outages became a significant problem.

Senator UDALL. Would you foresee a future where utilities, other power providers would help consumers actually put those batteries onsite because of the advantage you just referred to?

Mr. KOONIN. I think if outages became a significant problem, you could imagine broad programs to do that. Again, the plug-in hybrid battery, say, of order of 17 kilowatt hours or so, 10 kilowatt hours, would be such a device that you could use in an emergency when the outage occurred.

Senator UDALL. Chairman Wellinghoff, let me turn back to you in the remaining time I have. In my initial remarks, I mentioned I had been surprised in some of the briefings that I have held to find that although that—and I should clarify what I said earlier, technology still has a long ways to go, that some of the challenges in the regulatory space are almost equal to those in the technological space.

Is there anything else FERC can do? More hearings or reports to help us identify these regulatory barriers and identify solutions along with them?

Mr. WELLINGHOFF. We do have the opportunity to hold technical conferences, which we do periodically. We have had a number of them and would continue to do so. We are continually looking at what we need to do in these organized wholesale markets to change tariffs and to change rules, market rules in ways that will provide a level playing field for these kinds of technologies because, traditionally, these markets have been set up for central generation.

What we want to do is ensure that those markets give equal consideration to and, in fact, higher consideration to more valuable services like storage. So one thing is certainly holding the technical conference, which we have done in the past, with respect to storage specifically. But we want to continue to do this and want to continue to do everything we can to help integrate storage into the grid.

Senator UDALL. I would urge you to do so. I wonder if there wouldn't be a day where we, as we now today talk about generation, transmission, and distribution, GTD, that "S" for "storage" would not be on a level playing field as we consider the opportunity there. Or whether it would be generation-storage, distribution-storage, transmission-storage as how we think about them and then how we manage and how we——

Mr. WELLINGHOFF. The storage does have a role to play in all of those aspects.

Senator UDALL. In all of those.

Mr. WELLINGHOFF. That is true.

Senator UDALL. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Senator Shaheen.

Senator SHAHEEN. Thank you, Mr. Chairman. Thank you for holding this hearing.

My view is that as we think about our energy future, one of the areas that has not gotten as much attention as it should is the area of energy efficiency, and obviously, storage is a big part of that. If we look at what is the fastest, cheapest way to deal with our energy future, it is obviously energy efficiency and conservation and energy storage, as you all point out.

I think this is a question for you, Mr. Koonin. Can you tell us how—what other countries are doing in the development of energy storage technologies and how we currently rank compared to other countries in this area?

Mr. KOONIN. We are, I think, certainly the leader in storage concepts among the nations. You see a large deployment in other countries of pumped hydro, but if you look at some of the more advanced concepts, this country is significantly ahead. The Recovery Act, which I referred to before, the funding has helped significantly in mounting those demonstrations. For example, in compressed air storage, the projects that we have defined will double the world's capacity and experience in compressed air storage.

China, one naturally looks to these days as a sense of what the rest of the world is doing. They have a $100 million storage effort that is focused on both research and deployment, largely on flow batteries, and there is a potential there, I think, for an interesting collaboration with the Chinese on that technology.

Other countries not so active in the advanced concepts. So we are, with the stimulus money, significantly ahead of other folks.

Senator SHAHEEN. What about Europe? You didn't mention Europe.

Mr. KOONIN. A lot of pumped hydro in Europe right now. Some experience with flow batteries and other technologies, but I think we are pushing harder than the Europeans.

Senator SHAHEEN. You talked about the jumpstart that the Recovery Act has given to some of those initiatives. Is there more that we ought to be doing? I appreciated the exchange with Senator Wyden because I think having a plan is always the beginning of anything that we ought to be doing.

But are there other things that we should do as a Congress and as an administration to incentivize these new technologies and encourage their development?

Mr. KOONIN. Again, I would distinguish between research and deployment. I think deployment is, in the end, where it happens, and that very much depends upon how Congress sets the playing field or the incentives that we were talking about.

You could imagine—I will invent. I know little about regulation. But you could imagine an extra credit for putting energy that has been stored for some period of time into the grid rather than simply giving tax credits for the capital. Again, you would have to define that carefully to make sure you got the results you wanted. But you could imagine something like that.

On the research side, I would like to see more invested in the basic material science. So much of what we need to do in energy not only for electrical storage, but many other things has got to do with materials, our ability to characterize, synthesize, predict the

properties of materials has grown greatly. There are so many materials to explore out there. I would like to see us doing more of that as well.

Senator SHAHEEN. Thank you.

Apropos your mentioning regulations, Chairman Wellinghoff, as we are thinking about a new grid and upgrading the Nation's grid, one of the concerns that I have had, and I think many of us in the Northeast have had, is that we are looking at the potential for building a new grid or upgrading our current grid in a way that could bring us solar and wind energy from the West and that that will have a negative impact on the potential perhaps to develop some of those resources, new energy resources in the Northeast—offshore wind, other issues.

What should we be thinking about as we are thinking about upgrading our grid? Also, how do we look at the potential for distributed energy, and does it make sense, if that is our future, to develop a whole new transmission grid that is not going to address that?

Mr. WELLINGHOFF. Senator, I think we ultimately need to look again at sort of like what I was talking to Senator Corker about costs and benefits. Certainly, there may be substantial benefits to the local economy by developing distributed resources and developing local renewable resources, and I think the States and the regions certainly should take that as a priority.

But ultimately, what is going to get developed is where the capital flows. So I think the markets are ultimately going to decide between and among the various resource options. So what we need to do is make sure that we get the markets right, that we incorporate into the markets things like the price of carbon and other things that will ensure that, as those markets are structured, they can produce the policies, both the State and the national policies that we need to achieve our goals.

Senator SHAHEEN. Could I follow up on this, Mr. Chairman?

I appreciate that. On the other hand, the fact that the Government invested significantly in the Tennessee Valley Authority probably has a lot to do with the fact that Senator Corker is concerned about maintaining their low energy prices. The fact that we don't have a similar project in the Northeast means that we have some of the highest energy prices in the country.

So, Government regulatory policy is obviously going to have a major impact on what happens in those markets.

Mr. WELLINGHOFF. Right.

Senator SHAHEEN [continuing]. If what we do is to have a Government policy that says we are going to build a new transmission grid that is going to ignore storage or ignore distributed generation or ignore where those potential renewable energy sources are coming from, doesn't that put in place the potential to create a market that is going to have a different impact than if we did something different with our Government policy?

Mr. WELLINGHOFF. That is why I think we need to look at it from an analysis of cost and benefits. I saw a study yesterday from the National Renewable Energy Lab called EWITS that was an eastern interconnect-wide study looking at 20 percent wind, four different scenarios.

One scenario was to take most of the wind out of the Midwest and deliver it to the Northeast. The other scenario was to take a lot of offshore wind and deliver it to the Northeast. The cheapest scenario was to take the Midwest wind and deliver it to the Northeast.

So, again, I mean, people in the States need to decide do they want lower rates for their consumers, or do they want more local development of renewable resources? I don't think these decisions will be ones that will be made by the Federal Government because, right now, ultimately investments in transmission are made by the private sector.

So the private sector is the one who, through the markets, is going to decide what are the most appropriate investments to make. I don't know of anyone right now who is suggesting that there should be massive amounts of Federal money going into build transmission lines throughout the country. The money, as I understand it, will be coming from the private sector, and the markets will drive where that money goes.

Senator SHAHEEN. Thank you. My time is up.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much.

We have a second panel of expert witnesses which I would go ahead to unless—Senator Udall, did you have another question?

Senator UDALL. Mr. Chairman, if I might? No, I would like to get to the second panel, but I would like to submit a question for the record to Chairman Wellinghoff that focuses on independent system operators and regional transmission organizations. If I could do that?

The CHAIRMAN. That would be fine. Sure.

Senator UDALL. Thank you.

The CHAIRMAN. Thank you both very much for your testimony. It has been very informative, and we appreciate it.

Let me call the second panel forward. The second panel, let me introduce three of the members, and then Senator Udall wanted to make one of the introductions on this panel.

Dr. Ralph Masiello, who is senior vice president for energy systems consulting with KEMA, Inc., in Chalfont, Pennsylvania.

Mr. Kenneth Huber, who is senior technology and education principal with PJM Interconnection in Valley Forge, Pennsylvania.

Mr. Elliot Mainzer, who is executive vice president with corporate strategy in Bonneville Power Administration in Portland, Oregon.

Thank you all for being here. Dr. McGrath—I believe, Senator Udall, you wish to make an introduction of Dr. McGrath?

Senator UDALL. I do. Thank you, Mr. Chairman.

I am pleased to introduce Dr. McGrath of the National Renewable Energy Laboratory in my home State, located in Golden, Colorado. It is NREL. That is a real treasure, and I have always appreciated both the hard work they do and the Department of Energy's support of their work.

My understanding is that Dr. McGrath, here under the auspices of NREL, will expand upon an intriguing aspect of energy storage technologies, the role that they can play in facilitating the integration of renewable energy into the electric grid.

Thank you, Dr. McGrath, for making the long trip here to Washington, DC.

Thank you, Mr. Chairman, for bringing everybody on this panel here.

The CHAIRMAN. Thank you all for being here, and why don't we just start with you, Dr. Masiello? Is that the right pronunciation?

Mr. MASIELLO. That is fine. Yes, sir.

The CHAIRMAN. Go ahead and tell me the right—why don't you tell us the right pronunciation, and we will try to——

Mr. MASIELLO. Masiello is exactly correct.

The CHAIRMAN. Masiello.

Mr. MASIELLO. Yes, thank you.

The CHAIRMAN. Masiello. OK, thank you for being here, and please go right ahead. If each of you could take 5 or 6 minutes and give us the main points we need to understand, we will include your full statements in the record.

STATEMENT OF RALPH D. MASIELLO, SENIOR VICE PRESIDENT, ENERGY SYSTEMS CONSULTING, KEMA, INC

Dr. MASIELLO. Good. Mr. Chairman, Senator Murkowski, Senator Udall, thanks very much for the opportunity to contribute today. I hope I can shed some light.

Rather than repeat the comments of the commissioner and the Under Secretary, let me offer a few data points and then some thoughts on policy.

We are concluding a study for the California Energy Commission and the California ISO on the question of what happens at 20 and 30 percent renewables and how can storage be used? Confirming comments we heard earlier, 20 percent is manageable with today's engineering apparently, although the amount of ancillary services, meaning regulation, reserves, and so on, that would have to be procured by the market operator could double or triple with attendant impact, of course, on costs and emissions.

Thirty percent becomes much less manageable due to the characteristics of when the solar energy disappears in the late afternoon and when the wind energy picks up. Storage is maybe twice as effective as conventional generation at mitigating this. In fact, we concluded that a fast battery is two to three times as effective as a combustion turbine for purposes of regulation and ramping.

A second kind of highly technical point about a high renewable penetration that is, I think, just on the radar screen, most renewables are inverter based, meaning the power is produced by the wind mill. It goes through power electronics and an AC-to-DC-to-AC conversion as opposed to conventional generation that has a rotating AC generator.

At high renewables, 30 percent annual target could mean 50 percent at a given moment. The amount of rotating inertia in the system and the Governor response, the autonomous response of the generators to system frequency is down by half. If that statement held true, we lost half the inertia, it would mean that the transient stability planning that is done for the transmission grid in the interconnection has to be done over, and the stability is decreased.

I bring it up because fast storage offers the potential to use power electronics to perform a synthetic form of inertia and Gov-

ernor response and neatly avoid this problem. Of course, if the storage is used in conjunction with renewables, it is almost a free benefit from an infrastructure standpoint.

An alternative to managing renewables' variability and ramping, of course, is demand response. Smart grid certainly offers us the opportunity for increased demand response, consumer price response. I would like to suggest, however, that 30 percent demand response at 6 p.m. will not prove popular, and storage is a good way to avoid this.

Coming to the subject of distribution reliability, American Electric Power Corporation has a brilliant concept and, in fact, will be doing a DOE demonstration project called Community Storage. The really clever thing in their concept is to take used batteries out of electric vehicles as these become available, reconfigure them, and deploy them at distribution transformers, protecting the reliability of a small cluster of homes. They believe that with this, they can dramatically improve distribution reliability.

Finally, storage offers the opportunity to reduce emissions and provide benefits instead of backup power generation. Brad Roberts, the chairman of the Energy Storage Association, who is here today, would tell you that in their data center business, they are starting to deploy large batteries as backup power for 50-and 90-megawatt data centers. This avoids the need to store diesel, to run generation, avoids the emissions, and the batteries can be used for peak shaving.

If I might, I would like to throw out a couple of additional policy points for consideration. The efficiency of the storage system, how much energy is lost charging the battery and discharging, or whatever other storage medium is there, is very important, especially when you look at daily use with renewables or ancillary services. Efficiency of 70 percent in a storage system sounds good, but that means 30 percent of the renewables are lost and end up as heat in the storage system.

So if incentives over time or DOE research could be directed to improve the efficiency, this could be something to think about.

Second, we frequently get asked by manufacturers and developers to test storage technologies in our labs. There are IEC and IEEE standards for batteries, for instance, but these are aimed at laptop computers, power electronics, power tools. Standards don't exist yet for the physical performance of grid-scale connected storage. This will become important down the road if utilities are to procure it, to be able to specify it and know that their specifications have been complied with.

Another policy issue that will be in the way of deployment of storage, there are not accepted planning methodologies that utilities can use to determine how much to put where. Absent that, regulators can't approve the investments as being prudent, whether it is transmission or distribution.

If we had a date, say, by 2011, where we could say new transmissions proposed should demonstrate that the use of storage was considered in the design and the economics of the transmission, this would stimulate awareness, interest. It would stimulate the small software companies that support that capability for utilities to develop the capability.

So those are my comments. Thank you again for the opportunity.
[The prepared statement of Mr. Masiello follows:]

PREPARED STATEMENT OF RALPH D. MASIELLO, SENIOR VICE PRESIDENT, ENERGY SYSTEMS CONSULTING, KEMA, INC.

Chairman Bingaman, Senator Murkowski, and members of the Committee, thank you for the opportunity to participate in today's hearing on the role of grid-scale energy storage in meeting energy and climate goals. My name is Ralph Masiello. I am senior vice president of energy systems consulting at KEMA and I am responsible for innovation management within the company. I have been engaged in a number of energy storage related activities while at KEMA including serving on the U.S. Department of Energy "Energy Advisory Committee" and the Smart Grid and Storage subcommittees.

KEMA is an independent, global provider of business and technical consulting, operational support, measurement and inspection, and testing and certification for the energy and utility industry. We have over 1,400 professionals worldwide with 600 in the United States. KEMA, Inc. serves energy clients throughout the Americas and Caribbean. We have offices in 13 states, including Arizona, Michigan, North Carolina, and Oregon, and operate the only independent high voltage power apparatus testing lab in the United States.

KEMA has been actively engaged in projects across the energy storage value chain, ranging from technology development and evaluation to the advancement of large-scale storage applications. KEMA has worked to expand understanding of energy storage capabilities by developing analytic tools needed to plan for its use. We have been performing storage consulting and testing activities for manufacturers, developers, utilities, and the U.S. Army and the U.S. Navy via NATO for some time. While we are generally true believers in the many benefits that storage can bring to the electric power industry, we have no vested interest in any particular technologies or solutions.

Today, I will provide a brief overview of what storage is and how it relates to the electricity industry, including potential benefits of storage and current barriers. First, I will discuss storage's role in the electricity system. Then, I will provide an overview of storage technologies and applications. Finally, I will briefly discuss policy issues to consider regarding storage.

ENERGY AND STORAGE—WHAT IT IS AND WHERE WE ARE

At the turn of the 20th century, early electric power developers used batteries as part of the electricity generation and delivery infrastructure. However, batteries were quickly surpassed by other generation, transmission, and distribution technologies. For the past 100 years, electricity has been the only major commodity that is not stored anywhere in the value chain. As such, the electricity industry has been operating under a just-in-time delivery system, where power is produced on demand as energy consumers need it and where all that is produced is delivered. To maintain operations, grid operators must balance generation to match load in real-time.

The lack of storage in the electricity industry has led to relatively low capacity utilization throughout the production and delivery of electricity—capacity is built and maintained to support peak needs with adequate reserves against contingencies. Overall utilization may be as low as 30% for some parts of the system. In the case of production, peaking resources are often the most expensive and their use just a few hours a year leads to very high spot prices of electric power in the wholesale markets. Were we able to store electricity effectively, this expensive model of planning and operation could be much more efficient.

In addition to improving system efficiency, storage could help address grid management challenges stemming from the integration of variable resources. Unlike traditional fuelbased generation, many renewable resources are variable over time and are not easily controlled. With relatively small amounts of variable generation, load has been the main source of variability. However, as renewable penetration increases, grid operators will need to account for larger variability in supply. The current system has a certain degree of flexibility which it uses to balance demand and supply in real-time. Additional sources would help the system absorb increasing amounts of renewables. Storage, in particular, is one potential source of flexibility that acts as a bridge, buffer, and reliability component.

STORAGE FUTURE: CHANGING THE GAME

Renewables Resources

The industry is beginning to conclude that some increase in the use of ancillary services will be necessary to integrate renewable resources. Pacific Northwest National Labs, KEMA, and others have conducted studies on the impact of high levels of renewables on system operations and the results more or less agree on this point. While ancillary services traditionally have been provided by fossil-based generation, new sources are beginning to contribute. According to the results of a recent KEMA study with the California Independent System Operator (CAISO), a fast battery is two to three times as effective as a combustion turbine at providing regulation and ramping services. In addition, even where traditional generation sources are used for ancillary services, storage appears to be beneficial. Virtual power plants which integrate storage and production could supply ancillary services more efficiently. This enables a plant to supply regulation or reserves even while running near peak output.

Smart grid also offers ways to manage the demand side of the equation—whether by demand response programs controlled by the grid operator or via dynamic pricing schemes that induce consumer behavioral change or both. Though they are valuable resources, it is likely that demand response and dynamic pricing will not suffice at certain renewable penetration levels.

Storage can offer additional benefits for renewable generation beyond integration. With storage, producers of renewable energy could time-shift production from periods of low demand to higher demand when it is more valuable to the producer. Also, storage allows remote (and often renewable) resources to escape curtailments due to transmission congestion with the attendant cost exposure. Financially, the benefits of storage may be considerable in such applications. Today, storage is already proving itself economical for some of these applications in market environments, to the extent that the markets are correctly valuing the services. It is therefore likely to be economic in regulated environments as well. Nevertheless, due to high upfront costs, the challenge of investing in storage can compound existing challenges for renewable investment.

Storage and Emissions

Overall, the potential of storage to improve system efficiency and to facilitate renewables integration means that it can significantly reduce emissions as compared to ancillary provision from fossil generation. As noted earlier, storage's ability to quickly absorb the variable output of renewable generation makes it a strong integration tool for renewables. By any means, storage is able to provide a service—storing and dispatching energy—with fewer emissions than any comparable generation device. Examples of these savings are seen in the one of the more prominent applications of storage today, frequency regulation. A study by KEMA has shown that when replacing traditional fossil-fuel generation, storage technologies such as flywheels and fast-response storage systems can greatly reduce carbon dioxide emissions compared to the incumbent technologies.

Storage could feasibly reduce emissions associated with backup generation as well. KEMA recently performed a study for the California Energy Commission in which it was determined that 3,800 MW of backup generation, if replaced by battery storage, would result in reduction of the annual emissions attributable to backup generation of as much as 40%. Here, emissions associated with the backup generation of non-residential customers outweigh those associated with the grid-based portfolio powering replacement batteries.

While it is becoming clear that storage can offer reductions in emissions associated with the electricity system, further research is needed to better define potential reductions across the host of storage applications. Such reductions are likely to be specific to the region and the storage technology, as emissions associated with storage depend on the portfolio of generation used to power it and on the efficiency of the technology.

STORAGE TECHNOLOGIES AND APPLICATIONS

Storage Characteristics

Many electric storage technologies are available today and more are forthcoming. Advanced lead-acid batteries, large format Lithium Ion, and grid-scale Sodium Sulfur batteries are all commercially available. There are many more emerging battery technologies from numerous established and start-up manufacturers around the country. DOE has awarded R&D Energy Frontier Research Centers funding and smart grid demonstration funding to a number of these.

No single storage technology fits every application and technologies have varying capabilities. However, advancements in storage technology are resulting in characteristics that increase the applicability of storage as a whole. These include:

- Fast Response: For regulation and some other ancillary services as well as transmission reliability applications, the storage device must be able to respond to control signals and change its charge / discharge power level near instantaneously; some technologies easily support this.
- Cycle durability: Some technologies can provide multi-thousand range cycles, allowing them to be used for longer periods of time in applications that require frequent use.
- Duration: In some applications, storage devices must be able to sustain full charging or discharging power levels for 2 to 6 hours. Shifting the diurnal production cycles of wind production typically requires durations in this range, for instance.
- Transportability: Where devices are somewhat mobile, the range of possible applications increases and re-use becomes more feasible. Substation batteries used for reliability and peak load management can be moved once station capacity expansion is justified and re-used at another substation, for instance.
- Scalability: The ability of a technology to maintain its characteristics regardless of size makes designing its use more flexible.

As storage technology evolves, storage will likely have many applications. Each technology will likely have its own niche depending on which combination of the above characteristics define the device. Performance and cost ultimately determine which type of storage is right for which applications.

Application Areas for Advanced Electricity Storage

In addition to the generation-related applications of storage noted above, electricity storage can provide value at the transmission, distribution, and end-use levels of the electricity system. Currently, developers and utilities are aggressively pursuing storage for ancillary services provision, localized transmission reliability, and community or utility-side backup reliability as well as more traditional backup power applications.

Distribution

In many parts of the United States, distribution reliability is such that consumers can expect to be without power an hour or more each year—this significantly lags behind other countries, including Japan and most of Europe. It is more than an inconvenience for someone working at home and leads to consumers acquiring backup generators. Storage, however, is a tool that could help improve reliability. In particular, at the substation, storage can provide local ride-through if sub-transmission failures limit service to the station. Substation-based storage could also provide contingency coverage in the event of transformer failures at peak load. This allows deferral of transformer upgrade or replacement and avoids load curtailment.

On the feeder, storage can provide the same benefit at either primary or secondary voltage—providing power to customers that would be without service as a result of a feeder outage. This can be a tremendous benefit, given that distribution feeder outages are the greatest source of power outages. System average interruption duration index (SAIDI) can be reduced dramatically by community energy storage system. Storage out on the feeder can also be a way to temporally provide extra capacity during load roll-over to alternate feeder configurations—a way of enhancing reliability or deferring expansion.

The Community Storage concept as envisioned by AEP, a national electricity generator and transmission system owner, would re-use electric vehicle batteries (or other technologies) to provide one or two hours of service to homes clustered around each distribution transformer. This potentially has favorable impacts on the cost of ownership of electric vehicles and is of interest to the automotive community as well.

Transmission

Congestion relief, stability enhancement and capital deferral are some of the benefits storage can offer the transmission system. Storage can relieve congestion by timeshifting the energy in location as well—taking production off peak and storing it near the load center—downstream of the congestion point instead of at the generator. In market environments, congestion costs are applied in principle to the entire load in the congested zones or nodes. In this case, the benefit of storage can be leveraged several times the value of the direct megawatt shifted.

When the peak load in the congested area exceeds the production available plus the production transmitted in, storage can serve as a way to meet peak load and

thus can be a means to defer transmission expansion. (Generation expansion in many congested areas is impractical for siting reasons as congestion points typically occur in dense, urban areas).

The congestion problem will usually show up first as a contingency limit, not a direct lack of transmission capacity. Storage is a way to mitigate these contingency limits, with the fast storage picking up the load before the generation can be started. Furthermore, it is especially cost effective, as it avoids having to build transmission to provide redundancy, and it provides emission benefits, as it allows the use of downstream, uneconomic resources only after a contingency has occurred.

Finally, in some specialized problem areas, where stability concerns impose transfer limits that are more restrictive than the inherent transmission capacity limits, fast storage can be used as a stability enhancement device to relieve these stability constraints. The value of this in a particular instance is potentially very great and this application is worthy of serious engineering analysis and study.

End User

When storage is a more economical way to provide ancillaries, it reduces costs for everyone in the market. If enough storage is present to affect the clearing price, it reduces the price for all suppliers of the particular product. Similarly, by time-shifting lower cost generation to peak periods, it reduces the need for expensive peaking generation and reduces peak power prices. When storage reduces congestion this is inherently a market benefit.

The ability of storage to perform in certain applications is not limited to utility-scale devices. Generally, electricity storage is unique in the ease with which the technologies can be scaled. Whether the device is packaged as a kilowatt-scale application or a megawatt-scale application, the performance characteristics of the device can stay the same. For example, the same batteries that are being used in utility-scale megawatt devices are being used in today's electric vehicles.

POLICY ISSUES AND ACTIONS FOR CONSIDERATION

Beyond the technical and economic hurdles that a new technology in a new application has to overcome, there are a number of storage-specific policy issues worth considering. As storage becomes more versatile and commercially available, fitting storage into the existing policy framework becomes more challenging. For example, how best to classify storage, as a regulated or unregulated asset, is a primary concern as the classification can determine how to allocate costs and benefits. In addition, state utility commissions have to determine appropriate depreciation schedules and prudent expenditures for regulated distribution assets. The difficulty lies in the fact that a single device can serve multiple functions, and may at times play the roles of a regulated asset and an unregulated one.

Classifying the Type of Application

As noted above, storage can be used for many applications throughout the value chain—from generation to transmission and distribution to end-use. As such, a single storage asset can play the roles of what are currently distinct regulated and unregulated assets. Specifying the rules of engagement, in part to allocate costs and revenues, must therefore account for function as well as ownership. The example below discusses a case where transmission-based storage can serve multiple purposes.

Example: Transmission Storage—Multiple Services

When storage is used for transmission congestion relief by shifting energy in both time (off peak to peak) and location (remote to congested zone near the load), the storage increases the energy's value by both displacements. In essence, storage sets the marginal energy clearing price. If the storage is financed and operated as a purely merchant asset then the pricing, revenue sources, and cost allocations are clear. In this case, the primary regulatory concern would be whether the storage has undue pricing power or market concentration and must be subject to the same treatment as a "reliability must run" (RMR) unit.

If the storage asset is proposed as a transmission asset with a regulatory rate of return to the transmission owner then the question of the allocation of the profits from time and location shifting are very real. In effect it is allowing the transmission owner a share of the congestion rents that the storage device can garner. This is familiar ground to the industry; the new wrinkle here is that the storage device could also easily access ancillary markets as well as congestion. Storage deployed to relieve congestion is almost a perfect merchant transmission asset. There are no questions of loop flows or free rider usage. If the congestion relief economi-

cally justifies storage then the best regulatory role might be to provide some level of incentives or guarantees rather than to construct it as a regulatory asset.

However, the conundrum is that the most advantageous solution overall may be a level of storage deployment that reduces congestion costs to the level needed to justify the storage investment and no more. Whether market entrants will deploy the last increments of storage against diminishing returns is always unclear. If storage capital costs are on a decreasing curve it could be expected that new entrants might drive out existing facilities as is normal with high technology assets. That argues that merchant investors will want faster economic depreciation recovery rather than standards imposed by regulators. What is clear is that large-scale storage offers the first real opportunity for a kind of merchant transmission in a way that is environmentally and economically benign—and that we need the right regulatory and market solutions to facilitate it and not create a new form of regulated monopoly.

Some have argued that time shifting or locational storage uses more environmentally unfriendly resources; it is also as likely that storage fills in for intermittent renewable supplies. An interesting study would examine these empirical tradeoffs. Because gridscale storage will involve utility interconnection requests and technical requirements, these aspects have to be monitored carefully—and may prohibit the co-existence of regulatory and merchant assets in the same congestion zone. Another interesting corollary is the value of additional transmission when new renewable generation resources in addition to storage are sited. Does storage compete directly with transmission or is it the combination of renewables and storage that may obviate transmission benefits? Have we skirted the issue of benefits allocations through transmission upgrades or merely postponed it?

Is there an Industry Precedent?

The gas transmission industry offers one precedent which would not necessarily be attractive to today's merchant storage entrepreneurs. The storage asset is a regulated asset which earns a regulated rate of return based on a tariff for gas stored. The energy shipper/trader that contracts to use the storage pays a reservation fee and a storage fee based on usage with penalties for over or under scheduling; the time arbitrage gains on the stored gas are the profit or loss for the shipper/trader. This model neatly separates the questions raised by asset classification raised above. However, in this model it is not clear what the electricity industry economics would be for the storage investor. And as noted, the merchant electric storage operators today would find this discouraging.

One aspect of the natural gas industry which bears examination relative to electricity storage is the use of storage as part of transportation to meet just in time delivery needs. Independent marketers have more efficiently used both storage and pipeline capacity to deliver fuel to generators. Storage operators and transmission purchases can be bundled with energy to provide load. For the gas industry, this has contributed to price volatility as weather or outages have put pressure on local gas prices.

Other Barriers

The biggest challenge that faces adoption and deployment of storage is lack of routine methodologies about how to incorporate storage into system planning and operations. At the transmission level, this is largely within FERC's purview. At the distribution level, it is a matter for the states, of course.

NIST is developing standards for the interconnection of storage with the grid and its smart grid interoperability. KEMA assisted the ISO RTO Council in preparing the draft wholesale standards for storage this fall. Beyond these standards, we need standards developed for the description of storage in terms of efficiency, performance, life cycles, and the like. Manufacturers are asking us to test their new products in our laboratories in Pennsylvania and in Europe; most storage testing standards have been developed for electronic devices, back up power, and the like—and not for grid connected storage.

Tools to incentivize storage devices must be considered carefully. An Investment Tax Credit for storage, for example, likely has limited incentive for merchant developers and start ups as they cannot exploit these themselves because they have little or no income to offset. Rather, they arrange sale-leaseback with financial institutions that can utilize the tax credits. The number of financial institutions interested in these arrangements, however, is somewhat reduced right now. Loan guarantees might be a more effective tool for such markets.

Careful consideration of how to allocate the emissions benefits of storage is also important. Right now, when a regulated utility's storage investment leads to emission improvements, the credit will flow to the power production sector. Attribution

of reliability improvements is also complicated, but would serve to help spur reliabilityrelated storage investments.

CONCLUSION

The electricity grid is in the midst of historic transformation—modernizing its technologies and changing its generation mix to include a larger percentage of renewable resources. In the meantime, KEMA has observed that advanced electricity storage technologies have drawn attention from utilities, developers, governmental agencies, and consumers across the globe. Additional factors, such as the rapid growth in renewable generation investments and the increasing penetration of electric vehicles and plug-in hybrid electric vehicles, have increased the need for information that can help individuals navigate the wave of attention being placed on storage to address grid-related changes.

In the long-term, the implications of widespread, mass deployment of electricity storage across the power system are profound. It holds promise of dramatically increasing capacity utilizations of the generation and transmission and distribution system—essentially enabling a deferral of capital spending. Storage also can help significantly improve reliability, especially at the distribution level.

KEMA is heavily involved in expanding the understanding and capabilities of storage technologies by grid simulation. Through our studies on the business of storage and electrical vehicle integration in the grid, our knowledge of storage technology and its potential, our testing facilities for small-scale storage systems like batteries, our Flexible Power Grid Laboratory for grid integration of storage systems, and our knowledge of safety, environmental and customer aspects—we have been involved in formulating the key questions around the economy and efficacy of storage, and in developing the analytical and economic tools necessary to plan for its use. The level of industry interest in electricity storage is increasing very rapidly, and the policy sector is taking up the need for and design of incentive and regulatory structures for storage development.

Thank you for the opportunity to present electricity storage. I appreciate the Committee's interest in this topic and I look forward to answering your questions.

The CHAIRMAN. Thank you very much for your testimony.

Mr. McGrath.

STATEMENT OF ROBERT MCGRATH, DEPUTY LABORATORY DIRECTOR, SCIENCE AND TECHNOLOGY, NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN, CO

Mr. MCGRATH. Senator Bingaman, Senator Murkowski, Senator Udall, thank you for the opportunity to discuss how grid-scale energy storage can help achieve U.S. energy and climate goals by enabling extensive and cost-effective deployment of large amounts of renewable electricity generation.

I am fortunate to serve as the Deputy Laboratory Director for the National Renewable Energy Laboratory, the Department of Energy's primary laboratory for research and development on renewable energy and energy efficiency technologies. Addressing today's topic, earlier this year, the IEEE, in its national energy policy recommendations, emphatically stated that if wind and solar are to reach their full potential to contribute to the Nation's power requirements, the technology for large-scale energy storage must be developed and deployed.

For our electric grid, utility-scale storage not only can help increase penetration of renewable energy from variable sources, such as wind and solar, it can also enable renewable technologies to replace fossil-fueled base power loads, enhance the stability, reliability, and power quality of the electric grid, and optimize the performance of an electric modernized infrastructure.

At my laboratory, NREL, our researchers led for the Department of Energy a definitive examination of the potential for wind generation. Entitled "Twenty Percent Wind Energy by 2030," that study

showed that with ample grid capacity, wind penetration to 20 percent of U.S. electrical generation is feasible even without additional large-scale storage.

This study was addressing I think Senator Wyden's concern around a wait and see attitude. The study was aimed specifically at trying to understand what can we do immediately to advance wind energy penetration into the grid?

NREL analysts have also examined the impact of solar photovoltaics at high penetration. Those studies found that photovoltaic-generated electricity become increasingly difficult to manage beyond 20 percent penetration without substantial changes in the grid, including storage. Consequently, as higher penetrations of wind and solar find their way onto the grid, the availability of cost-effective energy storage systems become more and more important.

From a grid planning and operational perspective, renewable generation, transmission, and storage are inextricably intertwined. Given that complex coupling, as Dr. Koonin mentioned, we need improved analysis tools and forward-thinking policies to optimize investments needed to modernize and expand the electric grid. These tools would serve as assets for utilities, energy planners, and policymakers, helping them with decisions on how much, when, and in what mix grid-scale energy storage technologies should be deployed.

As wind power becomes more ubiquitous, it is likely, as we have heard earlier this morning, that the first storage technologies to be expanded will be compressed air and pumped hydro. Nonetheless, continued research and development efforts to improve flow batteries, superconductors, thermal storage, and hydrogen storage will make those options more cost competitive as well.

There are opportunities for improved science in nanostructured materials, proton exchange membranes, and chemistries to develop longer lived, higher capacity, and lower cost electrochemical batteries.

NREL and others are also looking at harnessing renewable electricity generation to meet the Nation's massive transportation needs. By combining an electric vehicle fleet with storage-backed renewable electricity, we can potentially tap the vast resources of wind and solar to support low-carbon, if not carbon-free, transportation.

Today, R&D efforts around energy storage are limited. Pacific Northwest Laboratories, Sandia National Laboratories, Oak Ridge Laboratories, and others are supporting DOE's current storage program. At my laboratory, NREL, our new Energy Systems Integration Facility, scheduled for completion in 2012, will be dedicated exclusively to addressing the integration of renewable energy sources with distribution, storage, energy efficiency, and transportation.

In summary, starting from a very modest space of only 4 percent renewable generation, the current electricity system can absorb much greater quantities of renewable power without large new energy storage. However, research and development is needed now if we are to have cost-effective storage solutions that aid at optimizing deployment of renewable sources required for a clean and secure energy future.

Thank you for this opportunity to address the committee this morning.

[The prepared statement of Mr. McGrath follows:]

PREPARED STATEMENT OF ROBERT MCGRATH, DEPUTY LABORATORY DIRECTOR, SCIENCE AND TECHNOLOGY, NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN, CO

Mr. Chairman, members of the Committee, thank you for this opportunity to discuss the role that energy storage can play in meeting our nation's future energy needs, and in reducing carbon emissions through greatly expanded use of clean, domestic renewable energy resources. I am Robert McGrath, deputy director of the National Renewable Energy Laboratory (NREL), the Department of Energy's primary laboratory for research and development of renewable energy and energy efficiency technologies.

At NREL, our mission is clear. We provide research, development and support deployment to enhance our nation's energy security and reduce greenhouse gas emissions, through large-scale production of electrical power from renewable sources, through utilization of biofuels to replace fossil-based transportation fuels, and through improved energy efficiency in building, transportation and industrial processes.

Currently, electricity generation accounts for approximately 40% of U.S. primary energy resource consumption. According to the U.S. Environmental Protection Agency, electrical generation also produces about one-third (34.2%) of our nation's CO2 emissions, roughly 2.5 billion metric tons per year (2,445 MMTons/yr)[1].

Consequently, increasing generation from renewable sources is essential if we are to effectively mitigate climate change. Importantly too, the innovation and job creation associated with development, manufacturing, installation and operation of advanced solar, wind and other renewable energy sources are vital to our nation's global competitiveness and continued economic vitality.

My testimony today will focus on how grid-scale energy storage can help achieve U.S. energy and climate goals by enabling extensive and cost-effective deployment of large amounts of renewable electricity generation.

Within our present grid, electricity is for the most part generated and then instantly consumed. This has been a result of the economies of scale for coal and nuclear central power stations. But as we move toward a clean, low-carbon energy future, that will change. The National Energy Policy Recommendations published by IEEE earlier this year state that if distributed and variable "sources of electrical power, such as wind and solar, are to reach their full potential to contribute to the nation's power requirements, technologies for large scale energy storage must be developed and deployed."[2]

The theoretical potential of renewable power from wind and solar resources is vast—estimated to be more than 600 terrawatts of power available from wind and solar alone, worldwide. That compares with today's maximum worldwide estimated demand of about 12.5 terrawatts. While plentiful, renewable resources vary by time and by region. Fully accessing those resources will require a more adaptive, flexible distribution system. A more adaptive grid will in turn require improved transmission and storage systems.

STORAGE TECHNOLOGIES CAN PROVIDE MANY BENEFITS

Large-scale energy storage technologies will have many benefits, including:

- Facilitating large scale penetration of renewable energy from variable sources such as wind or solar;
- Enabling renewable energy technologies to replace fossil fueled base-load power sources;
- Enhancing the stability, reliability and power quality of the electric grid;
- Optimizing the performance of a modernized electric infrastructure.

While the promise of energy storage is well recognized, there are many technology and policy challenges which must be solved. Technologies, such as zinc-bromine, lead-sulfide, sodium-sulfide, lithium-ion, nickel-cadmium batteries and high-energy-density super capacitors, are being developed for grid-scale storage. Additional research and development is essential, however, to lower costs and to increase their

[1] U.S. Environmental Protection Agency (2009) http://www.epa.gov/climatechange/emissions/downloads09/GHG2007entire__report-508.pdf

[2] IEEE-USA Policy Statement, Jan, 2009 www.IEEEUSA.ORG/POLICY/ENERGYPLAN

durability, power density and energy efficiency. Detailed technology assessments and associated system integration analysis tools are needed to assist utilities, energy planners and policy makers as they decide how much, when, and in what mix, grid-scale energy storage technologies will be deployed.

Even when the advantages of storage technology are clearly evident, utilities may not be willing to make needed investments in energy storage systems unless the complex economic and operational interrelationships between new renewable energy generation, grid improvement, and an array of other considerations, are understood as well. The 2008 Electricity Advisory Committee (EAC) report on energy storage called for a robust national program for research, development of cost-effective, efficient, large-scale energy storage technologies, along with greatly improved analysis for optimizing generation, storage, transmission and grid management.

At my laboratory, NREL, researchers are supporting the Department of Energy's Offices of Energy Efficiency and Renewable Energy, and Electricity Delivery and Energy Reliability in assessing the potential for, and projected costs of a broad spectrum of renewable energy electricity generation options. Recently, our specialists led for the Department of Energy one of the most definitive examinations of the potential for wind power generation ever produced for the United States. This report, entitled 20% Wind Energy by 2030[3], showed that with ample grid capacity for transmitting power from regions of high quality wind to load centers on the coasts, wind penetration to 20% of U.S. electrical capacity is possible within the next two decades without the necessity of large-scale storage.

The new transmission lines that are needed to take advantage of available wind resources can be cost effective when considered purely from the standpoint of construction and operation. Siting, regulatory and legal issues, however, can pose costly delays and uncertainty for even the most well planned new transmission projects. The lesson is that new renewable generation, transmission and storage are inextricably intertwined, and we will require clear analysis and forward-thinking policies to ensure we reap the full benefits of our abundant renewable resources.

Wind is the largest and fastest growing sector of the U.S. renewable energy generation market. Nonetheless, non-hydro renewable generation represents less than 4 percent of the total U.S. generation capacity, or just over 31 GW. To achieve 20 percent wind penetration by 2030 consequently requires more than a ten-fold increase in wind production, to more than 300 GW. (Studies suggest wind development to that level will require an investment approximately 2 percent higher than would occur without the wind power build out.) This will require annual installation of 16 GW of new wind turbines each year for the next two decades. By comparison, new wind turbine installations reached a record level during 2008 of 8 GW.

NREL researchers find that additional deployment of wind generation can be aggressively pursued in the near-term even without accompanying deployment of energy storage. However, as higher and higher penetrations of wind and solar find their way onto the grid, cost-effective energy storage systems may become more and more imperative.

NREL analysts have also examined the impact of solar photovoltaics (PV) at high penetration.[4] These studies found that photovoltaic-generated electricity becomes increasingly difficult to utilize beyond 20% penetration without substantial changes to the grid, such as incorporation of storage to enable temporal shifts in utilization of PV produced energy during periods of lower solar output. It should be noted, too, that the thermal working fluid inherent within concentrating solar power (CSP) can effectively facilitate thermal storage, which can add four to six hours of sustained generation capacity[5], and thus make CSP a more cost-effective technology.

Taken together, the emerging analytical consensus provides confidence that renewable energy can expand well beyond the niche role it has played to date, and is capable of providing at least 20 percent, and perhaps much more, of nation's electricity needs.

As wind and solar capacities continue to expand, the periods of time during which renewable generation exceeds the instantaneous consumption will become more prevalent—especially within regional and localized markets. At that point, the value of storage rises, because storage allows renewable resources to be captured when they are available, and shifted temporally to meet peak demands.

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[3] 20% Wind Energy by 2030, Increasing Wind Energy's Contribution to U.S. Electricity Supply, DOE/GO-102008-2578, Dec 2008

[4] Denholm, P., and R. M. Margolis. (2007) "Evaluating the Limits of Solar Photovoltaics (PV) in Electric Power Systems Utilizing Energy Storage and Other Enabling Technologies". Energy Policy. 35, 4424-4433

[5] Sioshansi, R. and P. Denholm (2009) "The Value of Concentrating Solar Power and Thermal Energy Storage." NREL/TP-6A2-45833

ENERGY STORAGE TECHNOLOGIES ARE VARIED, SOLUTIONS ARE COMPLEX

Additional, detailed studies, conducted using sophisticated analytical models, are needed to address the question of how our nation can best develop the full benefits of renewable energy, and in particular, how energy storage can support that development. For example, at present, the U.S. electrical system operates with about 21 GW of energy storage, provided almost exclusively via pumped hydro. This represents only about 2 percent of the total 1,000 GW U.S. electricity generation capacity.

As wind and solar power become more ubiquitous, it is likely that the first storage technologies to be expanded will be compressed air energy storage, since this technology may be geographically distributed, and where regionally feasible, some expansion of pumped hydro storage.

Continued research and development efforts to improve flow batteries, super capacitors, thermal storage and hydrogen storage, will make these options more cost competitive, and thereby give utilities greater flexibility to improve the stability, reliability, flexibility and power quality of the electrical grid. Although it may be some time before renewable energy options are deployed to the extent where utility-scale energy storage is unavoidable, a significant research and development program must be ongoing if we are to have cost-effective storage solutions when they are truly needed.

Given the broad array of storage technology options available, it is difficult to briefly summarize the development state and potential of each. It is clear, however, that additional research and development is needed to yield storage technologies with the improved performance and lower costs we will require. For example, new sciences for nano-structured materials, membranes and chemistries are needed for development of longer-lived, higher capacity, and lower cost electrochemical batteries, for new electrolytes and electrodes for higher voltage, greater capacity and lower cost capacitors, and for new power electronic devices supporting effective integration of storage devices into the electric grid. Even more mature technologies will benefit substantially from additional R&D. For example, advanced engineering on water and air turbines may improve efficiencies in pumped hydro and compressed air storage systems, and stronger materials and reduced friction in bearings will result in longer life and lower cost flywheels.

Another promising area of research and development at the utility scale uses hydrogen as an energy storage medium. At NREL's National Wind Technology Center, we have teamed with Xcel Energy, the nation's largest wind power utility, in a wind-to-hydrogen demonstration project, in which wind turbines are used to power hydrogen producing electrolyzers. The hydrogen can then be stored for later use in electricity generation, or as energy for hydrogen powered vehicles.

This brings us to another area of tremendous challenge and opportunity: harnessing renewable electricity generation, transmission and storage to meet the nation's massive transportation needs. Electrically powered vehicles have great potential to reduce our dependence on imported fossil fuels. By combining an electrical vehicle fleet with storage-backed renewable electricity, we can potentially tap the vast resources of wind and solar to support low-carbon, or carbon-free, transportation. Studies at NREL confirm that integration of plug-in hybrid electric vehicles (PHEVs) into the grid can not only reduce dependence on petroleum and stabilize carbon emissions [6] [7], but can also be used to provide grid services[8], while further enabling renewable technologies.[9]

Advanced battery technology is paving the way for gas-saving hybrids and the next generation of plug-in hybrid cars and trucks. As Dr. Koonin has mentioned, DOE is wisely investing in advanced technology development and manufacturing of batteries for transportation as well as for grid-level storage, exploring a broad array of promising options. Continued investments in development and demonstration projects for grid-scale energy storage, and for integration of the nation's vehicles, buildings, and electricity grid are important for achieving our national goals for a clean and secure energy future.

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[6] Denholm, P., and W. Short. (2006) "An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicles" NREL/TP-620-40293.

[7] Parks, K, P. Denholm, and T. Markel (2007) "Costs and Emissions Associated with Plug-In Hybrid Electric Vehicle Charging in the Xcel Energy Colorado Service Territory" NREL/TP-640-41410.

[8] Letendre, Steven, P. Denholm, and P. Lilienthal. (2006) "Electric and Plug-In Hybrid Cars" New Load, or New Resource?" Public Utilities Fortnightly. 28-37.

[9] Short, Walter, and P. Denholm. (2006) "A Preliminary Assessment of Plug-In Hybrid Electric Vehicles on Wind Energy Markets" NREL/TP-620-39729.

CURRENT R&D STATUS

With very limited resources, DOE is doing a good job of leveraging efforts of state, federal and international organizations in order to keep storage development moving forward. Several national laboratories are investing internal R&D funds in forward-looking energy storage solutions such as nanomaterials for batteries. Partnerships among the national labs are leveraging capabilities and resources to accelerate the development of energy storage solutions. For example, Pacific Northwest National Lab (PNNL) and Sandia National Labs (SNL) are combining grid operations and controls expertise with materials and systems integration talents in support of DOE's energy storage program, and NREL and SNL have a newly established partnership in high performance computing that will be applied to energy storage technology development and system integration analysis.

While significant work is underway, NREL will be able more aggressively and comprehensively address storage research and development through the new capabilities of its Energy Systems Integration Facility (ESIF). The ESIF will be a 180,000-square-foot laboratory dedicated to solving issues related to the integration of renewable energy and energy efficiency technologies deployed at scale. Anchored by a 400 teraflop high-performance computer, the ESIF will enable complex systems R&D that fully integrates the most advanced simulation, data analysis, engineering, and evaluation techniques to accelerate the integration of new energy technologies generally, and the broad deployment of storage technologies specifically. Using the ESIF's modeling and simulation capacity, new materials will be explored more rapidly, and existing materials can be improved for performance and cost. The high performance computer will also enable highly focused simulations of complex electric systems to optimize the deployment of new generation technologies that are coupled with storage to ensure the most cost-effective approach and to determine approaches that will maintain and even enhance the reliability of the electricity system. Having these fully interactive simulation, testing, and evaluation facilities in one laboratory will move grid integration and storage forward on the fastest path possible.

From the national perspective, ongoing research is critically needed in two broad areas. First, research and development is needed for storage materials and techniques, including: new storage materials for electrochemical storage; new mechanical energy storage techniques; increased energy densities in storage media; increased cycling/lifetimes; all to greatly reduce costs. Second, research is needed on the integration of storage into the grid: grid simulations and optimizations to explore what types of storage are needed, where they should interconnect in the system, and how to operate storage assets; development of new power electronics for integrating storage; and, development of new communications and control technologies for charging and discharging storage in an optimal fashion (smart grid technologies for storage).

CONCLUSION

The current electricity system can absorb much greater quantities of renewable generation than are currently deployed without significant increases in the deployment of storage technologies. As penetration levels increase in the future, storage will play a key enabling role for penetrations of variable generation in excess of 30 percent. Currently, storage technologies do not exist that can be cost-effectively deployed in the diversity of applications that are anticipated. To prepare for the time when is needed at scale, we must increase our research and development efforts in the near term.

Our nation will be served if recommendations from this year's IEEE-USA Policy Position Statement are implemented. According to IEEE, the U.S. will need significant and sustained research to develop affordable energy storage technologies to effectively move renewable energy onto the electric system. The IEEE statement urged Congress to fully fund the energy storage R&D program authorized in the Energy Independence and Security Act of 2007.

Thank you for the opportunity to address the Committee on this important topic.

The CHAIRMAN. Thank you very much.

Mr. Huber, please go ahead.

STATEMENT OF KENNETH HUBER, SENIOR TECHNOLOGY AND EDUCATION PRINCIPAL, PJM INTERCONNECTION

Mr. HUBER. Good morning. Thank you, Chairman Bingaman and Ranking Member Murkowski.

PJM is honored to be invited to this important hearing on energy storage this morning. Thank you.

We certainly have been pursuing—PJM, that is—the opportunities on everything from pumped storage, compressed air, battery systems, flywheels, ice making, even use of refrigeration systems in homes as opportunities for storage. All these are viable opportunities that we are pursuing and attempting to demo.

But I am going to take my time this morning and hone in on the opportunities of plug-in vehicles and how it pertains to grid storage capabilities that really look exciting to us.

When 1 million vehicles are deployed in the United States, hopefully, in 5 years or less, 18 percent of those, if we do it by population, will end up in the PJM territory. That means a distribution of storage capabilities extending from Illinois to New Jersey, down into Tennessee and North Carolina, including District of Columbia. The PJM territory will have 180,000 vehicles that are distributed energy sources for us to tap into.

The ability to aggregate those resources and have them act the same as stationary battery systems is underway already. Aggregators like General Motors, OnStar, regular aggregators, convergers, et cetera, are all pursuing how to do this. In fact, I will talk a little bit of an example where we are doing that today.

Almost more interesting than residential use of plug-in vehicles is fleet use. If you think about a local delivery vehicle and what it is doing today and its runs of stop/start, very low mileage per gallon usage, idling constantly. If you were to electrify those local delivery fleets, and we are pursuing opportunities and discussions with several of those, what you are talking about is a fleet with pretty regular routes that run the system the same way every day, return almost always to the same location, that allows the infrastructure for those fleets to be put in place and allows a capability for two-way communications and control back into the grid that really provides a reliable capability for storage when it is needed.

Now I will talk about smart charging incentive, both for the residential and for the fleet vehicles. The ability to deliver price signals, to deliver information about renewables, to deliver information about reliability of the grid to aggregators and then on to vehicles is really where we are working hard to obtain.

I was just with General Motors yesterday in Detroit talking about this smart charging capability. We really do believe that if you give the right information to the individual, they will be incented to respond to those. You know, people respond to the incentives they are given. The charging will happen at the times that is needed, and it will result in good usage of the automobile and good usage for the grid.

Let me flip over and talk about one other area of storage that is very important to us, which is frequency regulation. The ability to keep the frequency at 60 hertz at all times is an important operation within the PJM facility.

In 2007, PJM joined a consortium—the University of Delaware; Pepco Holdings, Pepco Electricity here in Washington; California converter company AC Propulsion; and a couple others—and produced a vehicle that has been operating to the PJM regulation signal since October 2007. For 2 years, we have experienced what it

means for a vehicle to not only charge and discharge on a 4-second signal sent to it, and we are seeing and gathering that data.

That vehicle has been operating to the market, but not in the market. It is too small. It is only 18 kilowatts. A very good occurrence happened over the course of 2008. AES, the generation company, brought into the PJM territory 1 megawatt of batteries, very, very similar to automotive batteries in their structure, and it entered the market in November 2008 and has been continuously in the PJM market since May 2009.

So 24 hours a day, 7 days a week, we are getting 1 megawatt of battery power responding to our 4-second regulation signal. The celebration that we are sort of having right now is that we have taken that vehicle, that MAGICC—Mid-Atlantic Grid Interactive Car Consortium—vehicle and its two sister vehicles and have now integrated them and aggregated with the batteries of the AES stationary system. So we now have 1.054 megawatts of energy in the regulation system.

So the batteries in the stationary system are being paid somewhere between $700 to $900 a day for just responding to our signal, and each of the three vehicles is now getting paid about $10 a day for doing the exact same thing. Just demonstrating the fact that the batteries can be distributed. They happen to be in Delaware, and the stationary battery system happens to be in Pennsylvania.

So a really exciting experiment of what we can do as we start seeing these vehicles become prevalent throughout our system. I will just end and talk about the one policy area. Certainly—I will talk about two.

The ability to standardize the communications, the two-way communications and the control from the RTO/ISO through the utility or the aggregator into the consumer is certainly important. There is very good activities being directed by DOE and done by NIST, National Institute of Standards and Technology, today that are addressing that.

The automotive companies are there. The utilities are there. It is a very good forum. We need to make that all happen so that we have the communications and the robustness that we need.

We need to work together, the automotive companies and the utilities, to develop the smart charging capability that—I mean, everyone talks about everyone is going to go home at 5 and plug their vehicles in. The automobiles are smart. The system is smart. There is no reason for that to happen with the right incentives in place.

Thank you very much for your time.

[The prepared statement of Mr. Huber follows:]

PREPARED STATEMENT OF KENNETH HUBER, SENIOR TECHNOLOGY AND EDUCATION PRINCIPAL, PJM INTERCONNECTION

EXECUTIVE SUMMARY

In the attached testimony, Kenneth Huber, Senior Technology and Education Principal at PJM Interconnection (PJM) details the activities presently underway within PJM's 13-state footprint regarding the potential of plug-in hybrid electric vehicles (PHEVs) serving as an energy storage resource. PJM is the Federal Energy Regulatory Commission (FERC) approved Regional Transmission Organization (RTO) serving all or parts of the states of Illinois, Michigan, Indiana, Ohio, Kentucky, Tennessee, West Virginia, North Carolina, Virginia, Maryland, Delaware,

Pennsylvania and New Jersey as well as the District of Columbia. PJM operates the bulk power grid in this region, plans transmission expansion and operates the largest competitive wholesale electricity market in the world.

The batteries within PHEVs carry with them the promise of serving as a new and highly effective, distributed energy storage resource. If done right, plug-in hybrid vehicles can enhance the efficiency of the grid by shifting load to off-peak nighttime hours — the very time when certain renewable resources, such as wind power, are most available. On the other hand, if customers plug in their cars at 6 p.m. and there are no economic incentives or communication and control technology to drive different customer behavior, then the nation could be worse off both in terms of efficient grid operation and in controlling emissions from fossil generation.

Mr. Huber details PJM's participation in three projects demonstrating and evaluating use of PHEVs for grid storage— the University of Delaware's Mid-Atlantic Grid Interactive Car Consortium (MAGICC), The Ohio State University's SMART@CAR initiative and the North Carolina State Freedom Engineering Research Center. The first MAGICC plug-in electric vehicle has been responding in real-time to the PJM regulation signal since October 2007 and has provided a wealth of data on the use and value of vehicle-to-grid operation. This month, AES, PJM and the University of Delaware will be aggregating three 18 KW vehicles with a 1 MW stationary battery trailer. This is the first demonstration of vehicleto-grid plug-in electric vehicles actively participating in any regulation market and providing a cash return to the vehicle owners. The three vehicles will be earning between $7-10 each for the 18-20 hours they are plugged in and contributing to the regulation storage needs of the grid. The batteries in plug-in electric vehicles become a source of regulation service that is more distributed and therefore provide the same, and in some cases, superior regulation service to what is today provide by central station generation.

Mr. Huber concludes his testimony by outlining some of the policy challenges associated with wide scale deployment of PHEVs. These include: (1) ensuring coordination between the transportation and electric industries on vehicle design and development; (2) addressing ownership rights associated with infrastructure and the sale of electricity to PHEVs; (3) ensuring seamless "roaming" and ability of back-office billing and settlement systems to match cars with electric customers; and (4) the role of enforcement of interoperability protocols being developed through the National Institute of Standards and Technology (NIST) process. Mr. Huber suggests that continued Committee oversight and focus on these issues will help to underscore the national and international policy benefits of "smart" plug-in hybrid electric vehicle technology.

TESTIMONY OF KENNETH HUBER, SENIOR TECHNOLOGY AND EDUCATION PRINCIPAL

On behalf of PJM Interconnection, L.L.C. (PJM), I want to thank the Committee for the opportunity to participate in this important discussion of the role of grid-scale energy storage in meeting the energy and climate goals of the United States. My name is Kenneth Huber and I am Senior Technology & Education Principal at PJM. My goal today is to discuss the reliability and economic value of grid-scale storage both for today's grid operation and for forecasting future grid operations. I will also discuss the value of storage as it relates to the anticipated emergence of renewable energy resources.

PJM is a Regional Transmission Organization (RTO) and one of the seven Independent System Operators (ISOs) and RTOs located throughout the country. PJM is responsible for the reliability of the bulk power grid in a 13-state region which encompasses over 51 million Americans. PJM operates the bulk power grid in this region, plans transmission expansion and operates the largest competitive wholesale electricity market in the world. Over two thirds of the nation is served by RTOs and ISOs. As an independent entity, we are dedicated to ensuring open access to the grid and embracing many new and sometimes competing technologies. PJM was privileged recently to be a recipient of one of the Department of Energy's Smart Grid grants — a grant for the installation of phasor measurement units to enhance the overall visibility of grid conditions on a minute-byminute basis and to improve the overall efficiency of the grid operations.

To keep the lights on, PJM must perform the real-time balancing of the electrical grid — every second of every minute of every day, PJM matches electricity demand with the 'least-cost group' of electricity generation and demand response resources. The dispatch of over 1,200 generators on our system must be undertaken with recognition of the physical constraints of the electric transmission system and the need to ensure adequate reserves available to keep the lights on in the event of a sudden loss of generation or transmission. This challenging balancing of the grid is com-

plicated by the unique physics of electricity. Electricity is not like oil which can be refined and stored easily for long periods until the time it is needed. Electricity must be generated at the near moment that it is required. I will discuss how grid storage, with a particular focus on plug-in electric vehicles, can and is being used to assist in this system balancing requirement. I will also highlight the specific activities PJM is undertaking to jump start the deployment of "smart" plug-in hybrid vehicles in our footprint, as well as, briefly address some of the policy challenges that will affect further deployment of plug in hybrid electric vehicles.

THE STATE OF THE GRID TODAY

Contrary to the beliefs of some, the bulk power grid already is very interactive and "smart". Today, we have more sophisticated operations and market-based tools to manage flows on the grid than ever before. These tools include our state estimator which monitors and reports on the state of the system every two minutes. They include our ability to redispatch generation to proactively clear congestion before reliability is threatened by overloads on a given transmission line or set of lines. In short, we have been able to utilize technology to help manage power flow more efficiently than in years past.

NEW OPPORTUNITIES—A SMARTER GRID

Although the bulk power grid can be considered "smart" today, emerging technologies and enhanced communication will put in place an even more robust grid. Advanced technology will open a new frontier for the grid in many ways. A grid that is based on smart grid technology, when coupled with electrification of transportation and the delivery of more real-time information, will provide new opportunities to better manage the grid and control both for price and environmental externalities. PJM is actively working on the agreement of and the eventual creation of the capabilities and role of the RTO/ISOs that will deliver that smarter grid. We are accomplishing this goal through active participation in the National Institute of Standards and Technology (NIST) Smart Grid Interoperability Panel, the North American Electric Reliability Council (NERC) Smart Grid Standards Task Force and the North American Energy Standards Board (NAESB) Smart Grid Standards Task Force. I have been focusing my participation in the NIST Priority Action Plans for Storage and Electric Transportation and am a voting member of the Society of Automotive Engineers (SAE) standards process.

GRID STORAGE—A KEY ELEMENT OF A SMARTER GRID

PJM Interconnection supports projects of all types to expand the electricity storage capability of the electric grid. More storage capacity will be needed to deal with the forecasted major expansion of intermittent renewable energy sources and their potential impact on system reliability.

One of the challenges facing grid operators like PJM is the inability to "store" electricity for use at times of high demand or when certain generation may be operationally or environmentally constrained. However, new technologies are being developed and tested that offer the promise of more widespread storage options for grid operators and utilities. These technologies will become even more important as intermittent renewable energy sources play a greater role in the nation's electricity supply.

Today, additional options for storing electricity are emerging and are being tested. These technologies—such things as battery arrays, flywheels, compressed air energy storage and even PHEVs[1]—may give grid operators additional flexibility in their efforts to ensure the reliability of the electric system. After outlining the general storage needs of the grid, I will be concentrating the bulk of my testimony on the grid storage applications afforded by PHEVs.

There are a number of reasons why additional storage capacity is needed on the grid. The dramatic expected increase in the penetration of renewable generation resources is the primary driver. These sources typically are intermittent—their production isn't available all the time, for example, when the wind isn't blowing or the sun isn't shining—and their output may not be available at times of peak demand when it is needed most.

In recent years, the nameplate capacity value of wind generation projects entering the PJM interconnection queues has steeply increased. There are currently 3,300 MW of nameplate wind capacity in operation, 1,500 MW under construction and ap-

[1] The term PHEV used in this testimony refers to different types of plug in electric vehicles including plug-in hybrid vehicles, extended range electric vehicles and battery extended vehicles.

proximately 42,000 MW nameplate capacity of wind generation in the interconnection queue in PJM.

Taking full advantage of renewable sources while dealing with the reliability challenges of the sources' power fluctuations will require a significant increase in storage on the grid.

Although the PJM system is one of the nation's largest and thus able to absorb a greater degree of intermittency than smaller systems, the lack of sufficient storage already is causing issues for PJM. In some areas, abundant wind production in the off-peak (night-time) hours has forced electricity prices into the negative range. During low load periods, storage will become critical to prevent curtailment of this wind generation. Figure 5 is illustrative of a common occurrence in PJM in which the wind output is rapidly declining just at the time (5:00 a.m. in this example) when the grid load is beginning its morning period of rapid load increase. Negative prices for wholesale electricity frequently result from these conditions. In this example the Locational Marginal Price of electricity in Chicago fell to minus $8. On this day at this hour, in order to maintain the system's load to generation balance, a storage facility would have been paid to store energy. From a PHEV perspective, the vehicle owner would be paid to charge their car during that hour.

Given the states' requirements for renewable energy and economic incentives for the development of renewable projects, the expected expansion of renewable power will magnify this situation, along with the challenges for grid operators to maintain reliability during such periods of fluctuations in the output of these power sources.

NEW BATTERY AND VEHICLE GRID STORAGE TECHNOLOGIES

Battery storage.—A one-megawatt (MW) array of lithium-ion batteries began offering regulation service in the PJM market in May of this year. The batteries, housed in a trailer on the PJM campus, are owned by AES Energy Services LLC, a subsidiary of The AES Corp., a PJM member. The facility can help PJM quickly balance variations in load to regulate frequency as an alternative to adjusting the output of fossil-fuel generators; it is capable of changing its output in less than one second. In response to PJM requests to balance the grid, the battery unit can supply power into the grid by discharging its batteries or store excess electricity from the grid to charge its batteries. Thirty four MWs of battery storage have been put in the PJM generation queues for 2010.

PHEVs.—The dual use of PHEV batteries to support both transportation (when the vehicle is being driven) and the grid (when the vehicle is parked and plugged in) is particularly attractive. Most vehicles are driven only several hours per day and are plugged in and available to provide grid support for the remaining time in the day. Fleet vehicles, while driven 8-12 hours per day, are typically returned to the same location and available for grid services the remaining 12-16 hours of the day.

Off-peak electricity from the grid could charge PHEVs, shifting load to the night-time hours. In addition, PHEVs also could provide regulation services to the grid whenever parked.

Regulation service, provided today principally by central station generators, matches generation and load and adjusts generation output to maintain the desired 60 Hz frequency. Regulation service corrects for short-term changes in electricity use that might affect the stability of the power system. Regulation is needed throughout the day and night to ensure system frequency despite constant fluctuation in demand and generation. Grid operators must continuously match the generation of power to the consumption. Regulation requires a generating facility that can ramp power up or down under real time control of the grid operator.

PJM is part of three initiatives — the University of Delaware's Mid-Atlantic Grid Interactive Car Consortium (MAGICC), The Ohio State University's SMART@CAR initiative and the North Carolina State Freedom Engineering Research Center—each of which is analyzing, demonstrating and evaluating use of PHEVs for grid storage. The MAGICC vehicle has been responding to the PJM regulation signal since October 2007 and has been evaluating the vehicle-to-grid (V2G) approach, which enables PHEVs to discharge their stored power to the grid based on regulation signals from PJM. This month AES, PJM and the University of Delaware will be aggregating three 18 KW vehicles with the 1 MW stationary battery trailer (Figure 6). This is the first realization of the 'cash-back' vehicle[2] as the three vehicles

[2] "How To Improve The Efficiency Of The World's Biggest Machine—While Solving A Few Other Problems Along The Way," Jon Wellinghoff, Commissioner, Federal Energy Regulatory Commission, May 7, 2007.

will be actively participating in the PJM regulation market and earning between $7—$10 each for the 18-20 hours they are plugged in and contributing to the regulation storage needs of the grid. The annual payment for each of these vehicles will be in the order of $2,500 to $3,500.

Of particular interest is the opportunity for automotive fleets to become an early adopter of PHEVs and showcase the direct economic and environmental value for both transportation and grid support. Local delivery fleets suffer from low fuel mileage, idle a large percentage of their time and are economically impacted by any increase in price of gasoline. As PHEVs, these fleet vehicles would charge at night with inexpensive electric, be available for regulation services and market revenues and would deliver green transportation while serving our neighborhoods.

Plug-in hybrid vehicles represent an exciting new opportunity to provide both ancillary services to the grid and utilize the power system assets more efficiently. If done right, plug-in hybrid vehicles can enhance the efficiency of the grid by shifting load to off-peak nighttime hours. On the other hand, if everyone plugs in their car at 5 p.m. and there are no economic incentives or communication and control technology to drive different customer behavior, a much higher peak load would have to be supported by high cost generation.

Figure 9 shows the minimal impact of 180,000 PHEVs (1,000,000 vehicles times the 18% of the nation's population that resides in the PJM territory). It also illustrates the potential for supporting 25 million PHEVs if the charging is done at off peak times.

The auto industry and the electric industry also must work together to make the future PHEVs deliver on their potential to reduce oil imports, to reduce carbon dioxide and to reduce the cost of transportation. The automobile manufactures, the local utilities, the RTO/ISOs and the Electric Power Research Institute (EPRI) are meeting regularly to discuss and work through the needs of our industries and of the end-use consumer to provide reliable, clean and economic transportation and electricity use.

A mixture of all of these storage technologies will help grid operators and utilities address the impact of a large-scale addition of renewable energy sources to the electricity system, including the intermittent nature of renewables, the off-peak timing of much wind energy output and the potential impact on the loading levels of baseload coal and nuclear plants.

POLICY CHALLENGES

While today we are seeing aftermarket conversions of plug-in hybrid electric vehicles (e.g. the BMW Mini) production vehicles from original equipment manufacturers will begin with the deployment of plug in hybrid electric vehicles in 2010, such as the Chevrolet Volt. As I mentioned previously, to truly realize the full benefit of PHEVs rather than simply swapping one set of increased emissions for another, we will need to ensure that there is smart charging of the vehicle with two way communications available between the vehicle and the grid. The customer remains in control. However, through appropriate price and control signals, parked plug-in hybrid electric vehicle, can provide a source of distributed generation that can better help us to manage the grid than we can today with large central station generators distant from the loads. And by using price signals to incent vehicle owners to charge their cars in off-peak times, we can avoid creating a whole new set of system peaks at the very time we are seeking to reduce carbon emissions and otherwise smooth out fluctuations in peak demand.

To achieve this vision, we will need to address a number of policy issues, some of which are well on their way to resolution and others which are only first being identified. Let me outline a few for the Committee's consideration:

Cooperation and coordination between the electric and transportation industries—These industries have traditionally not had to adjust their product to meet the needs of the other. However, both industries have now recognized the need to collaborate on infrastructure requirements, data exchange and ensuring a positive, holistic experience for the PHEV customer. The industries are working together in many forums, including the Society of Automotive Engineers standards activities, the EPRI PHEV collaboration programs and many local deployment projects. To truly realize the benefits of PHEVs, these collaborations will need to result in agreements on the minimal information that must be exchanged, the ownership of the data and how usage and revenue will be measured and verified.

Infrastructure Deployment—As part of the deployment of the smart grid, we will need to tackle issues such as who owns the infrastructure down to the outlet and what constitutes a permissible vs. impermissible sale for resale of elec-

tricity. For example, would the outlets deployed at a Walmart sm [3] parking lot be owned by Walmart, a separate aggregator or the local utility? Would Walmart serve as the intermediary between the utility and the customer and aggregate the purchase of electricity to vehicles on its lots during the day. For residential uses, can a landlord of an apartment building insist that he or she own the infrastructure? Does a customer have a "right" to connect in order to charge their battery (so long as they are financially in good standing with the electric company) just as customers have a right to electric service under state law today? The industry is beginning to consider these regulatory and policy issues. Let me give an example of a working system today; AES has aggregated its 1 MW stationary battery system with the three 18 KW plug-in electric vehicles in the University of Delaware. The total energy of 1.054 MW participates in the PJM Regulation Market. AES allocates approximately 5% of the PJM market payment to the University of Delaware and AES is allocated 95%. The University vehicles are plugged in at home and at the university and the net usage of the vehicle is measured on standard utility meters and usage payments are made to the local utility (Delmarva Power and Light). A retail net metering tariff completes the picture allowing the customer to participate in the service he or she is providing to the grid.

To tackle these questions more broadly, we will all need to look at the typical utility tariff in a new light and determine what is the best legal relationship that is fair to the utility, the vehicle owner and the owner of the garage or parking lot itself.

Roaming—Although the plethora of different electricity rates by geography is often cited as an impediment to properly linking mobile cars to customer accounts, I do believe that technology development from the transportation and telecommunication industries has provided us clear guidance in this area. Today, states still have a variety of different toll rates on their highways just as different cellular companies have different rates and plans. The advent of the E-Z Pass demonstrates that these different state and utility requirements can be harmonized and a system of billing and collection can be managed for vehicles. We will need the "smart" grid to be able to identify vehicles and their location and match them to utility customers. We will further need to develop new inter-utility billing and settlement systems to manage this mobile fleet. But, at least from a technology viewpoint, the path forward on this issue has already been demonstrated.

Need for Comprehensive Interoperability Standards — The Smart Grid Interoperability Panel work of the NIST with cooperation of the automotive companies, utilities and the RTO/ISO is actively addressing and coordinating this need in the NIST Electric Transportation Priority Action Plan. Of critical importance is the need for deployment that conforms to the NIST interoperability agreements and for appropriate enforcement at the state and federal level.

Need to Retain Policy Focus — The future of PHEVs as an energy storage resource is highly dependent on close coordination between the electricity and transportation industries — two industries that have had limited interaction in the past. Moreover, the infrastructure needed to be deployed potentially spans the traditional jurisdictional reach of both federal and state regulators and policymakers. As a result, continued Congressional oversight on this issue and the progress being made would be helpful to underscore the importance of PHEV deployment to meet national (and even international) policy goals We at PJM look forward to working with this Committee and the Congress as a whole as we move forward in this important area.

[All figures have been retained in committee files.]

The CHAIRMAN. Thank you very much.

Mr. Mainzer.

STATEMENT OF ELLIOT MAINZER, EXECUTIVE VICE PRESIDENT FOR CORPORATE STRATEGY, BONNEVILLE POWER ADMINISTRATION

Mr. MAINZER. Thank you, Chairman Bingaman, Ranking Member Murkowski. I really appreciate the opportunity to be here this morning.

[3] Walmart is a service mark of Wal-Mart Stores, Inc

My comments today are focused on the role that storage technologies could play in the context of a set of initiatives we are undertaking to improve our ability to integrate variable renewable generation into the Federal Columbia River Power System.

As of this morning, we now have 2,500 megawatts of wind energy connected to our system, having seen another 200 megawatts come online just this past week. We are planning for 3,000 megawatts by the end of 2010 and as much as 6,000 megawatts by 2013. Figure 2 of my written testimony portrays this rapid pace of growth.

Like our colleagues at PJM, as we integrate this variable supply of renewable energy, we must maintain system reliability. When actual wind generation varies from scheduled generation, we must dispatch or curtail other generation in very short time to maintain system balance.

With 2,500 megawatts of wind, we have seen swings of more than 1,000 megawatts in less than an hour on our system, and there is limited correlation between wind generation and system demand, often leading to surpluses of wind generation during off-peak periods. Figure 3 in my written testimony illustrates the type of variability we are seeing on our system.

To date, we have been able to use our existing hydro assets to manage the variable output of the wind on our system, but we do not expect to be able to integrate all of the expected wind generation without making some infrastructure investments as well as commercial and operational changes.

As a result, we are working on three categories of actions to increase the amount of wind that could be interconnected to the BPA system. These include, first of all, constructing additional transmission capacity; second, developing mechanisms to stretch the balancing capacity of our existing hydro assets as far as possible; and third, exploring the development of new resources to provide generating capacity and flexibility.

With respect to transmission, BPA has proposed three new transmission projects that will facilitate collectively 1,800 megawatts of new wind generation. We have begun the environmental review process for those three projects. With additional borrowing authority provided by the American Recovery and Reinvestment Act, we are ahead of schedule on the construction of a fourth line that will support 575 megawatts of additional wind generation.

These transmission projects resulted from the completion of our 2008 network open season process. The network open season allowed us to efficiently process our queue of transmission service requests and set priorities for financing and building transmission projects. This was a significant development because it addressed planning and financing barriers that impede transmission construction for renewable energy development across the Nation.

It also allowed us to confirm the most efficient use of our existing transmission system before proposing new construction. On the reliability and operations front, BPA has established a wind integration team that is working with the wind community on a set of initiatives designed to increase the amount of wind generation that can be supported from the existing capacity of the Federal hydro system.

These initiatives include developing new operating protocols to manage extreme wind variability, investing in new wind forecasting applications, developing new scheduling practices to manage generation imbalances, and enabling customers to seek sources of wind integration services from other suppliers besides BPA.

More broadly, we are collaborating with other balancing authorities in the western interconnection to pool resources and increase the availability of cost effective balancing services. These types of collaborative activities are an essential part of an effective renewable integration strategy for the Western United States.

Ultimately, although we do intend to wring all of the efficiencies that can be wrung from the existing system, it is likely that the region will need to add additional capacity and flexibility resources to assist with the management of variable generation. To prepare for that day, we have begun to explore storage options. We are working with the Pacific Northwest National Laboratory on their study of various storage technologies, including pumped storage, compressed air, batteries, and flywheels.

We are looking forward to seeing the results of this analysis and giving further consideration to such variables as cost, sustained capacity, location, and lead times that will impact the economic viability of these technologies in the Pacific Northwest. Given the hydroelectric profile of our generating resources, we are placing particular emphasis on pumped storage. Pumped storage has potential to provide a variety of grid support services and to shape the variable output of wind and other renewable resources into firm blocks of power with energy and capacity value.

BPA is working with our partners at the Bureau of Reclamation and Army Corps of Engineers to explore the potential for additional pumped storage in the Pacific Northwest. We expect to have an initial evaluation complete in mid 2010.

Mr. Chairman and Ranking Member Murkowski, I appreciate the opportunity to be here with you today and relate our experience in leveraging the capabilities of the Federal Columbia River Power System in support of new renewable electric generation. I am happy to respond to any questions.

Thank you.

[The prepared statement of Mr. Mainzer follows:]

PREPARED STATEMENT OF ELLIOT MAINZER, EXECUTIVE VICE PRESIDENT FOR CORPORATE STRATEGY, BONNEVILLE POWER ADMINISTRATION

Thank you, Mr. Chairman. My name is Elliot Mainzer and I am the Executive Vice President for Corporate Strategy for the Bonneville Power Administration (BPA). I am pleased to be here today to describe the significance of BPA's efforts to facilitate wind energy into the Western transmission system and the role storage technologies could play as one tool in the suite of initiatives we are developing to improve our ability to integrate variable renewable generation into our grid.

BACKGROUND

BPA, established in 1937 by an Act of Congress, is a power marketing agency within the Department of Energy. Our headquarters are in the Pacific Northwest, where we operate about three-quarters of the high voltage transmission system and market the power from 31 federal dams in the Columbia River Basin as well as the output of one nuclear plant. We supply about 40 percent of the Northwest's electricity, selling at wholesale and at cost.

Our service area covers Washington, Oregon, Idaho, western Montana, and small parts of eastern Montana, California, Nevada, Utah, and Wyoming. BPA is a self-

financed agency that recovers its full costs and repayment obligations from power and transmission rates. Our power customers include Northwest cooperatives, municipalities, public utility districts, federal agencies, investor-owned utilities, direct-service industries, port districts, irrigation districts, and tribal utilities.

We sell transmission and related services to more than 200 utilities, power generators (including wind generators), and power marketers. Pursuant to our open access tariff, BPA provides transmission services to all customer utilities, power generators and marketers under the same rates, terms, and conditions that it applies to its own Power Services business line for use of transmission services.

RENEWABLES DEVELOPMENT IN THE PACIFIC NORTHWEST

BPA is maintaining a remarkable pace of connecting new renewable wind generation to its transmission system. All but one of the states in our service territory have enacted renewable electric generation standards for their retail utilities. These requirements, coupled with those of other Western states, have brought developers to our area looking for opportunities to develop and sell new renewable generation. They come to us for transmission services because of the capacity of our existing transmission system and the proximity of reasonably good sites for wind generation. To date we have almost 2,300 megawatts of wind generation connected to our system.

Figure 1* shows the three categories of actions we are working on to expand wind power interconnection to the BPA system: 1) constructing additional transmission capacity; 2) developing the means to provide additional balancing services for reliability from existing system assets, and; 3) exploring the development of new resources that provide capacity and flexibility.

TRANSMISSION

The large amount of new wind generation in our region, combined with increases in electricity demand due to a growing population and changing patterns of seasonal energy use, has led BPA to propose three new transmission projects that will collectively facilitate about 1,800 megawatts of new wind generation. We have begun the environmental review process for those projects. With additional borrowing authority provided by the American Recovery and Reinvestment Act of 2009 (ARRA), we are ahead of schedule on the construction of a fourth line—the McNary to John Day 500-kilovolt transmission line that will support 575 megawatts of additional wind generation.

Our proposals for these projects, and the decision to begin construction on the McNary to John Day project, resulted from the completion of our first-in-the-nation 2008 Network Open Season. The Network Open Season is a new commercial approach to manage transmission requests and set priorities for financing and building transmission projects. BPA's first Network Open Season resulted in 6,410 megawatts of transmission service requests with financial commitments by the customers who asked for the service. Three-quarters of the requested service capacity were for wind generation. Because we were able to clarify commitments to take transmission service, we were able to accommodate more than 20 percent of the requests with existing capacity. We were also able to offer a new Conditional Firm service to provide still more transmission service from the existing capacity of the system. These approaches are significant because they resolved planning and financing barriers that impeded transmission planning for renewable energy development across the Nation. They also allowed us to confirm the most efficient use of our existing system to serve new renewable generation before proposing new construction. We are completing our second Network Open Season and will continue to conduct the process annually.

RELIABILITY

The pace of wind development and its concentration in our balancing authority, as shown in Figure 2, was initially surprising to us. Only five years ago, the Northwest Power and Conservation Council (Council), the four-state entity responsible for long-range energy resource planning in our region, projected that the region could support 6,000 megawatts of wind development by 2025. In response, BPA and the Council convened the Northwest Wind Integration Forum, a regional steering committee and technical work group, to evaluate wind integration issues and develop a Wind Integration Action Plan. The Plan emphasized that wind energy is a renewable resource that can lower the fuel consumption and environmental emissions of

* Figures 1–3 have been retained in committee files.

other resources, but that wind energy cannot provide reliable electric service on its own. The Plan said that wind generation, with its natural variability and uncertainty, increases the need for flexible resources or dispatchable loads to maintain utility system reliability.

Almost five years after the Council's projection, we now expect we could be asked to connect 6,000 megawatts to our system alone and as soon as within the next four years. Much of that development remains concentrated in areas of Washington and Oregon east of the Columbia River Gorge. We have among the highest penetration in the country of wind generation relative to peak load on our system.

The substantial amount of wind on our system has given us significant insight into the challenges of maintaining reliability with a large amount of variable generating resource. The nature of wind generation is, of course, that it increases and decreases depending on the weather. On our system that can mean swings of more than 1,000 megawatts in less than an hour. We have also found that there is limited correlation between wind generation and system demand, often leading to surpluses of wind generation during off-peak periods. When the wind generation is concentrated as geographically as it is in the Pacific Northwest, it intensifies the magnitudes of its peaks, valleys and ramps, as Figure 3 illustrates. Electric power systems must perfectly balance generation and load in real time. We must dispatch or curtail other generation in very short time frames when actual wind generation varies from scheduled generation. This type of balancing is necessary to maintain electric system reliability.

Balancing variable generation using the flexibility of the existing hydro system has been a major focus for us. To date, we have been able to use our existing hydro assets to manage the variable output of the wind on our system. In essence, we are able to operate the hydroelectric system as a giant storage battery for the variable output of the wind while simultaneously meeting regional power demands consistent with our obligations to protect, mitigate, and enhance fish and wildlife. However, the system has its limits if reliability is to be maintained.

The greater the amount of hydro capacity we must maintain to support the growing wind resource, the more significant are the cost implications for our public power customers, and the greater are the reliability implications for the transmission system. The cost issues stem from the changes in system operations we must make in order to ensure we have sufficient reserve capacity to meet demand if the wind generation forecasted by the wind operators does not closely match actual generation. Until last year, the costs of carrying such reserves were paid by our public power customers. Because the amount of reserve capacity needed to support the burgeoning wind resource also grew, the cost to our public power customers also increased. This concern was exacerbated by the fact that approximately 80 percent of the wind interconnected to our system is sold for delivery to utilities outside of our balancing authority. Consequently, the cost of balancing wind generation is a concern for our public power customers who do not use the resource, yet were covering the cost of integrating it. In 2008, BPA began to charge the wind generators a portion of the cost of holding the reserves needed to manage the variability of the wind generation. When a revised wind integration rate was first proposed for 2009, it represented a significant increase in the cost of integrating wind for the wind developers. This was primarily due to the fact that we now had more wind on the system and it was creating additional costs. In response, BPA and the wind developers held many discussions that resulted in several new initiatives designed to maintain the reliability of the transmission system, yet at a lower cost to the wind generators and their customers.

Establishing a rate for wind integration also sent a price signal for the cost of wind integration services that is encouraging wind operators to more efficiently use those services. This stretches the capability of the existing system, allowing more wind to interconnect to our system.

The decisions in this last rate case have already bought us time relative to the need to secure new generating resources for balancing services. In addition, we are exploring additional strategies to increase the amount of wind we can reliably integrate into the system. We have agreed with the wind community on a set of initiatives we expect will allow still more wind to connect to our system without building new balancing resources. The initiatives we agreed to pursue hold promise to secure additional breathing room by allowing us to wring more efficiencies from operational improvements, and from collaboration with the wind generators and our neighboring transmission systems.

These initiatives encompass developing new operating protocols for our system, working with our partners in the Western Interconnection to pool resources and increase the availability of balancing services, and working with our customers to improve the accuracy of wind forecasting to allow a larger amount of wind generation

to be supported from the existing reserve capacity of the hydrosystem. We think these initiatives can make a significant dent in the amount of balancing reserves needed to support a tripling of the wind generation supported by our system, allowing more wind to be connected to our system, and limiting the costs to the wind generators and their utility customers.

OPERATING PROTOCOLS AND IMPROVED FORECASTING INITIATIVES

BPA has established an internal Wind Integration Team (WIT) to implement new operational and forecasting tools. Earlier this year, BPA met with its stakeholders, including wind developers, to determine which of the WIT initiatives are of the highest priority to the region. BPA reached agreement on pursuing several high-value initiatives with an estimated cost for completion of up to $15 million over two years. The accelerated initiatives include:

Wind Forecasting: In October 2009, BPA completed installing 14 new wind measurement sites. We will share the new wind measurement data in real-time with all interested parties. We expect to develop a complete wind forecasting system by March 2010. By September 2010, we will give BPA dispatchers displays of real-time wind generation and next-hour wind forecasts so dispatchers can better anticipate changes in wind output and adjust generation to make more efficient use of combined wind, hydro, and other available resources.

Dynamic Transfer Limits Study and Pilot Project: We are working with our neighboring transmission systems to develop new methods to determine the transmission available to allow one of our utilities to remotely control and manage a power plant in another utility's transmission system. This is known as dynamic transfer, and such capability would allow us to serve more variable generation than the hydro system could otherwise support. We expect this study to be completed by mid-February 2010. Shortly thereafter, we will launch a test of such capability on a set of Pacific Northwest transmission interconnections to gain experience in the operational technology.

Wind Generators' Self-Supply of Reserves: BPA is also planning to use the results of the Dynamic Transfer Limits Study to allow wind projects to purchase balancing reserves from suppliers other than BPA. This enables wind projects to manage their own costs in acquiring balancing services. BPA, the receiving utility and the appropriate wind project all must install significant control and communications equipment to make this work. By October 2010, BPA will launch the first pilot project for self-supply of generation imbalance reserves.

Intra-Hour Scheduling: Our current transmission scheduling is based on 60 minute delivery schedules. We are developing tools to allow power schedules to change at the half-hour as well as the hour to let customers sell power from fast changes in wind output. This would help reduce reserve requirements and maintain the transmission system's reliability. Last week, we initiated a pilot project to test such practices.

OPERATING PROTOCOLS

In the power and transmission rate cases for Fiscal Years 2010 and 2011, we worked with wind developers on an operating protocol that allows us to maintain lower levels of reserves while at the same time protecting system reliability. This protocol defines procedures that go into place when we are close to depleting our reserves because of the gap between actual wind generation and what was scheduled. We began implementing the protocol this fall and, in return, the customers' rate for balancing services is lower by nearly a half than we originally proposed. Essentially, the wind customers accepted more risk in return for a lower rate. They have also responded by investing in improving the accuracy of their scheduling. We appreciate the effort they made to help us reach these outcomes.

SMART GRID

We are also a partner in two significant regional smart grid efforts that have recently won funding from the Department of Energy. The first is the $53 million Western Electricity Coordinating Council (WECC) project that will test a large-scale synchrophasor measurement system with smart grid functions. The benefits would include increased transfer capability, better congestion management, and improved efficiency and lower costs for supporting variable renewable generation. The second is the Pacific Northwest Smart Grid Demonstration Project led by the Battelle Memorial Institute. That project received $89 million in ARRA funds from the Department of Energy. It spans five states and includes 12 utilities. The objectives of this demonstration project include validation of new smart grid technologies and busi-

nesses, quantifying smart grid costs and benefits, improving transmission system resiliency, and advancing interoperability standards and cyber security requirements for smart grid devices and systems. Both initiatives have the potential to significantly improve the regional transmission system's ability to facilitate variable renewable energy generation.

ADDING NEW CAPACITY

Ultimately, though we will wring all the efficiencies that can be wrung from the existing system, it is quite likely that the region will need to add additional resources to provide balancing services for variable renewable resources. To prepare for that day, we have begun to explore storage options. From a broad perspective, we are working with the Pacific Northwest National Laboratory on their study of various storage options including pumped storage, compressed air storage, batteries, and flywheels.

At the same time, we are placing a particular emphasis on evaluating pumped storage. Given the hydroelectric profile of our generating resources, pumped storage appears to be particularly attractive to our region. Secretary of Energy Steven Chu emphasized this in his response to a letter written earlier this year by the four Pacific Northwest Governors, saying, "Pumped storage has unique potential in the Pacific Northwest where a higher percentage of wind generation has already been integrated into the region's transmission system than anywhere else in the Nation."

Pumped storage facilities have been in commercial operation for decades. The technology was originally conceived as a means of using low value surplus energy generated during nighttime hours to store water that could then be used to generate more valuable energy during heavy load hours. Systems that rely on large centralized coal and nuclear generation anticipated the need for pumped storage much earlier than hydro-oriented systems. This was because thermal generation was difficult to reduce during periods of low demand and to ramp up quickly to meet the next peak demand. In the WECC area—encompassing 14 Western states plus Alberta and British Columbia, Canada—the thermal dominated systems are located primarily in California and the inland Southwest. That's why the large, existing pumped storage plants in WECC are located in those regions.

The only existing pumped storage facility in the Pacific Northwest is in the state of Washington at Banks Lake, which is part of the Federal Columbia River Power System's (FCRPS) Grand Coulee complex. Its operation is largely dedicated to pumping water from Lake Roosevelt into Banks Lake to meet Bureau of Reclamation irrigation obligations. With the large recent penetration of variable renewable resources such as wind in the WECC area, pumped storage has the potential to be an additional resource that could be used to manage the variable output of wind projects and other renewable resources. BPA is currently exploring the potential for pumped storage in the Pacific Northwest, and expects to have its initial evaluation completed in mid-2010.

CONCLUSION

Mr. Chairman, I appreciate the opportunity to be here with you today and relate our experience in leveraging the reserve capabilities of the Columbia River power system in support of new renewable electric generation. We, our customers, wind developers, and our partner systems in the Western Interconnection have been on a steep learning curve. We will stay focused on the suite of measures I have described and continue our role in meeting the region's demand for new carbon-free resources. I am happy to respond to any questions from the Committee.

The CHAIRMAN. Thank you all very much. Thanks for the valuable testimony.

Let me start. Mr. Huber, I had breakfast with some folks this morning who were concerned—these are folks in the automobile industry, and they were saying that one of the challenges that we face in trying to move to plug-in hybrids is the lack of standardization and just the physical making available of the power to power the vehicles, I guess.

They were saying not only is there variation between communities and between States. There is also variation from building to building within communities. Now I don't know if this standardization of communications that you referred to with NIST doing, are

they trying to address that type of a concrete issue as well as the other types of standards that are needed to get to a smart grid?

Mr. HUBER. Mr. Chairman, there are many issues on the standards front, and some of them are being addressed by the Society of Automotive Engineers. That is the actual plug that is acceptable such that you can have public charging types of things.

The actual communications between the vehicle and its connection point is another standard that is being addressed by the Society of Automotive Engineers. NIST and EPRI and others are working together to do the communications capability to bring the information from the grid to the vehicle. So there is an awful lot of activity there.

There is a lot of concerns by the automotive companies, and my own perspective would be that the first generation of vehicles are not going to be as smart as what we would really like. But we are working closely with them, and I believe the evolution of those vehicles, when they start to become predominant, will be there.

The CHAIRMAN. OK. I think, Mr. Masiello, you were talking about the need for planning methodologies for the use of storage in meeting our energy needs, I guess. It would seem that as the demand, as the peak demand for a utility continued to rise, a logical thing to do to meet the additional peak requirement—a logical thing would be to make a judgment. Should we meet that additional peak requirement through additional generation or meet that additional peak requirement through storage of some kind?

As I am understanding you, you are saying that is not happening now, that kind of judgment is not made, or is it just that the options available for storage of power are insufficient to make that a real question?

Dr. MASIELLO. What I was trying to say is that the utility planning engineers who are doing the design of distribution circuits or new transmission lines or capacity increases in substations rely on well-established methodologies. They use software tools, proven, available from a handful of suppliers, and the regulatory commissions are accustomed to seeing the results of those studies.

Today, innovative utilities will start to look at storage as a solution. For instance, in west Texas, AEP put a 6–megawatt battery in a substation to solve a transmission reliability problem, and it was much more economical than putting in a redundant transmission line.

So the innovators are able to do it. But it is a very conservative industry, and utilities that don't have the engineering staff to solve the problems when they can't purchase the tools, say, will move more slowly.

The CHAIRMAN. So what was your suggestion as to how we get these planning methodologies developed?

Mr. MASIELLO. My suggestion was that, for instance, FERC could identify a point in time and say that as of, hypothetically, 2011 proposed new transmission projects, the plans for them should demonstrate that storage was considered as an alternative. Not necessarily approved or justified, but just that it was considered. I think that alone would trigger a lot of awareness and learning.

The CHAIRMAN. OK.

Senator Murkowski.

Senator MURKOWSKI. To continue, Mr. Masiello, you mentioned the issue of efficiency within storage and that is an area that we can really be looking to. I think you said about 70 percent efficiencies, but then you are losing 30. Are there any emerging technologies that we have either talked about here today or that are available that are more promising in terms of their level of efficiencies than others?

I know we don't want to be picking winners and losers, but I am curious to know where we might see some gains.

Mr. MASIELLO. Certainly. The advanced lithium ion technologies are well over 90 percent. The battery that Mr. Huber described in the PJM parking lot is one such. For regulation service in particular, high efficiency is very desirable.

A storage system that is purely backup power that is only charged and discharged once or twice a year has a completely different problem, which is you don't want it to lose energy through self-discharge the way a car battery can. So the answer I think is there are technologies with different characteristics, and we are still learning which ones are best suited for which application.

Senator MURKOWSKI. Mr. Huber, you and the chairman were talking about standardization. Just in terms of necessary infrastructure to accommodate the integration of plug-in vehicles, where there is the charging stations, the electric metering, what do we really need in terms of meeting the infrastructure requirements to fully integrate? I know that is loosely defined, but how do we integrate the plug-in vehicles into the system. How much do we need in terms of investment infusion?

Mr. HUBER. Yes. A lot of that infrastructure is in place today. The communications capability with the utility is in place. There are well-defined standards. We have to find the acceptance from all the players, the RTOs and ISOs, the utilities, and the vehicles, to actually adopt those standards.

The wireless communications to the vehicle is there to allow the communications. The charging infrastructure, the vehicles initially and even throughout are going to be primarily charged at home. So one of the infrastructure issues is for level one charging, 120 volts, to be able to plug in is pretty straightforward.

When they go to level two charging, where I need 240 volts in my garage or I need it where it is made available, that is going to be one of the early challenges from an infrastructure point of view.

Senator MURKOWSKI. You mentioned the fleet vehicles and how we deal with that.

Mr. HUBER. Yes, very attractive because if I am fleet owner, I can construct the infrastructure in my facility, have it optimized to my actual devices and the communications, have direct communications, even private communications back into the grid. So that is a very attractive alternative.

Senator MURKOWSKI. In my opening comments, I mentioned specifically my interest in the pumped hydro and recognized that it has been the workhorse for utility-scale energy storage. But we recognize that suitable locations for pumped hydro are considered limited.

Mr. Masiello, when was the last survey that we have had insofar as the potential sites for locating new pumped hydro? Do we have anything current out there that identifies?

Mr. MASIELLO. I believe so, but I think Dr. McGrath probably is better equipped to answer that.

Senator MURKOWSKI. OK. We will punt to you, Dr. McGrath.

Mr. MCGRATH. Yes, our laboratory is concentrating on identifying the resource base. More specifically, we tend to concentrate on non-hydro renewables. But as we heard earlier this morning, what is needed is an integrated simulation and model that can help us assess all of these capacities that are out there. These——

Senator MURKOWSKI. Do we have that model currently?

Mr. MCGRATH. I don't have the answer to your specific question around where are the resources for pumped hydro. In many respects, they are largely in place, as we heard from our friends at Bonneville Power. Many of the existing operations have some of that capacity in place. I believe the number is 21 gigawatts total of storage that is available currently across the country.

Senator MURKOWSKI. I assume we can add pumped storage stations to the existing hydro facilities. Is that correct, Mr. Mainzer?

Mr. MAINZER. We are certainly looking at that. We have an existing pumped storage facility at the Grand Coulee complex known as Bank's Lake. It is about 315 megawatts of capacity, and part of our assessment is to see if it would be possible to expand the capacity of that facility. So we are going to be getting a good look at that between now and the middle of next year.

More broadly, we are looking at the broader footprint of the Columbia River Power System to see if there are some other potential sites for pumped storage.

Senator MURKOWSKI. A follow-up questions because you prompted this, Dr. McGrath. At NREL, you have indicated that you are not really focused on the hydro side. Does the NREL model include the availability to add pumped hydro or the advanced battery technology?

Mr. MCGRATH. Absolutely, Senator. One of the things that we have done is to establish partnerships, very specific and detailed partnerships with, for example, the Idaho National Laboratory, that has responsibility for—specifically for commercial nuclear power, for the National Energy Technology Laboratory and their responsibility for fossil. So we are trying to work with our sister laboratories and with researchers around the country to pull together a comprehensive plan.

Within our Energy Systems Integration Facility, as I mentioned, we have advice coming from all of those different groups, looking to bring forward a collective system of energy information. I will use the word "Google" because we are, in fact, talking with them around putting together an energy information system that will allow planners and policymakers and technologists to access what are the potentials, where are the resources, how do we get at them, what is the state of the development of technology for their utilization?

As Dr. Koonin mentioned this morning, what would help us tremendously is that overarching model of this rather complicated system and all the variables and options that come forward. So, we

are looking forward to developing those models further in cooperation with experts from all areas.

Senator MURKOWSKI. Thank you. My time has expired, Mr. Chairman.

The CHAIRMAN. Senator Udall.

Senator UDALL. Thank you, Mr. Chairman.

Welcome to the panel. Dr. Masiello, thank you for your important testimony. Thank you also for taking some time to further educate me. I thought in your testimony, toward the end, there was a nugget of insight that really presents the opportunity that we have in front of us where you pointed out that the long-term implications of widespread mass deployment of storage across our power systems are profound.

It holds the promise of dramatically increasing capacity utilizations of the generation, transmission, and distribution system and essentially enabling a deferral of capital spending, which could go to other uses that our society identifies. It also, I think, would result in an ideal setting where consumer prices would remain steady, perhaps even you would see benefits there to the consumer.

So, in that spirit, I wanted to ask you about your testimony. You talked about loan guarantees would be a more effective tool than a tax credit. Do you envision such a loan guarantee program as supporting all types of storage, and could you expand?

Mr. MASIELLO. I offered that thought because merchant developers, whether it is wind or storage, usually can't make direct use of a tax credit. The practice was that they would do a sale leaseback or some other arrangement with, say, Citicorp who would then take advantage of the tax credit, and the developer would get that reflected somehow in the financing.

But the number of financial institutions in a position to take advantage of a tax credit has decreased, and consequently, developers can't create the same kind of financial packages to finance a wind farm or concentrating solar plant. So I was simply saying there may be other financial mechanisms, loan guarantees being one.

I am a power engineer more than a financial engineer. So I am not sure I can get too much beyond that.

Senator UDALL. Thank you for that thought.

Mr. McGrath, you mentioned that for renewable energy to really reach its full potential you have to have technologies for large energy storage developed and deployed. Can you expand a little bit on what NREL is working on to help us understand what type of technologies would be necessary and then how you would integrate those into the grid?

Mr. MCGRATH. As has been mentioned earlier, there are a variety of technologies ranging from flywheels to flow batteries and to larger systems such as pumped hydro and compressed air storage. We are working with a number of groups, the Electrical Power Research Institution among them, to look at these various technologies.

On the planning and policy side, the question also does come up again around where is the best place to deploy such storage? Is it large-scale storage at the point of origin of the power? For example, adjacent to the large-scale wind farm. If you put the stored energy

there, then you potentially can confront congestion on the distribution system.

Alternatively, the power or energy can be distributed and stored at the substation level or even at the community and residential level. So, there are tradeoffs both with cost and efficiency and system integration issues that come into play in all of those areas. Again, we are working with experts in all areas, trying to coordinate that type of analysis and planning.

Senator UDALL. So, at this point, you are exploring both the idea of a centralized storage approach and a decentralized storage approach. I understand you are currently working on a report that would touch on these issues. Is that correct?

Mr. MCGRATH. We have been tasked by the Department of Energy to have a look at the renewable energy futures study, which asks us to try to envision what large-scale deployment of renewable resources would look like at the scale of 50 or even 80 percent of our electric generation capacity. The question is what does such a State look like? What are the key elements of such a State?

Of course, storage is a high priority and necessary part of such a situation. But we are excited about conducting that work this year and next.

Senator UDALL. I am, too. I look forward to receiving a copy of it when you complete it.

Mr. Huber, if I could turn to you, you say that 34 megawatts of battery storage has been put into the PJM generation queue for 2010. Do you anticipate more storage after 2010? If so, how much? What do you expect the effect of that would be on the price of regulation services?

Mr. HUBER. Excellent, Senator. Actually, I anticipate more in 2010. Those are the initial two battery organizations who have come to us. One is lithium ion. The other is zinc air. We have been talking to many battery manufacturers who are looking at our regulation signal. We have got a test signal for them to look at.

So I believe there will be more coming in 2010. Some of the DOE grants actually had requested 100 megawatts of battery storage in the PJM territory that were not successful in the grant proposal. I foresee—I am not a good forecaster—hundreds in the next—I would say 500, 700 megawatts of battery in the PJM system is not unreasonable to expect. We are a huge system, probably at 90,000 megawatts today as our peak for a day like today.

There was another part of your question, and I——

Senator UDALL. The effect on the price of regulation services.

Mr. HUBER. Very interesting because certainly the automotive companies are looking at this well. What happens when we exhaust this? Because it is a very lucrative market today, and it is a very attractive market to enter into first.

I believe the transition will happen from that type of immediate regulation service to extended services, either early morning compensation for loss of wind or throughout the day compensation. Using these batteries for storage in the evening and discharge during the peak periods will be the evolution of this technology over time.

Senator UDALL. Dr. Masiello is nodding vigorously along with you in agreement.

Thank you again to this panel. This has been a very important hearing. I want to again thank the chairman and the ranking member for taking the time to convene us all and explore this real opportunity in front of us.

Thank you.

The CHAIRMAN. Thank you.

Senator Shaheen.

Senator SHAHEEN. Yes, I will echo Senator Udall's comments and everyone's here, really, on the panel. Thank you all very much for being here.

Given the interconnection between renewables that we are trying to incentivize and get deployed and energy storage, should we find a way to link promotion and deployment of energy storage to the incentives that we are trying to provide for renewables? I will just throw that out for any and all of you if you have a view of it?

Mr. MCGRATH. I will begin. But, yes, I think they are linked, and I think your question was around linking the incentives. Correct?

Senator SHAHEEN. Right.

Mr. MCGRATH. So, I would have to defer to some of my more skilled regulatory and financial colleagues. But certainly, I think our studies indicate that you can only get so far. Twenty percent wind may be a little beyond that, and then we are going to need storage.

It is a bit of a—right now, we are using natural gas and gas-fired generators effectively as our backup storage. That has some advantages and disadvantages, one of them being carbon footprint. The other one being, as we heard from Senator Wyden this morning, there is a lot of wind blowing out there. Let us not let it get away.

So if we are to capture it and save it for appropriate peak-hour use, obviously, we are going to need storage. Clearly, our policies need to incentivize that and help make it affordable, and then issues around who pays for what portion of it, of course, need to be thought through carefully.

So we need both technology development, sound and clear policy, and then real careful analysis tools that help us guide how both of those are developed.

Senator SHAHEEN. I don't know if—this is a follow-up to you. But as we are thinking about that, particularly the cost piece and how that is shared, are there examples—for all of you who are in the market now, are there examples that you can look to and say this is the way it is working that we think is working very well?

Mr. MASIELLO. There is a model to look at in the natural gas industry where gas storage resources, whether it is in the physical pipeline or in an actual cavern, say, are an asset that is operated by the storage owner. The merchant side—the gas producers, the gas traders—pay a fee for the use of the storage. But they retain the equity ownership of the gas.

That model could apply, for instance, if a regulated transmission company had storage on the grid which was a regulated asset, regulated cost recovery, and the merchant side of the power equation, the generators and the traders, made use of that on a fee basis. Because right now, there is a lack of clarity in policy and regulatory treatment in the deregulated electric power markets over that problem.

The regulated wires company is taking delivery of the electricity at night when it is cheap and redelivering it to consumers during the day when it is expensive. That arbitrage profit in today's world should be on the merchant side.

That lack of clarity is another hurdle, shall we say, to moving forward, and I believe FERC is taking it up and plans to resolve it.

Senator SHAHEEN. Just to be clear, the example that you are talking about, the cost is on the rate base for the ultimate end-users of the power?

Mr. MASIELLO. That is really a good question. If it is a rate-based asset, then the transmission utility is charging a rate per megawatt hour on the grid, and that is ultimately borne by the consumer. If it is not a rate-based asset, then a merchant operator of storage is trying to make money on it, and the generator or the trader would mark up the cost of the wholesale energy, which is, again, passed to the consumer. So it is different mechanisms.

Senator SHAHEEN. Thank you. My time is up.

The CHAIRMAN. I did not have additional questions. Did you have anything else you wanted to ask ofthis panel?

Senator SHAHEEN. Actually, if I could just follow up on one other issue that you raised earlier?

The CHAIRMAN. Go ahead.

Senator SHAHEEN. You talked about, Dr. Masiello again, that FERC—that one example you used was requiring FERC to consider storage before approving new generation. In that kind of a consideration, are there other things that ought to be looked at other than just the cost? So, as we are thinking about generation, we look at environmental impacts, lots of other things. What else, as we are thinking about storage——

Mr. MASIELLO. Yes, I actually should have been more clear. I was saying in the context of transmission planning, I believe that the generation developers will be pretty aggressive at looking at it if they think they can make money. The difficulty is when it is a transmission or a distribution asset, and the regulatory approval process is today unable to make an informed decision. So that is what I was saying. It would be one mechanism to spur it along.

Senator SHAHEEN. Great. Thank you for the clarification.

Did anybody else want to add to that?

[No response.]

Senator SHAHEEN. OK, thanks very much.

The CHAIRMAN. Thank you all very much.

This has been useful testimony, and I think it has been a good hearing.

Thank you very much. That will conclude our hearing.

[Whereupon, at 11:57 a.m., the hearing was adjourned.]

APPENDIXES

APPENDIX I

Responses to Additional Questions

RESPONSES OF STEVEN E. KOONIN TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Under Secretary Koonin, where does the US stand compared to China/Japan/Korea in developing grid scale energy storage technologies? It is my understanding that these countries are now investing heavily in this area, leveraging their significant expertise and capacity in the vehicle battery sector.

a. How much are we spending on grid-scale energy storage research, development and demonstration compared to those nations?

b. What we need to do maintain our leadership in this area?

Answer. (a). The Departmental approach to energy storage spans the full RD&D chain, from basic research through technology demonstration projects. The Office of Electricity Delivery and Energy Reliability (OE) is the focal point for development and demonstration of grid-scale energy storage technologies within the Department of Energy. Funding for OE's energy storage program was $3.5 million in Fiscal Year (FY) 2009 and $14 million in FY 2010. In addition, under the American Recovery and Reinvestment (Recovery Act), the Department awarded $185 million for grid storage demonstration projects, and $30 million to date for Advanced Research Projects Agency-Energy's (ARPA-E) advanced battery research. Further, while not specifically investing in grid-level applications, the Office of Science is supporting basic research by funding a host of projects including six Energy Frontier Research Centers that are directly related to energy storage, and the Office of Energy Efficiency and Renewable Energy funded $39 million of research in 2009 to move the state of the art for vehicular electrochemical batteries.

Private industry and several States are also actively investing in the development of new grid-level storage technologies; the investment community is becoming interested in providing venture capital for companies developing new technologies and in funding ambitious large scale projects; and utilities are increasingly considering storage demonstration projects.

The Chinese government is investing approximately $100 million in energy storage research annually. Chinese researchers are investigating sodium sulfur batteries and several flow battery systems. In addition, the Chinese Academy of Science just announced development of a 650 amp-hour sodium sulfur battery by the Shanghai Ceramic Institute.

The Japanese government mandates that new wind developments can be built only with appropriate energy storage capability installed. However Japan provides one-third of the cost of a new storage facility to the owner. Research is carried out by Japanese industry on sodium sulfur batteries, flow batteries, and lead carbon batteries.

Answer. (b). Key performance characteristics such as cost, durability, energy density, and power must be improved if the U.S. is to maintain leadership in grid energy storage technology. These improvements will be enabled by continued Departmental efforts ranging from basic research to demonstration projects for promising storage technologies. In addition to these technology advances, significant improvements are necessary in the analytic tools data and parameters used to characterize storage technologies in modeling the grid.

In deregulated energy markets, where generation, transmission, and distribution assets can be owned and operated by different groups, the economic and operational value of individual storage technologies must be fully characterized for each applica-

tion. Without such detailed understanding, and until these benefits can be fully modeled and incorporated into economic and operational planning tools for the grid, deployment rates for grid scale storage will not reach potential.

Question 2. Under Secretary Koonin, concerning the DOE Energy Storage Demonstration Grants, how soon can we expect the Department to obligate funds to the award winners so that these projects can proceed?

Answer. Selections of Recovery Act demonstration projects were announced by Secretary Chu on November 25, 2009. Grants are expected to be awarded by the second quarter of FY 2010.

Question 3. Under Secretary Koonin, some of the commercial software that grid planners use today grew out of previous DOE-funded research. What is DOE doing to help develop grid planning software that takes account of energy storage and renewable energy? What are the national labs doing to support transmission planning models and software? How much funding is going towards this work now, and how does this compare to past funding levels?

Answer. The Department's Energy Storage Program in the Office of Electricity Delivery and Energy Reliability will fund a new project beginning in FY 2010 to develop energy storage modules for commercial grid planning software. A second project will utilize existing grid modeling software at a national laboratory to analyze the applicability of storage in specific sections of the transmission grid, such as the Bonneville Power Authority system. These efforts are funded at a level of $650,000 in FY 2010; FY 2009 funding for these type of activities was $50,000. In addition, through Recovery Act funding the Department recently announced grants totaling $60 million for interconnection-level infrastructure planning; the planning effort, which will make use of national laboratory support, will incorporate energy storage as one of a range of technological options. The Department's Office of Energy Efficiency and Renewable Energy has begun a study to evaluate the barriers and opportunities associated with significantly increasing the integration of multiple sources of renewable electricity into the electric grid. The study, planned to be completed in 2010, will evaluate and quantify the need for energy storage in scenarios with very high penetration of renewable energy generation.

Question 4. What data does the Federal government collect on grid-scale energy storage? Does it fit into the data collection forms used by the EIA and the FERC? If not, what work is underway to add energy storage to these data collection forms?

Answer. The U.S. Energy Information Administration (EIA) currently collects some limited electricity storage data. Additional collection of storage data is planned for EIA's updated electricity surveys that are scheduled for deployment starting in January 2011.

Electricity storage data are currently collected by EIA for pumped hydroelectric and compressed air energy storage (CAES). The most recent annual net summer capacity data (2007) show that the United States has 21,886 megawatts (MW) of hydroelectric pumped storage capacity. Operational data for 2008 show pumped hydro generated 25.3 million megawatt-hours (MIMI) and required 29.6 million MWh for pumping.

EIA's proposed revisions to electricity surveys were in the public-comment phase in the fall of 2009 (see the October 15, 2009, Federal Register Notice at http://www.eia.doe.govicneaf/e1ectricity/page/fednotice/elect_2011.html); the comment period closed on January 15, 2010. Storage-related proposals include:

- storage associated with dispersed and distributed generation data (by fuel type categories); and
- capacity and generation for flywheel, thermal, and battery technologies that supply electricity to the grid and have at least 1 MW of capacity.

The Federal Energy Regulatory Commission (FERC) also addresses energy storage in its data collection. The FERC "Annual Report of Major Electric Utilities, Licensees and Others" and "Annual Report of Nonmajor Public Utilities and Licensees" contain financial and operational data for pumped storage. This information includes plant identities, depreciation and amortization charges, generation data, construction year, operational year, and other specifics. Balance sheet information (i.e., electric plant in service and additions) is also available for "storage battery equipment." EIA defers to FERC for additional information on its energy storage data activities.

Question 5. How are DOE and FERC working together to develop and deploy grid-scale energy storage technologies?

Answer. Department of Energy (DOE) develops energy storage technologies. The Federal Energy Regulatory Commission (FERC) regulates interstate transmission and sale of electricity. FERC has been proactive in evaluating the potential for energy storage, devising market mechanisms appropriate for energy storage tech-

nologies, and directing Regional Transmission Organizations to provide a level playing field for the application of storage technologies. In response, the New York Independent System Operator (NYISO) requested FERC approval for new storage-oriented market rules, which FERC approved in May 2009, and a 20 megawatt flywheel system in NYSIO has been issued a conditional comittrnent under DOE's Title XVII loan guarantee program. In addition, in FY 2010, the DOE Wind Program is supporting the FERC Office of Energy Policy with a full-time expert from the National Renewable Energy Laboratory who provides renewable grid integration and transmission technical and analytical expertise.

FERC and DOE are aware of activities in each other's programs. Successful introduction of energy storage technologies into the grid depends on the success of efforts by both organizations.

RESPONSES OF STEVEN E. KOONIN TO QUESTIONS FROM SENATOR MURKOWSKI

Question 1a. Many of the battery technologies and the magnets used in electric motors utilize rare earth minerals, much of which are currently imported from China.

If so, does the government have a role in researching alternatives to the use of rare earth minerals in batteries and magnets?

Answer. Rare earth materials are not a major issue for battery technology (although transition metal availability is important for batteries). However, for electric motor technologies, availability of rare earth materials is a significant issue. There are some options that can help minimize the impact of rare earth minerals' availability. One option is induction motor technology, which can be practical for certain applications but tends to be less efficient. Improving the efficiency of induction motor technology is one area of research underway in the Department's Vehicle Technologies Program.

Even for traditional motor technology the need for rare earth materials can be minimized, or perhaps even eliminated, through research and development (R&D). Because alternative magnet compositions that do not have rare earth materials are typically not strong enough to be practical, the Department has initiated R&D to both minimize rare earth content and improve the performance of non-rare earth magnets (the subject of a recent ARPA-E project grant).

Additional research has been initiated by the Department and others, including the Department of Defense, and studies have been conducted by the U.S. Geological Survey and the National Academies in this area.

Question 1b. Given the importance of rare earth minerals for energy storage applications, do we have sufficient knowledge of the availability of rare earth mineral deposits in the U.S.?

Answer. There is a reasonable knowledge of U.S. rare earth mineral resources through the U.S. Geological Survey. Undeveloped deposits in the U.S. and across the world have been identified (although these are typically not as favorable as the Chinese deposits). One excellent U.S. deposit is the Molycorp site in Mountain Pass, California, near the Nevada border. This site was active until a few years ago and is attempting to restart mining operations. The Department is collaborating with Molycorp through work at Ames National Laboratory. This work is aimed at improving the performance of rare earth magnets, as well as minimizing the processing required to produce magnets which is a major cost factor.

Question 2. In your testimony, you reference a situation in West Texas during one month in 2008 where wind generation resulted in over nine hundred 15 minute intervals of negative pricing. "Negative pricing" essentially means that you have more generation than demand since, and is supposed to serve as a signal not to produce electricity at that time. However, I understand that in Texas, wind generators will continue to offer their energy at negative prices in order to get the federal Production Tax Credit and the value of a state Renewable Energy Credit. Additionally, due to transmission constraints, wind developers can be paid to remove their production from the grid. Please comment on this situation.

Answer. Negative pricing in energy markets sends a variety of signals to market participants and is an artifact of transmission constraints within a system. Even during periods of negative pricing, positive pricing exists beyond the transmission constrained wind energy areas, thereby indicating a demand opportunity for energy exists. The transmission system operator within Texas, the Electric Reliability Council of Texas (ERCOT), is currently working though its Competitive Renewable Energy Zone process to upgrade the transmission system in West Texas and increase the transfer capacity for wind energy. These upgrades are expected to greatly reduce occurrences of negative pricing in the region. There is also considerable in-

terest in energy storage in the area, including a 20 megawatt demonstration project recently selected for an American Recovery and Reinvestment Act award.

Question 3. Compressed air energy systems are considered an energy storage mechanism because electrical energy is used to compress air that is stored in a pressurized reservoir. Given the fact that compressed air energy systems require some method to use the compressed air to make electricity, should these systems be classified as a generation technology or a transmission and distribution technology?

Answer. Compressed Air Energy Storage (CABS) systems differ from other energy storage technologies in that many use natural gas to heat the compressed air prior to generating electricity. This is similar to a generator except that, in effect, two-thirds of the electricity generated by a CAES system was stored at an earlier time through physical compression of air. Additionally, while the most common current implementations of CAES systems use both compressed air and natural gas synergistically, the compression and storage of air is a significant and necessary aspect of system function while combustion is not. Furthermore, new forms of CABS currently under development will require little-to-no natural gas in order to transition the stored energy from compressed air back to electricity.

Grid scale energy storage is neither a generation asset nor a transmission and distribution (T&D) asset, but is in a category of its own. Categorizing storage either as a generation or T&D asset limits the possible uses of energy storage. In some areas, classifying storage as a generation asset would prevent transmission or distribution utilities from owning storage and obtaining the benefits storage can provide.

Question 4. You testified that several types of rechargeable batteries are being tested and installed in pilot projects by the utility industry. What is the typical useful life of rechargeable batteries as compared to other forms of grid-scale energy storage? How does the per-kilowatt cost of a battery compare to existing pumped storage systems and compressed air energy storage systems?

Answer. The expected life of rechargeable batteries varies and depends on the type: sodium sulfur batteries have an expected lifetime of 20 years; lead acid battery systems typically need cell replacement every 4 to 6 years, depending on the application; and flow batteries and lithium-based batteries have minimum expected lifetimes of 10 years or greater. Ongoing research is exploring a new class of lead carbon batteries with greatly increased lifetime as well. The current cost of sodium sulfur systems is approximately $2500 per kilowatt (kW), Flow batteries (an emerging technology) range from $800 to $4,000 per kW; pumped hydro systems cost approximately $200 to $800 per kW depending on size and terrain; and CABS are estimated to cost $800 to $1000 per kW. However, these storage technologies have different storage periods, and many of these cost figures are estimates only since the technologies are not yet fully commercial.

RESPONSES OF STEVEN E. KOONIN TO QUESTIONS FROM SENATOR WYDEN

Question 1. As we discussed in the hearing, energy storage technologies have many promising applications—from enabling deployment of large amounts of intermittent renewables, to helping meeting peak demand, to more effectively managing the electric grid, to deployment in hybrid and plug-in vehicles. As noted in your testimony, no less than four separate offices within the Department are engaged in some form of research and demonstration efforts involving storage technologies. You committed to provide a road map—an overall strategy—for how the Department is going to pursue the development of storage technologies. I expect this road map to cover research, development, and demonstration projects of energy storage technologies, including integration technologies, over the next few years. I also expect the road map to address the full range of potential storage technologies and applications, not just those technologies that are not currently in the DOE's portfolio. You committed to providing this plan within 60 days, admittedly an ambitious schedule. Please confirm your commitment on behalf of the Department to provide this plan.

Answer. The Office of Electricity Delivery and Energy Reliability (OE) is working with the Offices of Science, Advanced Research Projects Agency-Energy, and Energy Efficiency and Renewable Energy to develop a strategy for supporting research, development, and deployment of grid storage technologies, in response to this request. The Department expects to provide the strategy to the Committee within 60 days.

Question 2. Your written testimony of the issues surrounding energy storage was fairly complete, touching on the important issues. However, there were some noticeable gaps in some of the technologies and applications, particularly fuel cells, hydrogen, and on-premises storage.

Answer. The Department's recent analysis concluded that additional research and development will be required to make hydrogen economically competitive as an en-

ergy storage medium. The study compared the life cycle costs of energy storage technologies including: pumped hydro, compressed air energy storage (CAES), nickel-cadmium batteries, sodium-sulfur batteries, vanadium flow batteries, and hydrogen combustion turbines. The report can be found at www.osti.gov/servlets/pur1/968186-wRSj x1/.

Current hydrogen and fuel cell R&D efforts focus on reducing the cost and increasing the performance and durability of both water electrolyzers and fuel cells. With success in these efforts, hydrogen as an energy storage technology could be competitive with batteries but may not be competitive with the largest scale systems that use CAES or pumped hydro.

Question 3. The DOE's hydrogen program was recently restored after originally being cut earlier this year. Please describe the relationship between the hydrogen program and the energy storage program. What will the Department be doing in the future to integrate them? How much emphasis will the Department be placing on fuel cell technology, both for generating hydrogen as stored energy and for generating electricity for power? Will the Department look at the potential for transporting hydrogen through pipelines as an alternative to building electric transmission lines?

Answer. The hydrogen and energy storage programs continue to coordinate related activities. To evaluate the feasibility of hydrogen for energy storage, the Department's hydrogen program is operating a small scale water electrolyzer with hydrogen storage and electricity generation at the National Renewable Energy Laboratory in collaboration with Xcel Energy. The Department's Hydrogen and Fuel Cell Technologies Program is also identifying regions where hydrogen and fuel cells may be a viable option for energy storage or combined heat and power for distributed generation due to high electricity costs and available power from renewable energy sources. These activities will help guide research and development for hydrogen technologies while providing useful information on the challenges of using hydrogen as grid energy storage. To address hydrogen infrastructure and transmission issues the Department is evaluating a number of options, including hydrogen delivery through pipelines as a potential long-term approach.

Question 4. Your written testimony discussed grid-connected distributed energy storage. However, other than a passing mention of electric vehicles, you did not mention any research or development activities related to on-premises storage; i.e., on the customer side of the meter. There are many opportunities for innovative solutions, including ice-storage systems running at night instead of air-conditioning compressors running during peak times of the day. End-users who install solar panels or small wind turbines may benefit from on-site storage for the same reasons that utilities do for intermittent renewables. What will be the DOE's program for extending energy-storage research and development into systems that might be on customers' premises?

Answer. The economic cost points for on-premises energy storage of distributed generation would likely be significantly less than those for advanced electric vehicle applications. Suitable technological solutions could come from the current candidates for vehicle batteries, large scale utility battery systems, or a new breakthrough technology. The Department's programs are exploring options, including on-premises active and passive thermal energy storage systems. As these programs progress, the Department will use the results to develop specific initiatives that address the challenging requirements of distributed storage. Active and passive solutions such as running ice-storage systems at night instead of air-conditioning during the day or using a building's mass for thermal storage have the potential to reduce building energy use and result in lower peak electricity demand. Pacific Northwest National Laboratory's work on Efficient Low-Lift Baseload Cooling Equipment offers increased energy saving by cooling a building at night and using the building mass for theiinal storage.

Question 5. In his testimony, the Deputy Director of NREL—Bob McGrath—stated that electrical energy produced by wind up "to 20% of U.S. capacity" can be integrated into the grid without the need for storage, which was based on an NREL study. By repeating this statement, which is also prominently used by the American Wind Energy Association (AWEA), DOE gives the impression that the grid does not yet need energy storage. Yet Bonneville Power Administration has already experienced operational problems at current levels of wind generation, and wind farms in Texas are paying customers to buy the electricity they produce at certain times during the night because there is inadequate demand at that time.

Answer. DOE's *20% Wind Energy by 2030* report is based on an analysis scenario that assumes power system operators utilize a broad suite of other available, typically less capital-intensive, sources of system flexibility to accommodate wind energy's added variability. These sources of flexibility can include the use of larger bal-

ancing authorities, the use of sub-hourly energy scheduling, and the addition of new gas-fired generation. In addition, pumped hydro is used by many utilities, providing 2.5 percent of the Nation's generation capacity. There is also considerable interest in Compressed Air Energy Storage, including two demonstration projects totaling 450 megawatts recently selected for American Recovery and Reinvestment Act awards. In addition, a growing need for frequency regulation can be cost effectively met by fast storage.

System operators, such as the Bonneville Power Administration, are currently evaluating how to best incorporate system flexibility options into their operations. As more of these operational changes are implemented, higher levels of wind energy and other variable energy sources can be integrated at lowest cost. Storage technologies are also under consideration as an option for augmenting integration capability beyond that available from operational changes. Under certain circumstances, the addition of storage may be required to balance the variability associated with wind generation.

Question 6. Furthermore, the NREL study did not address combinations of inteimittent technologies; e.g., is storage needed if wind is 15%, but solar rises to 10%? The "Eastern Wind Integration and Transmission Study" suffers from the same lack of breadth; again, we do not know if there are better solutions that use storage technologies unless they are actually included in these sorts of Department sponsored studies. What steps will DOE take to ensure that storage technologies be considered in future work on the electrical infrastructure?

Answer. The analysis tools and datasets necessary to perform integrated reliability studies incorporating multiple variable generation technologies are continually being developed and improved. Only recently have these tools achieved a level of maturity which allows for the creation of meaningful results, and studies that are still being completed will include evaluation of multiple variable generation and energy storage technology options. For example, DOE's Western Wind and Solar Integration Study will evaluate energy penetrations of up to 30 percent wind energy and five percent solar energy. This study will include analysis of the energy storage capabilities of concentrating solar power systems and existing and planned pumped hydroelectric storage. Another study currently underway is the Renewable Energy Futures Study, which will analyze the barriers and opportunities associated with significantly increasing the integration of multiple sources of renewable electricity into the electric grid. The study, planned to be completed in 2010, will evaluate and quantify the need for energy storage in scenarios with very high penetration of renewable energy generation. Finally, the Department also seeks to support interconnection-wide transmission planning that will include analysis of energy storage opportunities. Through evaluation of the energy storage deployment projects funded through the Recovery Act, knowledge of grid-scale storage technologies and associated characteristics will improve thereby enhancing the value of current and future integrated technology analyses.

RESPONSES OF ELLIOT MAINZER TO QUESTIONS FROM SENATOR MURKOWSKI

Question 1. Of the 2,300 MW of wind now connected to BPA's system, what is the actual percentage of electricity that is produced from that nameplate capacity?

Answer. Actual generation compared to plant nameplate capacity averaged 28 percent in the twelve months ending November 2009. Also, as of January 12, 2010, with the recent addition of three more interconnections totaling nearly 400 megawatts, we now support a total of 2,680 megawatts of wind capacity.

Question 2. In order to deal with the variable nature of wind energy, BPA is now using its hydroelectric system as a giant storage battery. Is there a limit to the amount of wind energy that you can accommodate given its intermittency while also maintaining the reliability of your electricity transmission? How can pumped storage assist BPA?

Answer. There will be a limit to the amount of hydroelectric system flexibility BPA can use to balance variable resources. BPA has been able to utilize the capability of our hydroelectric system to accommodate wind generation increases through the implementation of the initiatives I described in our testimony and as the wind industry responds to new operating protocols and improves their scheduling accuracy. With all of these improvements, we estimate that using our hydrosystem alone we can reliably integrate approximately 4,000 megawatts of wind generation capacity. We expect that amount to continue to increase as we succeed in implementing our priority wind integration initiatives.

Pumped storage offers potential value when we have exhausted the operational protocols that we can implement and need additional storage capacity to support a

higher level of variable generation. As I mentioned in my testimony, BPA is studying the feasibility of pumped storage in the Columbia River Power System, and we expect to have more information in mid-2010.

Question 3. Of course maintaining an additional reserve capacity to support the wind resources now in the BPA system has resulted in increased costs for consumers. To address these costs, BPA has imposed a wind integration rate on wind generators that was not without controversy. I understand that BPA believes this price signal for wind integration costs has encouraged wind operators to operate more efficiently. Please elaborate on the amount of the increased costs and the wind generators' response.

Answer. BPA believes that the efforts we undertook in the last rate case did in fact motivate wind operators to improve their scheduling accuracy, which resulted in lower costs to BPA and a lower rate to the wind generators. Our cost of providing generating reserves to support variable wind generation is the primary driver for the wind integration rate. When we conducted the rate case for fiscal years 2010 and 2011, we noted that those costs are significantly affected by the wind plants' scheduling accuracy. The closer actual generation matches schedules, the smaller the amount of generation reserves we need to maintain relative to the amount of wind generation connected to our system. Our initial rate case proposal for the wind rate was $2.72 per kilowatt/month. We worked with the wind industry on measures to improve scheduling accuracies, and they accepted more risk that their generation could be curtailed at certain times if their schedules were not sufficiently accurate. Our final rate of $1.29 per kilowatt/month—less than half of our initially proposed rate—was significantly influenced by these agreements that allowed us to reduce the amount of reserves required for wind generation.

RESPONSE OF ELLIOT MAINZER TO QUESTION FROM SENATOR WYDEN

Question 1. BPA's Strategic Objectives include the statement, "Climate change concerns also are driving major new investments in renewables, energy efficiency, smart grid, new large-scale storage and the electrification of transportation." As noted in your testimony, pumped hydro storage is also being considered as part of BPA's wind integration efforts. However, there are many other types of storage technologies, such as compressed air, fly wheels, and batteries that are being developed to store and manage grid-connected energy systems. What are BPA's specific plans for examining and deploying energy storage technologies for both grid management and to help bring more renewable energy into the grid? Please provide copies of the applicable plans and planning documents.

Answer. BPA is examining energy storage options through a set of evaluations that will be conducted through mid-2010. The Pacific Northwest National Laboratory (PNNL) conducted a nationwide evaluation of storage technologies to accommodate large amounts of variable renewable generation. This evaluation included a variety of storage technologies. BPA has asked PNNL to use this information for an evaluation of the application of a broad array of storage technologies, including pumped hydro and compressed air, to the characteristics of the Pacific Northwest. With this information, BPA will complete a study of the potential for pumped storage in the Pacific Northwest as one option. These studies will consider power system requirements for capacity and ramp rates for the various storage technologies. BPA will share this analysis with you upon its completion.

BPA's draft Resource Program forecasts what resources it may need to meet its power supply obligations in the next ten years. The draft Resource Program concludes BPA should be able to meet its near term requirements through energy conservation and that longer term requirements depend on a number of uncertainties, one of which is, the amount of additional load its preference customers ask it to supply under the terms of the Regional Dialogue. The draft Resource Program identifies BPA's need to provide balancing services for wind and energy in Heavy Load Hours as being the largest and most likely power need after conservation.

The draft Resource Program identifies pumped storage as a unique opportunity to meet those needs, and points to the evaluations described above as needed to assess this potential. The draft Resource Program also discusses how BPA's wind integration activities provide more efficient use of BPA's existing capacity reserves before it needs to develop new generating capacity resources to support variable renewable generation. We have attached a copy of the draft Resource Program. The draft BPA Resources Program Plan can be found at: http://www.bpa.gov/power/P/ResourceProgram/documents/2009-0930__DraftResourceProgram.pdf.

RESPONSES OF JON WELLINGHOFF TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Chairman Wellinghoff, in your testimony, you discussed the need for considering energy storage in transmission planning. S.1462 includes energy storage as an alternative that must be considered in transmission planning. Is this sufficient? What other legislative language may be necessary?

Answer. As you note, I believe that it is appropriate to consider energy storage as part of the transmission planning process. The requirement in S.1462 that energy storage must be considered as an alternative in transmission planning is sufficient for this purpose and is an important reinforcement of the Commission's actions.

The Commission took an important step to promote such consideration in February 2007, when it issued Order No. 890. In Order No. 890, the Commission required all transmission providers to develop a regional transmission planning process that satisfies nine principles, one of which is comparability. To reflect that principle, the Commission required transmission providers to outline in their tariffs how they will treat comparably in the transmission planning process all resources, including nontraditional resources that could impact the need for transmission expansion.

I would also note that the Strategic Plan that I provided to Congress this fall states that as transmission providers refine their transmission planning processes, the Commission will assess best practices, including the potential for collaborative decision making, and adopt reforms as necessary to its transmission planning process requirements. Toward that end, Commission Staff this fall completed a series of conferences held around the country to review how well the transmission planning requirements of Order No. 890 are meeting the needs of our Nation, and to collect input as to how the Commission can improve upon the regional transmission planning processes.

The Commission is now in the process of reviewing comments that were submitted in response to questions that Commission Staff posed as a follow-up to the conferences held this fall. Among many other issues, commenters discussed the relationship between the regional transmission planning processes that must satisfy the principles established in Order No. 890 and the integrated resource planning processes through which load-serving entities in some states, and often their retail regulators, identify appropriate investments to meet consumers' long-term resource needs. That issue may be particularly relevant for energy storage, which has some characteristics that resemble generation and some characteristics that resemble transmission. In addition, because energy storage often interconnects at relatively low voltages, considering these resources in the transmission planning process often requires information about the portion of the electric system for which disputes are most likely to arise as to classification as transmission or distribution facilities.

Question 2. Chairman Wellinghoff, how is energy storage currently addressed in transmission and generation planning processes? What planning, analysis, and modeling tools do we need to develop to be able to determine where to best site storage technologies?

Answer. As discussed above in my response to your first question, the Commission in Order No. 890 required transmission providers to treat comparably in the transmission planning process all resources, including non-traditional resources that could impact the need for transmission expansion. More specifically, energy storage technologies are considered by transmission and generation planners as part of the portfolio of potential solutions to manage costs, assure resource adequacy to serve load, and maintain the reliability of the grid. Energy storage technologies also may be attractive to independent developers in light of their potential to provide profits through the differences in energy prices between off-peak and peak periods. In addition, there is a close relationship between the development and implementation of energy storage and our Nation's ability to harness the potential of our renewable energy resources.

Planners and developers regularly use power flow studies (or load flow studies) to determine the limitations of the grid when interconnecting new customer loads and generation sources and when anticipating growth in demand from existing customers. For a power system to accept the new load and/or generation, it must be deemed reliable and therefore resilient enough to withstand pre-defined events. Power flow studies are used to determine whether transmission overloads would result if these events occurred and whether system improvements such as new transmission are needed to achieve the desired performance.

Planning studies traditionally have focused on peak load conditions to ensure that there would be adequate generation and transmission capacity to meet the maximum forecasted demand. However, the development and deployment of significant levels of renewable energy resources requires a new focus on the capability of the

grid to accept variable generation when it is being produced. For some types of renewable energy resources and in some areas, that production is likely to be greater during periods of relatively low demand; energy storage can play an important role in addressing that issue. In addition, the development and implementation of improved forecasting tools could assist system operators in reliably and efficiently utilizing renewable energy resources in conjunction with dispatching and replacing stored energy.

Question 3. Chairman Wellinghoff, what kinds of system information-sharing and collaboration must exist, to ensure that storage and distributed renewable generation (two sides of the same coin) can be effectively dispatched such that the bulk power grid is managed most reliably and efficiently? What role must interoperability and cybersecurity standards play, to ensure this becomes a reality? How do transmission system operators need to change their practices and software to accommodate efficient dispatch of energy storage?

Answer. I agree that there is a close relationship between the development and implementation of energy storage and our Nation's ability to harness the potential of our renewable energy resources. As I stated in my December 10, 2009 testimony to this Committee, energy storage can make integration of renewable energy resources not only reliable, but also efficient and cost-effective.

Illustrating this point, I noted in my December 10, 2009 testimony that some energy storage technologies appear able to provide a nearly instantaneous response to regulation signals, in a manner that is also more accurate than traditional resources. These characteristics could reduce the size and overall expense of the regulation market. Most existing tariffs or markets do not compensate resources for superior speed or accuracy of regulation response, but such payment may be appropriate in the future as system operators gain experience with the capabilities of storage technologies. In the meantime, the unique characteristics of energy storage technologies could warrant different market rules for providing energy and ancillary services than those established based on the characteristics of traditional resources.

I also agree that increased information sharing and collaboration are important to ensuring that renewable energy and energy storage resources are incorporated into the electric system and dispatched in a reliable and efficient manner. For example, modeling for the type of power flow studies that I noted above in response to your second question will need to include these resources and will require information sharing. Energy management system equipment and software may need to be revised to properl y model energy storage facilities, such as to indicate time to respond to dispatch signals, time-to-depletion, or time remaining until full storage.

Another example of information sharing and collaboration stems from the distributed nature and relatively small scale of many energy storage resources. To ensure their reliable and efficient use, such resources may need to be aggregated and remotely dispatched and verified. These needs could be met through two-way communications between the energy storage resource and the local balancing authority's control center (where generation and load are balanced) to monitor the availability of the resource and to issue commands for the resource to generate or store electricity.

It is noteworthy that the combination of dispersed locations and two-way communications presents both physical and cyber security issues. For example, it is essential to ensure that communications with the local balancing authority's control center are secured to prevent the use of those communications as an entry point to evade the control center's cyber security protection measures. The mandatory and enforceable cyber security standards applicable to the electric industry are the Critical Infrastructure Protection (CIP) reliability standards developed by the North American Electric Reliability Corporation (NERC) and eight Regional Entities, subject to the Commission's oversight. However, these standards apply to only the bulk power system, thereby excluding facilities, including some energy storage and distributed generation resources, which are interconnected to the distribution system. Moreover, the Commission has directed that NERC make major modifications to the CIP reliability standards, and until such time as those revisions are completed, the standards are inadequate to assure protection of the bulk power system.

Separate from the NERC process for developing mandatory and enforceable reliability standards, the Energy Independence and Security Act of 2007 (EISA) directs the National Institute of Standards and Technology (Institute) to coordinate the development of a framework to achieve interoperability of smart grid devices and systems. The EISA also directs the Commission, once it is satisfied that the Institute's work has led to "sufficient consensus" on interoperability standards, to institute a rulemaking proceeding to adopt such standards and protocols as may be necessary to ensure smart grid functionality and interoperability in interstate transmission of electric power and regional and wholesale electric markets. It is unclear at this time

to what extent the standards that result from the Institute's process will address the cyber security or physical security of distributed smart grid devices and systems.

In July 2009, the Commission issued a Smart Grid Policy Statement that discussed its above-noted responsibility pursuant to EISA. Among other steps, the Smart Grid Policy Statement identified the development of cyber security standards as a key priority in protecting the grid and identified electric storage as a key functionality of the smart grid, stating that standards related to storage should be treated as a priority in the Institute's process. The Smart Grid Policy Statement also noted that EISA does not make any standards mandatory and does not give the Commission authority to enforce any such standards. Although the Commission will not itself develop or enforce these standards, the Commission continues to encourage the Institute and standards development organizations (SDOs) participating in the Institute's process to ensure that the reliability and security, both cyber and physical, of the bulk power system is a priority in their standard development work.

Question 4. Chairman Wellinghoff, how are DOE and FERC working together to develop and deploy grid-scale energy storage technologies?

Answer. DOE and the Commission play different but complementary roles on this issue. As Under Secretary Koonin described at this Committee's December 10, 2009 hearing, DOE is directly supporting research and development and pilot projects for energy storage and related technologies. The Commission's role, meanwhile, involves in part ensuring appropriate treatment of and compensation for energy storage resources that participate in Commission-jurisdictional markets.

Such roles are among those recognized in the Memorandum of Understanding (MOU) that DOE and the Commission entered in December 2009 with respect to the Resource Assessment and Interconnection Planning project funded by the American Recovery and Reinvestment Act of 2009. The MOU observes that energy storage and other non-traditional resources will play an increasing role in meeting the energy needs of consumers. The MOU also states that the long-term transmission plans to be developed through the Resource Assessment and Interconnection Planning project should achieve and balance several objectives, while maintaining reliability. Those objectives include considering all available technologies, including energy storage technologies, to the extent that they may become commercially viable and economic.

Additionally, as I noted above in response to your third question, the Commission has identified electric storage as a key functionality of the smart grid. The Commission is working with DOE and other federal agencies, as well as state regulators and many other interested entities, on smart grid issues, including standards development.

Question 5. Chairman Wellinghoff, what data does the Federal government collect on gridscale energy storage? Does it fit into the data collection forms used by the FERC? Ifnot, what work is underway to add energy storage to these data collection forms?

Answer. The Energy Information Administration Form No. 860 collects energy storage data on pumped storage and compressed air energy systems for all electricity producers. In addition, the Commission collects pumped storage generating plant statistics for individual companies in the FERC Form No.1, Annual Report. This data includes certain statistical and historical information about the property and its operation during a given year. Apart from pumped storage, however, the FERC Form No.1 generally collects cost accounting information on a company-wide basis and does not break down such data by type of technology. Moreover, companies authorized to sell at market-based rates, rather than at cost-based rates, generally are not required to file the FERC Form No.1. The Commission does require all public utility sellers to file Electric Quarterly Reports including all wholesale power sales. While not broken out separately, this information could include sales from storage.

The Commission has begun a review of barriers that may inhibit participation by energy storage resources in Commission-jurisdictional markets. As that review progresses and as the role of storage in wholesale electric markets expands, the Commission will also consider whether developing additional reporting requirements is appropriate.

RESPONSES OF JON WELLINGHOFF TO QUESTIONS FROM SENATOR MURKOWSKI

Question 1a. In your testimony you indicated that FERC has issued preliminary permits for an additional 27,000 MW of pumped storage capacity.

How many preliminary permits for pumped storage systems has FERC issued in the past year?

Answer. During calendar year 2009, the Commission issued 17 preliminary permits for pumped storage projects that would have a total installed capacity of 16,411 megawatts (MW).

Question 1b. What percentage of preliminary permits in the past has resulted in actual license applications for pumped storage systems?

Answer. In the past three years, the Commission has issued 36 preliminary permits for pumped storage projects. To date, one permittee, Eagle Crest Energy Company Inc., has filed a license application, for the L300-MW Eagle Mountain Pumped Storage Project No. 13123. to be located in Riverside County, California. In addition, five permittees for pumped storage projects, having a proposed total installed capacity of 3,732 MW, have begun preparing license applications by filing notices of intent to do so, along with preliminary application documents that contain all currently-available project information.

Question 1c. What is the typical time period for licensing a pumped storage system? For how long is a pumped storage system license valid?

Answer. The time period for licensing a pumped storage project is largely site-specific and may vary widely depending upon the configuration of the project, whether closed loop (i.e., using off-stream and/or underground upper and lower reservoirs) or conventional (i.e., using a new upper reservoir and an existing lower reservoir that is located on a river). The relative potential for impacts on environmental resources will weigh heavily on the process length. Under existing licensing procedures, it is possible that an appropriately-sited pumped storage project having minimal potential for environmental impacts could be licensed in 1.5 years or less from the filing of an acceptable license application. The process would likely be longer if the project had the potential to cause significant adverse effects on cultural resources or environmental resources including, but not limited to, endangered species or their habitats, or water quality. Also, delays in receiving authorizations from other Federal or state agencies (pursuant to, for example, the Clean Water Act or the Endangered Species Act) might delay a final Commission licensing action.

The Federal Power Act authorizes the Commission to issue original licenses for a period not to exceed 50 years. Original pumped storage project licenses have typically been issued for a 50-year term.

Question 1d. How many of the existing pumped storage facilities have been relicensed by FERC? What is the typical time period for re-licensing?

Answer. To date, the Commission has relicensed three pumped storage projects. The time period for relicensing those projects has averaged 2.6 years from the filing of the application to the issuance of the license.

Question 2. Much of the new pumped storage development proposals are for off-river, closed-loop systems that are low impact. Currently, these projects must navigate the federal licensing process, which can take several years. With the immediate needs we have for energy storage, what can FERC do to achieve a more efficient licensing timeframe for these types of pumped storage projects?

Answer. As discussed above in my response to your Question 1 (c), proposed pumped storage projects using off-river, closed-loop systems that are low impact likely could be processed in 1.5 years or less from application filing. Where consensus can be reached with Federal and state agencies and other stakeholders that project impacts will be minor, the Commission may be able to waive various procedural regulations and thus reduce the length of the licensing process.

Question 3. In your testimony, you reference a situation in West Texas during one month in 2008 where wind generation resulted in over nine hundred 15 minute intervals of negative pricing. "Negative pricing" essentially means that you have more generation than demand since, and is supposed to serve as a signal not to produce electricity at that time. However, I understand that in Texas, wind generators will continue to offer their energy at negative prices in order to get the federal Production Tax Credit and the value of a state Renewable Energy Credit. Additionally, due to transmission constraints, wind developers can be paid to remove their production from the grid. Please comment on this situation.

Answer. A negative price need not signal only that electricity production should be reduced. It could also signal that using more electricity during such periods would be appropriate. Energy storage could be particularly valuable in responding to such a signal, in that energy could be retained for use at a time when demand would otherwise outstrip supply or would require use of higher-cost generation. Much as one application of demand response involves "load shifting," this application of energy storage resources could be viewed as "generation shifting."

I would note that wind generation is not the only potential contributor to negative pncmg. Certain base-load generators that must operate at a more or less steady state around the clock (i.e., they have inflexible dispatch characteristics) may have a strong incentive to continue generating even when there is not enough load to bal-

ance their output. Thus, they also may contribute to the incidence of negative pricing.

Question 4. Compressed air energy systems are considered an energy storage mechanism because electrical energy is used to compress air that is stored in a pressurized reservoir. Given the fact that compressed air energy systems require some method to use the compressed air to make electricity, should these systems be classified as a generation technology or a transmission and distribution technology?

Answer. Traditional generation, transmission, and distribution resources are associated with well understood functions and methods of rate recovery. At a high level, generators are used to produce electricity, transmission lines move that electricity to the distribution grid, and distribution lines move that electricity to end-use consumers.

Energy storage technologies, by contrast, have some characteristics that resemble generation and some characteristics that resemble transmission. For example, like a generator, an energy storage resource may be able to act as a power marketer, arbitraging differences in peak and off-peak energy prices or selling ancillary services. The same energy storage resource also may be able to support transmission service, such as by supporting voltage on a transmission line, in which case it might be categorized as transmission, much as some static VAR compensators and capacitor banks already are. In addition, energy storage resources may be used as a substitute, temporary or otherwise, for traditional resources in some circumstances. For example, where peak period transmission congestion might prevent the importation of sufficient power to serve peak load, but where there is available off-peak transmission capacity that could be used to charge an energy storage resource, that energy storage resource could be used to maintain uninterrupted electric service until additional transmission or generation assets could be installed.

Thus, energy storage resources, including those that involve energy conversion steps like compressed air energy systems and hydro pumped storage, can perform different functions on the grid. In light of these characteristics, the Commission has not yet made a generally applicable classification of compressed air energy systems, nor has the Commission determined whether such a generally applicable classification would be appropriate.

RESPONSES OF JON WELLINGHOFF TO QUESTIONS FROM SENATOR SHAHEEN

Question 1. As we think about policies to support the development of new transmission lines to connect location-constrained resources, such as wind and solar resources, how should energy storage be considered?

Answer. I believe that effective transmission planning is an important step in the development of new transmission lines designed primarily to connect location-constrained resources such as generators of wind and solar energy. I also believe that it is appropriate to consider energy storage as part of the transmission planning process.

In February 2007, the Commission issued Order No. 890, which marked an important step to promote consideration of energy storage in the transmission planning process. In Order No. 890, the Commission required all transmission providers to develop a regional transmission planning process that satisfies nine principles, one of which is comparability. To reflect that principle, the Commission required transmission providers to outline in their tariffs how they will treat comparably in the transmission planning process all resources, including non-traditional resources that could impact the need for transmission expansion. Such an impact might arise, for example, where it is practical to use energy storage resources as a substitute, temporary or otherwise, for new transmission facilities.

I would also note that the Strategic Plan that I provided to Congress this fall states that as transmission providers refine their transmission planning processes, the Commission will assess best practices, including the potential for collaborative decision making, and adopt reforms as necessary to its transmission planning process requirements. Toward that end, Commission Staff this fall completed a series of conferences held around the country to review how well the transmission planning requirements of Order No. 890 are meeting the needs of our Nation, and to collect input as to how the Commission can improve upon the regional transmission planning processes. The Commission is now in the process of reviewing comments that were submitted in response to questions that Commission Staff posed as a follow-up to the conferences held this fall.

Question 2. One of the proposals put forward to connect these resources with new transmission lines is to spread out or "regionalize" the costs of these new transmission investments.

Question 3. If we regionalize the cost of new high voltage transmission lines for renewables as a part of transmission rates without storage, we could end up with a big transmission line with a relatively low capacity factor because of the intermittent nature of many renewable resources. When a lower overall cost option might be to have storage near the intermittent generation, like a wind farm, and a smaller transmission line with a higher capacity factor and higher utilization rate.

Question 4. As Congress considers policies to connect our renewable resources to the grid, how can we achieve that objective in a cost-effective manner? How should energy storage technologies be incentivized under broader transmission and renewable policies?

Answer. I agree that decisions related to development of new transmission lines should be made based on meeting energy needs in a cost-effective way. Toward this end, it is important to promote effective transmission planning, as discussed above in my response to your first question. It is also important to carefully consider a proposed project's costs and benefits. As you know, cost allocation is often a threshold consideration in the development of transmission facilities. For example, there are often significant costs associated with building the transmission facilities needed to deliver power from remote renewable energy resources. If the resource developer or the host utility is compelled to bear all of the cost of such transmission facilities, regardless of benefits to others, then it is less likely that the associated renewable energy resources will be developed. A closely related point is that the Commission must and, I believe, does ensure that costs of new transmission lines are allocated fairly to the appropriate entities that benefit from the projects.

With regard to incentivizing energy storage technologies, I would note first that some such technologies appear able to provide a nearly instantaneous response to regulation signals, in a manner that is also more accurate than traditional resources. These characteristics could reduce the size and overall expense of the regulation market. Most existing tariffs or markets do not compensate resources for superior speed or accuracy of regulation response, but such payment may be appropriate in the future as system operators gain experience with the capabilities of storage technologies. In the meantime, the unique characteristics of energy storage technologies could warrant different market rules for providing energy and ancillary services than those established based on the characteristics of traditional resources.

I would also note that in section 1223 of the Energy Policy Act of 2005 (EP Act 2005), Congress identified "energy storage devices" as an "advanced transmission technology" and also stated that in carrying out the Federal Power Act (FPA), the Commission shall "encourage, as appropriate" the deployment of advanced transmission technologies. The Commission has recognized that Congress envisioned a connection between section 1223 and section 1241 of EP Act 2005, which added section 219 to the FPA and directed the Commission to establish, by rule, incentive-based rate treatments to promote capital investment in transmission infrastructure. The Commission subsequently issued Order No. 679, which set forth the criteria by which a public utility may obtain transmission rate incentives pursuant to FP A section 219. The Commission has carefully considered applications for such incentives filed by energy storage developers and will continue to do so.

Question 5. As you may know, an amendment pertaining to cost allocation was adopted during consideration of the transmission title of the S. 1462, American Clean Energy Leadership Act. The provision reads:

> *Sec. 121 (i)—COST ALLOCATION*
>
> *. '(B) may permit allocation ofcosts for high-priority national transmission projects to load-serving entities within all or a part ofa region, except that costs shall not be allocated to a region, or subregion, unless the costs are reasonably proportionate to measurable economic and reliability benefits; "*

If approved, how would this policy affect, if any, New England's existing cost allocation methodology for reliability-based and participant-funded transmission infrastructure improvements? As you know, the methodology, established in 2004, provides for regional cost support of regionally planned transmission upgrades that provide region-wide benefits. I am interested in how the cost allocation language in S. 1462 may affect New England's existing policies for transmission improvements necessary for reliability purposes.

Answer. In my view, the first clause of the language that you quoted from S.1462 includes an important clarification to the Commission's authority in the area of transmission cost allocation. It is critically important that the Commission continue to have the flexibility to approve cost allocation methods that meet local and regional needs in a manner that provides just and reasonable rates for consumers as well as nondiscriminatory access to the transmission system. It is also appropriate

that Congress clarify that the Commission has authority to allocate transmission costs to all loadserving entities within an interconnection or part of an interconnection where it is appropriate to do so. Of course, as I noted above in response to your previous question, the Commission would need to ensure, as it does today, that the costs are allocated fairly to the appropriate entities.

However, I am very concerned about another aspect of the language that you quoted from S.1462. Legislation should avoid unduly restrictive language on cost allocation, particularly language that could be read as imposing a requirement to calculate the precise monetary benefits expected to accrue from a new transmission facility. It is possible that ISO New England's existing cost allocation method would be found inconsistent with the restrictive language in S.1462 that requires a showing that "costs are reasonably proportionate to measurable economic and reliability benefits."

Question 6. As you may know, thermal energy storage—that is the thermal momentum of buildings, both heating and cooling, can mimic the same characteristics of electric energy storage technology—like pumped storage, air compression, flywheels or battery technologies.

Do you consider thermal storage technologies, such as offpeak cooling with thermal energy storage, as an electricity storage technology like pumped storage, air compression, flywheel and battery technologies? Ifnot, why not?

Answer. I generally agree that thermal energy storage can be classified as an energy storage technology. It is noteworthy that there are a variety of thermal energy storage technologies and applications, which can be located on different parts of the electric system. For example, some large concentrating solar thermal electricity generation plants can be designed to include on-site thermal storage capability for excess heat to permit electricity generation to continue after the sun has set. Another form of thermal storage can involve controlled cooling at large refrigeration plants that serve industrial, commercial, or residential cooling loads. Yet another technology involves smaller distributed thermal energy storage for shifting cooling loads from peak to offpeak periods. Each of these technologies could constitute an "energy storage device" and thus could also be considered as possible "advanced transmission technologies" as defined in section 1223 of EPAct 2005.

Question 7. Considering that 40% of the summer peak demand in New England consists of air conditioning and cooling loads, what can we do to promote offpeak cooling with thermal energy storage, such as ice energy, to avoid paying more for transmission and generation capacity that is only used a few hours per year?

Answer. Because thermal energy storage for cooling requires the storage to be located at the cooling location, support for distributed thermal storage or possibly some type of district cooling (e.g., large thermal ponds at the neighborhood level) may have particular promise. In both cases, this equipment would likely be located at the retail end of the electric grid. Given that location, in circumstances where a developer of a distributed thermal storage technology chooses to work with an electric utility to encourage consumers to adopt that technology, retail regulators could promote that use of distributed thermal storage by permitting the utility to recover the cost of such investments in bundled retail rates. Where a developer of a distributed thermal storage technology does not choose to work with an electric utility, changes in retail rate design or other policies such as tax credits could make investments in such technologies more attractive to prospective users. In addition, to the extent that a developer of a distributed thermal storage technology does not choose to work with an electric utility, it may be possible to develop tariffs for wholesale markets under which users could receive compensation for the demand reductions they achieve by deploying such technologies. I would be supportive of exploring such mechanisms.

Question 8. Anyone who has spent time studying renewable energy sources and how they work knows that having grid-scale energy storage assets will be crucial to the effectiveness and extent of renewable integration into our electrical power system. When you want power from a generator that burns fossil fuels, you turn it on. Solar panels and windmills, however, require sun to shine and wind to blow to generate power. Since that might not happen at exactly the moment that power is needed, the capability to store the energy and use it at a later time, whether it's 10 seconds or 10 hours later, is crucial.

Question 9. As we increase the amount of renewable on the grid, how much energy storage and what type of storage, will be required to meet our goals? I say what type of storage, because I understand there are two types of challenges to making the renewable generation system work effectively. One relates to balancing the supply and demand of power on the grid at any moment, called regulation. Regulation requires energy storage that can absorb and inject energy into the grid very quickly. The other relates to what's called diurnal storage—storing energy when the

wind blows, for example, and using it when the wind dies down but demand for electricity stays high.

Question 10. How much of each type of storage do we need to make our renewables, both current and planned, work most effectively?

Question 11. Is there a clear ratio that we need to achieve between storage and renewable resources?

Answer. I agree that there is a close relationship between the development and implementation of energy storage and our Nation's ability to harness the potential of our renewable energy resources. As I stated in my December 10, 2009 testimony to this Committee, energy storage can make integration of renewable energy resources not only reliable, but also efficient and cost-effective.

I would note that I have directed Commission Staff to conduct a study to determine the appropriate metrics for use in assessing the reliability impact of integrating large amounts of variable renewable energy into the grid. That study, which is being undertaken by Lawrence Berkeley National Laboratory and overseen by Commission Staff, is due to be completed in the spring of 201O. When the study is complete, it will help to inform policy makers about the current limitations of the grid, and to identify what investments will be necessary to reliably accommodate continued growth of renewable energy resources.

However, generalizing about either the amount or type of storage needed to integrate renewable energy most effectively into the electric system is difficult given the variances in renewable generation types (e.g., solar as compared to wind) and the varying capacity factors of each resource depending on location and other characteristics (e.g., on-shore wind as compared to off-shore wind). The Commission also has not identified a ratio as to the amount of energy storage needed per amount of a particular type of renewable energy. In addition, I would note that other non-traditional resources, such as demand response, also can contribute to the reliable, efficient, and cost-effective integration of renewable energy resources.

Question 12. Is energy storage keeping up with renewables deployment, or do we have to ramp up the rate at which energy storage is made available to keep pace with our plans and goals for integration of renewables?

Answer. The recent expansion of our Nation's reliance on renewable energy resources has progressed more quickly than deployment of energy storage. Several factors have helped to accommodate this expansion, such as pre-existing flexibility in the system and, in some regions, greater use of demand response in coordination with variable renewable energy resources. With pre-existing system flexibility diminishing, however, and for the reasons discussed above in response to several of your previous questions, I believe that there are substantial potential benefits to increasing the pace of deployment for energy storage resources. The lag in development of energy storage resources is also one of the primary reasons why, as noted in my response to your previous question, I directed Commission Staff to conduct a study to determine the appropriate metrics for use in assessing the reliability impact of integrating large amounts of variable renewable energy into the grid. I am hopeful that the results of that study will provide information to assist in assessing what investments in energy storage and other types of resources will be necessary to reliably accommodate continued growth of renewable energy resources.

Question 13. Do we need to find a way to link the promotion and deployment of energy storage to the incentives we provide for renewables? It seems that renew abIes and energy storage are complementary components of a single system.

Answer. Yes. It would be ideal if we could associate sufficient energy storage with each new megawatt of variable renewable energy resource developed to ensure the consistent capacity factor necessary to deliver the energy when and where needed. However, we should not lose sight of the fact that energy storage is not the only mechanism to accomplish this task. For example, transmission can provide for delivery of energy from diverse and non-coincident renewable energy resources and, therefore, also should be linked to that complementary single system. Thus, the aim should be to develop a market incentive system supported by federal policy that encourages the appropriate development of renewable energy resources, supports storage and other appropriate resources for balancing and delivering those renewable energy resources when needed, and a transmission system that enables that delivery from any of the renewable energy resource, a non-coincident alternative resource, or storage.

Question 14. FERC Order 890 mandates that all independent system operators open their markets to non-generation resources to provide grid ancillary services, such as grid regulation. Electricity storage has been cited as one technology that can provide some of these services, with one company already using a flywheel energy storage system to provide grid regulation in Massachusetts, by which I mean the process of balancing the power injected into the grid with the level of power con-

sumed at any given moment. I understand from the experience of this company, Beacon Power, that the extent of compliance with Order 890 varies greatly among the ISOs. Some ISOs have moved relatively quickly to adjust their tariffs and control technologies to meet this new technology, whereas others have been more resistant to FERC's mandate.

Question 15. Do you agree with this characterization?

Question 16. What is the FERC doing to enforce compliance with Order 890?

Answer. In Order No. 890, the Commission modified most ancillary services schedules of the pro forma Open Access Transmission Tariff to indicate that those ancillary services may be provided by generating units as well as non-generation resources, such as demand resources, where appropriate. The Commission also stated that sales of those ancillary services by load resources should be permitted where appropriate on a comparable basis to service provided by generation resources.

I agree with the characterization in your question to the extent that it recognizes that various regional transmission organizations (RTO) and independent system operators (ISO) are at different stages of developing appropriate tariff mechanisms for energy storage resources to provide ancillary services. All of the RTOs and ISOs that operate energy and ancillary services markets are working with their stakeholders to determine how non-generation resources, including energy storage resources, can provide ancillary services in those markets. As I described in my December lO, 2009 testimony to this Committee, some of the RTOs and ISOs have also made or proposed specific tariff changes, while others have established pilot programs. Achieving compliance with major initiatives such as Order No. 890 often involves an iterative process, rather than a single compliance filing.

I would also note that the Strategic Plan that I provided to Congress this fall sets as a long-term performance goal that all resources technically capable of providing ancillary services wil1 have the opportunity to provide those services. Toward that end, the Commission will consider instituting formal proceedings that may address the modification or creation of ancillary services. as well as the removal of additional barriers that may exist to any resource capable of providing an ancillary service from having the opportunity to do so.

RESPONSES OF JON WELLINGHOFF TO QUESTIONS FROM SENATOR UDALL

Question 1. Chairman Wellinghoff, how would you assess the changes that Independent System Operators and Regional Transmission Organizations have made in recent years to allow storage to compete in their markets? Would you judge that they have made significant progress? What do you think is still left to do?

Answer. Various regional transmission organizations (RTO) and independent system operators (ISO) are at different stages of developing appropriate tariff mechanisms for energy storage resources to provide ancillary services. All of the RTOs and ISOs that operate energy and ancillary services markets are working with their stakeholders to determine how non-generation resources, including energy storage resources, can provide ancillary services in those markets. As I described in my December 10, 2009 testimony to this Committee, some of the RTOs and ISOs have also made or proposed specific tariff changes, while others have established pilot programs.

I believe that these actions taken by the RTOs and ISOs constitute significant progress. Nonetheless, I would note that the Strategic Plan that I provided to Congress this fall sets as a long-term performance goal that all resources technically capable of providing ancillary services will have the opportunity to provide those services. Toward that end, the Commission will consider instituting formal proceedings that may address the modification or creation of ancillary services, as well as the removal of additional barriers that may exist to any resource capable of providing an ancillary service from having the opportunity to do so.

I also stated in my December 10, 2009 testimony that some energy storage technologies appear able to provide a nearly instantaneous response to regulation signals, in a manner that is also more accurate than traditional resources. These characteristics could reduce the size and overall expense of the regulation market. Most existing tariffs or markets do not compensate resources for superior speed or accuracy of regulation response, but such payment may be appropriate in the future as system operators gain experience with the capabilities of storage technologies. In the meantime, the unique characteristics of energy storage technologies could warrant different market rules for providing energy and ancillary services than those established based on the characteristics of traditional resources.

Question 2. Chairman Wellinghoff, what is your view on how rate recovery should be done for storage projects that are built to defer the need for new investments in transmission infrastructure or to relieve transmission congestion?

Answer. Energy storage technologies have some characteristics that resemble generation and some characteristics that resemble transmission. For example, like a generator, an energy storage resource may be able to act as a power marketer, arbitraging differences in peak and off-peak energy prices or selling ancillary services. The same energy storage resource also may be able to support transmission service, such as by supporting voltage on a transmission line, in which case it might be categorized as transmission, much as some static VAR compensators and capacitor banks already are. In addition, energy storage resources may be used as a substitute, temporary or otherwise, for traditional resources in some circumstances. For example, where peak period transmission congestion might prevent the importation of sufficient power to serve peak load, but where there is available off-peak transmission capacity that could be used to charge an energy storage resource, that energy storage resource could be used to maintain unintelTupted electric service until additional transmission or generation assets could be installed. In light of these characteristics, the Commission has not yet made a generally applicable classification of energy storage resources for purposes of cost recovery, nor has the Commission determined whether such a generally applicable classification would be appropriate.

RESPONSES OF JON WELLINGHOFF TO QUESTIONS FROM SENATOR STABENOW

Question 1. I appreciate the opportunity to hear more about the potential for energy storage technology usage in our energy grid.

Continuing to pursue energy storage technologies like those mentioned in your testimony will help make our grid more efficient, connect renewable technologies to our systems, and ultimately lead to less greenhouse gas emissions and more jobs for our workers.

I would like to point out a connection between grid energy storage issues to another interest important to my state of Michigan—advanced batteries for vehicles.

Advanced electric vehicles provide two benefits for the electricity grid. First, vehicle battery technology can improve store energy for the grid. Second, those vehicles can communicate with the grid and use more energy at low demand periods when energy is cheaper or more renewables are available.

I was proud to help provide funding for advanced batteries in the Recovery Act which provided nearly $2.3 billion for advanced battery manufacturing. :Many companies and universities in Michigan, such as A123 systems and the University of Michigan, have used this funding to make Michigan and the United States a leader in advanced battery technology development. A123 is also working with our Michigan utility, Detroit Edison, to demonstrate its battery technology for grid storage.

Certainly energy storage technology and cost will depend on both the vehicle and electrical industries. Please provide examples of the need for government R&D efforts and these two industries to continue to work together to develop the next generation of advanced batteries required by both industries.

Answer. I agree that both the electric and vehicle industries will benefit from the development of advanced batteries that can enhance the operation of electric transportation, as will consumers who purchase electric vehicles. I also agree that to fully realize such benefits, government support for research and development in this area is appropriate, and cooperation between the electric and vehicle industries is essential.

As you know, there are many examples of technologies that originally emerged from research and development that was conducted with Federal government support. Indeed, much of today' s existing battery technology for electric vehicles could be placed in that category, although to date much subsequent development and commercialization of that technology has occurred outside of the United States. I believe that continuing the Nation's commitment to research and development in this area offers the promise of further technology breakthroughs.

One illustration of the need for cooperation between the electric and vehicle industries is related to the potential for the batteries in electric vehicles to provide services to the grid. As I stated in my December 10, 2009 testimony to this Committee, researchers at the University of Delaware have demonstrated that electric vehicles can provide regulation service. In fact, P1M Interconnection (P1M) is currently paying electric vehicles to do so. P1M aggregates a 1 megawatt battery that a utility installed at P1M headquarters with the batteries of three electric cars associated with the University of Delaware's research. The batteries then sell into P1M's regulation market.

The University of Delaware researchers believe that, using this technology, parked electric vehicles connected and aggregated in large numbers in places like parking garages could be made available as energy storage to support grid oper-

ations. Achieving that larger-scale potential will involve increased cooperation between the electric and vehicle industries, such that electric vehicles are equipped with appropriate vehicle-to-grid (V2G) technology that allows the necessary two-way communication and bidirectional controlled flow between the vehicle and the grid.

Question 2. How critical are auto technologies to the electrical industry and infrastructure as we strive to use energy more efficiently and tap into more renewable sources?

Answer. I believe that energy storage resources have great potential to complement our Nation's efforts to reliably incorporate into the grid increased output from variable renewable energy resources. With increasing commercial availability, electric vehicles could become a widespread energy storage resource and contribute to reaching that goal. For example, as I noted above in response to your first question, electric vehicles can provide ancillary services, like regulation service, to the grid and thus assist system operators in balancing the variability of many renewable energy resources.

Question 3. In addition, are there any regulatory or statutory barriers that would make FERC's efforts to integrate this kind of technology more effective?

Answer. As I stated in my December 10 testimony, the Commission recognizes and is taking steps to address the challenge of removing regulatory barriers that impede the vast potential of energy storage to support our national energy goals.

For example, the Strategic Plan that I provided to Congress this fall sets as a long-term performance goal that all resources technically capable of providing ancillary services will have the opportunity to provide those services. Toward that end, the Commission will consider instituting formal proceedings that may address the modification or creation of ancillary services, as well as the removal of additional barriers that may exist to any resource capable of providing an ancillary service from having the opportunity to do so.

More specifically, I would note that most existing tariffs or markets do not compensate resources for superior speed or accuracy of regulation response. Such payment may be appropriate in the future as system operators gain experience with the capabilities of storage technologies. In the meantime, the unique characteristics of energy storage technologies, including electric vehicles, could warrant different market rules for providing energy and ancillary services than those established based on the characteristics of traditional resources. The Commission is working toward removal of such barriers to market participation by energy storage resources.

Question 4. Does FERC require any additional authority to advance energy storage technology and use?

Answer. PJM's compensation of electric vehicles for providing regulation service demonstrates that it is possible under existing authority to integrate electric vehicles into Commission-jurisdictional markets. Removing the types of barriers described in my response to your previous question will create additional opportunities for market participation by electric vehicles and other energy storage resources.

It also should be noted that retail regulatory authorities have an important opportunity to directly support the widespread adoption of energy storage technologies, including electric vehicles. To date, states have led the way in pushing for increased reliance on our Nation's still largely untapped renewable energy resources, and in light of the potential for energy storage to complement those often variable resources, retail regulators may come to see benefits of supporting storage development through retail rate recovery. The Commission will look for ways to work with the states to ensure that innovative retail rates do not raise concerns for the operation of Commission jurisdictional wholesale markets.

RESPONSES OF RALPH D. MASIELLO TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Dr. Masiello, in your testimony you discussed the need for considering energy storage in transmission planning. S.1462 includes energy storage as an alternative that must be considered in transmission planning. Is this sufficient? What other legislative language may be necessary?

Answer. Storage on the distribution system offers new capabilities that can affect the need for transmission capacity expansion. This poses the challenge that transmission planning would have to include some consideration of how storage at the distribution level can be a transmission resource. Given that many renewable resources are developed as "distributed generation" on the distribution system, this will become an increasingly important consideration. Ideally, transmission planning would have to show quantitative evaluation of energy storage as an alternative in transmission planning, including its impacts on reliability and congestion.

I cannot speak as an expert as to how best to implement the requirement via legislation or regulation. It may be that requiring how to demonstrate consideration of energy storage is something FERC would do via a regulatory process. However, FERC oversight today generally does not extend to distribution systems though we now have the potential for transmission assets on the distribution system to be a factor in transmission planning.

Question 2. Dr. Masiello, how is energy storage currently addressed in transmission and generation planning processes? What planning, analysis, and modeling tools do we need to develop to be able to determine where to best site storage technologies?

Answer. Storage is already considered in generation planning processes today where known storage alternatives to generation such as pumped hydroelectric storage are viable resources. Generally speaking, however, storage is not a routine consideration today in transmission planning either from a reliability perspective or a transmission congestion perspective. Storage is beginning to be considered in the context of renewable generation that is subject to transmission congestion, as in the case of remote wind farms.

To allow for storage to be routinely considered in system planning, the industry needs to have standard models for storage systems which can be parameterized to represent different technologies and sizes. This is the case today with generation systems and with transmission apparatus—there are formal standards from the Institute of Electrical and Electronics Engineers (IEEE) for models of different equipment classes that are identified as suitable for particular planning purposes such as transient stability, load flow, and other analyses. These standard models allow for the exchange of planning data as well as a degree of compatibility across different software applications from different vendors. One key step, therefore, is the development of similar standards for storage systems so that they may be consistently represented in the various planning models and tools. Because many storage technologies are novel and somewhat developmental, and because the life expectancy of storage systems as a function of their usage is central to the economic analysis of different applications, considerable work is required to develop methodologies for characterizing and modeling storage system life cycles as well as validating those characterizations over time.

A key inherent benefit of storage systems is in the ability to shift energy delivery in time; that is to deliver energy at a time later than when it is generated. In general, transmission studies today analyze a "shapshot" of the system at a moment in time (usually assumed to be at peak loading) as opposed to analyzing conditions over a period of time. Determining the optimal size of a storage system requires that the transmission planning analysis look at system performance over a time period during which the storage system is optimally used. Thus, new methodologies for optimization and simulation are required and these must be incorporated into transmission planning tools. Storage inherently transforms the "economic dispatch" problem—how to best allocate generation at a given moment in time—to a "unit commitment" problem—how to best allocate resources over time. As such, it will require that transmission planning must also consider these time dynamics.

Question 3. Dr. Masiello, what kinds of system information-sharing and collaboration must exist, to ensure that storage and distributed renewable generation (two sides of the same coin) can be effectively dispatched such that the bulk power grid is managed most reliably and efficiently? What role must interoperability and cybersecurity standards play, to ensure this becomes a reality? How do transmission system operators need to change their practices and software to accommodate efficient dispatch of energy storage?

Answer. The ISO RTO Council of North American Independent System Operators is developing proposed business process, data model, and interoperability standards for storage and distributed generation as inputs to the National Institute of Standards and Technology (NIST) Smart Grid interoperability standards process. These will include proposals for what information must be exchanged and with what periodicity for different reliability, dispatching, and control purposes at the wholesale or transmission level. These proposed standards will be reviewed by the appropriate teams and working groups within the NIST standards framework, and will have to be compatible and compliant with the broader set of NIST interoperability standards, including cyber security provisions.

The key issues for distributed resources and renewable resources are: forecasting, visibility or monitoring, and control. At low levels of penetration inaccurate forecasts of renewable production and a lack of direct visibility are manageable. At high levels of penetration (i.e., over 20%), the system operators will require more accurate forecasts of production and real time visibility of actual production of both grid connected and distributed resources. Controlling renewable resources requires the

means to avoid unanticipated and sudden fall offs in production. This implies that a grid operator might require renewable resources to "ramp down" or be curtailed in anticipation of near-term weather changes. Alternatively, storage as a local resource or as a grid service could help resolve sudden drops in renewable generation.

The variable nature of renewable resources will add more uncertainty to the daily and hourly scheduling processes. Grid operators will have to adapt to this via changed protocols for scheduling reserves and perhaps "ramping" capability in the system.

The algorithms used by market operators or by vertically integrated utilities to optimally schedule day-ahead, hour-ahead, and real-time generation will all have to be able to consider and optimize the ability of storage to shift energy demand and production in time. In general, this is a difficult problem which is addressed today only in specific cases of hydro thermal scheduling that have incorporated models of particular pumped hydroelectric facilities. Even in these cases, because existing pumped hydroelectric storage is not controllable when pumping, the solutions are not at the level of sophistication that will be required in the presence of high renewable production and large amounts of available and distributed storage.

RESPONSES OF RALPH D. MASIELLO TO QUESTIONS FROM SENATOR MURKOWSKI

Question 1. In your written testimony, you indicated that demand response and dynamic pricing cannot be maintained at certain renewable penetration levels. The energy bill passed by this Committee would require up to 15% of the electricity supply from renewable sources or energy efficiency by 2021. Is this percentage practically achievable if the energy storage technologies are not deployed on a large scale given the intermittency of the renewable sources? Will development and deployment of energy storage technologies proceed at a pace sufficient to match the need for meeting a federal renewable mandate?

Answer. To clarify this point, my intention was to say that managing the production characteristics and variability of renewable resources when they are over 20% of the portfolio may be difficult with demand response and dynamic pricing alone, as it is not clear what level of demand control the public might accept. (This is a personal opinion of mine). In conjunction with demand response and dynamic pricing, storage offers another resource for mitigating the intermittent behavior of renewables.

For storage development to proceed as rapidly as mandated renewable development, the technology must be proven and either the economics must be attractive (such as with the time arbitrage of energy for the renewable developer or storage developer). Today, there is no easy way for a storage developer to anticipate what the time arbitrage of energy prices will be under high renewable levels if demand response or dynamic pricing is the key determinant in setting marginal prices—there is not sufficient data to understand what consumer price levels for demand response will need to be to achieve high levels of demand control. The tradeoffs between high levels of renewables, demand response or dynamic pricing, and storage are not well understood economically. Studies are needed to identify the various tradeoffs and begin to assess the quantitative economics.

Question 2a. Pumped hydro has been the workhorse for utility-scale energy storage and provides 21 gigaWatts (GW) of electrical capacity. However, suitable locations for pumped hydro are considered limited.

Of the nearly 80,000 dams in the U.S., how many have hydroelectric generating capabilities?

Answer. Though KEMA has expertise in hydroelectric generation, the national labs appear to have developed national assessments of hydropower potential in the U.S. In particular, Idaho National Laboratories (INL) has completed a series of reports over the past decade to assess hydropower potential in the U.S. and have developed tools for modeling the potential and the economics of a given site. Dr. McGrath of (NREL) may also be able to provide better information on national inventories. However, it appears that according to the Army Corp of Engineers, 2,400 of the nearly 80,000 dams in the U.S. have hydroelectric generating capabilities.

Question 2b. If so, how much additional capacity could be obtained in doing so?

Answer. The 2003 INL report identified potential conventional hydropower capacity additions of 30,000 MW by developing feasible sites to full potential. Other analyses may differ, especially in the weighting factors used to assess issues such as environmental and land use factors. This estimate includes run-of-the-river hydropower as well as other hydropower sources not typically conducive to pumped storage. As such, these studies do not explicitly identify potential hydroelectric pumped storage project potentials.

Other sources identify significant numbers of projects in the permitting stage for the construction of above-ground and cavern-based pumped storage—as much as 31,000 MW of pumped storage capacity. Whether these projects will pass federal, state, and local environmental, land use, and eminent domain reviews and processes and proceed to construction is difficult to assess, as is predicting the timeline for such approvals.

Pumped storage can be the most economically attractive large scale storage technology (00's to 000's of MWh) if the siting provides sufficient elevation difference between low and high reservoirs and sufficient acreage for large amounts of storage. Efficiencies can be as high as 80% overall if elevation differences are great enough and if the reservoirs do not lose water to leakage into the water table or to evaporation. Unfortunately, most existing hydroelectric generation facilities are not suitable for pumped storage applications due to lack of a sizable reservoir below the dam. One notable exception to this is at Niagra Falls where a very large pumped storage facility has been proposed. There are obvious environmental and public factors that come into play in such a location.

RESPONSES OF ROBERT MCGRATH TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Dr. McGrath, what planning, analysis, and modeling tools do we need to develop to be able to determine where to site storage technologies that may be able to defer or negate the need for distribution and transmission upgrades or even the need for new generation/transmission/distribution?

Answer. Analysis is required at multiple scales to quantify the need for energy storage and to develop the appropriate decision-making tools sufficient to balance trade-offs among new transmission, generation, load management (e.g. SmartGrid) and energy storage. Because energy storage can be considered by utilities and grid operators as either a central (large) or distributed source of dispatchable generation, modeling and simulation will need to cover a range of scales from single renewable energy sources to regional zones and the entire grid. Analysis is needed to understand the options under a number of potential scenarios at regional and national scale, to determine the scale(s) and timeframe(s) required for energy storage technology development and deployment, and provide the necessary information for market assessments. The need for a more holistic national-scale study is made all the more acute by the proliferation of renewable portfolio standards at the state level.

For scenarios that look at increasing the use of Variable-Resource Renewable Energy (VRRE) options such as wind and solar, significant improvements are needed to quantitatively describe the actual electric grid and power flows to incorporate the complexities of storage and transmission technology options for planning scenarios. These improved analysis tools are needed to address a variety of problems ranging from long-term planning for capacity expansion decisions, to hourly decisions supporting least-cost system operation, and finally to sub-hourly decisions affecting emissions, reliability, ramping and reserve considerations.

DOE has funded the development of significant electric grid modeling and analysis capabilities at national laboratories, e.g. ORNL, PNNL, SNL, LANL, and LBNL, mainly to address questions related to overall grid reliability and homeland security. NREL has developed collaborations with these national laboratories to specifically apply their data and analytic capability to studies of renewable energy penetration into the electric grid for multiple regions and scales.

A number of efforts are underway to assess the interrelationship of storage and transmission and generation, but no significant large-scale studies have been completed. The bulk of the work to date has been to demonstrate that renewable energy can be integrated into the electric grid. Little work has been targeted to date at developing optimal solutions. Additional efforts should be directed at large-scale, detailed models, using large datasets. These models can then be used to draft broad potential scenarios, and reveal the proper balance of storage and transmission upgrades.

As an example of work specific to renewable energy integration, NREL has developed the Regional Energy Deployment Systems (ReEDS) model for the long-term capacity expansion modeling at the national level. This model includes in considerable detail Variable-Resource Renewable Energy options (VRREs), along with more simplified analytical descriptions of storage and transmission. NREL is in the process of improving how transmission is represented in the ReEDS model, to better represent actual power flows. Detailed descriptions of distribution and storage considerations, however, remain outside the present scope of the model. Additional investments are required, supporting work at NREL and other sites, to develop, validate

and integrate detailed descriptions of storage, transmission and distribution into models such as ReEDS in order to support long-term grid planning and associated national policy formation.

For least-cost system operation throughout a year at the individual utility, regional reliability entity, or ISO/RTO level, there are a number of existing commercially-available optimal power flow models that address renewables and generation/transmission/storage tradeoffs, with varying degrees of accuracy. Providing these models with valid hourly renewable resource data, obtained from actual operation over multiple years, is an ongoing challenge now being addressed by NREL. Approximating these detailed hourly model results in the capacity expansion models described in the preceding paragraph is another crucial ongoing modeling effort. Modeling at the sub-hourly level for system reliability, carbon and local air emissions, ramping, and reserves, in a system with large amounts of VRREs, will be critical as we look to the future—though limited funding has kept such effort in its infancy. Finally, it is important to recall that the authority for generation, transmission and distribution approval is largely in the purview of state government.

Question 2. Dr. McGrath, some of the commercial software that grid planners use today grew out of previous DOE-funded research. What is DOE doing to help develop grid planning software that takes account of energy storage and renewable energy? What are the national labs doing to support transmission planning models and software? How much funding is going towards this work now, and how does this compare to past funding levels?

Answer. Energy storage will be an important element in the extremely complex process of integrating large quantities of renewable energy into the electric grid. As pointed out by Undersecretary Koonin, a national grid-scale energy storage RD&D program aimed at developing and implementing cost-effective, energy-efficient, large-scale energy storage technologies will require a serious commitment to grid optimization analysis, as well as to energy storage technology development.

In the area of grid analysis, the DOE Office of Electricity funds several national laboratories, including NREL, PNNL, ORNL, LBNL and ANL as well as universities to advance tools, develop methods, and perform specific studies. For example, ORNL and PNNL have developed extensive visualization capabilities in collaboration with utilities. Los Alamos and Sandia have developed extensive physics-based models of the existing national electric grid that include real-time power generation and flows to predict the impacts of disruptions, either natural or man-made, on the electric grid. This model was developed initially through DOE-OE, then through the Department of Homeland Security's National Infrastructure Simulation and Analysis Center (NISAC). DOE-EERE is supporting data development and looking at needed advancements to accurately capture the characteristics and effects of variable renewable energy sources.

NREL has specifically been engaged in grid analysis for renewable energy integration and has developed collaborations with a number of national laboratories and companies to apply their models and data to studies of renewable energy penetration into the electric grid for multiple regions and scales. In the Western Wind and Solar Integration Study (WWSIS), NREL is working with GE and its GE-MAPS software to examine the potential synergies between pumped hydro storage and VRREs. In another effort, the Renewable Electricity Futures Study, NREL is working with ABB to use and improve their GridView model for assessing the role of transmission and storage under high renewable penetration scenarios. In a third effort, the Western Renewable Energy Zone (WREZ) initiative, NREL provided highly detailed VRRE data maps, then worked with western states, Canadian provinces, and Mexico (which encompass the western grid interconnection), for assessing renewable resource potential, and transmission requirements necessary to deliver these resources to load centers.

Recently, NREL has been collaborating with Los Alamos National Laboratory through funding from the DOE-EERE wind program to incorporate models and data from LANL's large DHS-funded NISAC. These models use power flows on the existing grid and will allow for detailed "what-if" analysis as to when, where, and how best to enhance the grid for maximum integration of renewable energy.

NREL has been working with Western Electricity Coordinating Council (WECC) to create a support partnership with national laboratories that will draw upon prior work and existing capabilities across the national lab complex. WECC was notified by DOE on Dec. 18 that it has been selected for an award to research options for alternative electricity supplies and associated transmission requirements, in an integrated approach to the western grid that could involve several laboratories in addition to NREL. The goal of this effort would be to create a tool that would allow for "what if" assessments for the effective integration of renewable energy into the existing and future electric grid. A total of about $80 million in Recovery Act funding

is to be obligated by DOE toward this and other projects also selected in December. Through ARRA funding, DOE has additionally funded a number of relevant solicitations, including studies on high penetration of solar energy and two large blocks of grants on SmartGrid at the distribution level.

To realize the goal of high penetration of renewable energy and enable utility companies to meet their goals, understand their options (including integration, storage, or new transmission capacity), and assess the impacts and economics of future scenarios over multiple timescales, additional investment is needed both for applying current models to renewable energy integration scenarios (in multiple regions and at the national level), and for developing more quantitative models and processing large complex datasets. Akin to the emerging partnership NREL has helped facilitate between WECC and National Laboratories, DOE and its National Laboratories can play a particularly important role in objective planning over longer timeframes (i.e., greater than 10 years) in integrating among planning groups across regions. DOE and its National Laboratories can also assist by making available, in a non-regulatory environment, the massive amounts of data and information that will be generated from large renewable energy installations, from the SmartGrid and from utilities in general. Decision-making tools would also be valuable for analysis of future government investment and policy options.

RESPONSES OF ROBERT MCGRATH TO QUESTIONS FROM SENATOR MURKOWSKI

Question 1. In your testimony you state that "To achieve 20 percent wind penetration by 2030 consequently requires more than a ten-fold increase in wind production, to more than 300 GW."

a. For this additional 300GW of actual electricity that would need to be produced, what would be the total name plate capacity? Do you have cost estimates for the production of this much electricity from wind?

b. What is the projected cost of the additional transmission and distribution assets for utilizing this much wind power?

Answer. Based on analysis conducted for the DOE 20 Percent Wind Energy by 2030 report, 300 GW of wind nameplate generation capacity would provide 20 percent (1200 TWh annually) of the projected US electricity demand in 2030. Total system cost (including capital investment for conventional and wind generation technology, fuel costs, operation and maintenance cost, and transmission expansion costs) for a scenario encompassing 300 GW of wind capacity was compared to the total system cost for a scenario with essentially no additional wind capacity. It was found that the 20 Percent Wind Scenario requires higher initial capital costs, yet offers lower ongoing energy costs for operations, maintenance and fuel. Overall, a 20 Percent Wind Scenario was estimated to cost about 2% more than a scenario that did not include new wind capacity.

The proposed transmission expansion associated with the addition of 300 GW of wind capacity is estimated at $20 billion in net present value (NPV). The actual grid investment required could involve additional costs for permitting delays, construction of grid extensions to remote areas with wind resources, and investments in advanced grid controls, as well as training to enable regional load balancing of wind resources. This estimate is similar to a conceptual transmission plan that provides for 19,000 miles of new 765 kV transmission line at an NPV cost of $26 billion. Distribution asset cost was not included in this analysis. As electric demand grows in the future, distribution assets will also require upgrading, regardless of the central generation technology that supplies the electricity.

Question 2. In your testimony you state that the current electricity system can absorb much greater quantities of renewable generation than are currently deployed without significant increases in storage technologies. But, given the experiences in West Texas in which excess wind generation in off-peak hours resulted in negative pricing is it prudent to pursue broader deployment of renewable technologies when the electricity produced cannot or is not stored? Should wind generators produce electricity only in order to get the federal production tax credit?

Answer. Short-term negative prices in West Texas are a result of excess generation from an area where transmission to load in East Texas is currently inadequate. The Electric Reliability Council of Texas recognized the problem, and in anticipation of further wind generation deployment to meet the state-mandated Renewable Portfolio Standard, conceived and is implementing what is known as the Competitive Renewable Energy Zone process. The Texas CREZ proactively identifies renewable resource areas, then plans and builds long-lead time transmission in advance of short-lead time specific renewable generation projects.

The DOE 20 Percent Wind report states that there are no fundamental technical barriers to the integration of 20 percent wind energy into the nation's electrical system. However, there needs to be a continuing evolution of transmission planning and system operation policy and market development if this is to be economically achieved. CREZ is a good example of the non-traditional, creative thinking that will be necessary to economically integrate large amounts of variable renewable power onto the grid. Storage is another, albeit relatively high-cost, option to bring more flexibility to grid operations. In a future that may progress beyond 20-30 percent variable renewable generation, storage may play an increasingly important role—particularly if storage technology costs can be reduced and efficiency increased.

In all cases today, negative pricing and curtailment are not common or widespread issues. Continued transmission expansion, electricity market practice revision and perhaps broader use of storage and other grid flexibility technology options in the future, are issues that NREL continues to analyze as part of our work to anticipate an expansion of renewable power's role. For example, NREL and Oak Ridge National Laboratory researchers have shown that market practice revisions that permit cooperation among larger balancing areas within an interconnection (and even between interconnections) can help mitigate the changing output of large numbers of variable generators.

With regard to your final question, production of electricity with the sole purpose of receiving tax credits is not in the national interest. Isolated occurrences like the negative pricing that occurred in West Texas, points out the need to diligently determine the most economic ways to integrate increasing amounts of renewable electricity onto the grid. NREL will continue to be a resource to the DOE and to the public interest in this ongoing endeavor.

Moreover, the broader deployment of renewables should be directed at satisfying multiple policy goals, including energy security, environmental protection and climate change mitigation, as well as economic prosperity and job creation.

Question 3. Pumped hydropower storage is an existing and readily deployable large-scale energy storage technology. Currently, the U.S. has over 20,000 MW of pumped storage capacity with dozens of new projects under consideration, particularly in the West. Yet pumped storage is often overlooked in the discussion of energy storage options for this country. Please discuss the role you believe pumped storage can play as we look to increase and integrate intermittent renewable resources, such as wind and solar, as well as provide other grid services.

Answer. Pumped Storage can be an economic technology that is currently available. Future expansion of this technology may be limited by geography, but advanced concepts now under development may make pumped hydro attractive across more regions of the country. Pumped hydro may be able to play an extremely important role in integration of variable renewables. In Colorado, Xcel Energy has examined the value of more frequent cycling of an existing pumped hydro plant to take advantage of increased wind deployment, and found integration costs can be decreased by approximately one-third at penetration of 10 percent wind.

NREL is currently completing a Western Wind and Solar Integration Study examining integration issues across the Western electric grid. The production cost simulation modeling being performed by GE shows that for high-penetration scenarios (up to 30 percent wind and 5 percent solar), the existing pumped hydro fleet can play an important role in economic renewables integration. Pumped hydro appears to be an underappreciated technology and a potentially valuable resource toward meeting grid ancillary services and contingency and operational reserve needs.

Question 4. What kind of work is NREL undertaking on hydropower in general and pumped storage in particular?

Answer. NREL has no current research underway with respect to conventional hydropower and pumped storage facilities, each of which uses impoundments such as dams. Other organizations such as the Electric Power Research Institute have projects underway to develop and test more "fish-friendly" and efficient turbines to help mitigate environmental impact from conventional facilities. NREL is, however, using its unique and long-standing expertise in wind energy to help meet the research and development needs of a new class of renewable energy technologies—wave, tidal, river current and ocean thermal energy conversion. These technologies are not related to conventional hydropower technologies. Many of these technologies more resemble wind turbines and are often thus referred to as marine hydrokinetic energy converters because they convert the kinetic energy of moving water or the thermal energy of hot water into electrical energy.

NREL has been funded by DOE through a competitive solicitation to perform R&D to accelerate the development and deployment of these marine and hydrokinetic technologies by providing industry with the support it needs to model machine dynamic performance, increase device efficiency and capacity factors, and

reduce capital costs. This is expected to increase investment and regulatory confidence in this emerging field and hasten the deployment by 2015 of what will be the first commercial marine hydrokinetic energy technologies in the U.S.

Regarding continued development and deployment of pumped hydro storage, in the many regions where this option is geographically and ecologically feasible, pumped hydro will continue to be a desirable approach—even as costs are reduced for other storage technologies such as batteries. Consequently, continued research and development efforts are needed on advanced engineering of water turbines to improve efficiencies, methods and technologies to lower excavation and construction costs, and on continued resource assessment to determine when and where additional pumped hydro storage represents the most cost effective and reliable addition to local electricity generation, storage and delivery systems. Clearly, mountainous regions with ample precipitation, such as the Rocky Mountain and Pacific Rim States represent regions well suited for potential deployment of additional pumped hydro storage.

RESPONSE OF KENNETH HUBER TO QUESTION FROM SENATOR BINGAMAN

Question 1. Mr. Huber, in your testimony you state that 34 megawatts of battery storage have been put in the PJM generation queues for 2010. Given that storage has inherently different capabilities and characteristics than generation resources, can the generation queue process appropriately and expeditiously accommodate energy storage technologies (especially since storage technologies rely on a two-way flow of energy) or does storage need its own process?

Answer. PJM's current interconnection process accommodates both generation technologies and storage technologies. To date, one battery and four flywheel storage systems have gone through this interconnection process. The one battery storage system, a 1 MW system, has been interconnected with the PJM grid. Recently, two battery systems (one 20 MW and one 14 MW) have entered into the PJM generation queues and are being evaluated by PJM to determine their impact, if any, on the transmission grid.

The PJM System Planning interconnection process is a three-phase process utilizing network studies to test for a proposed project's impact on the grid in meeting reliability standards promulgated by the North American Electric Reliability Corporation (NERC) and approved by the Federal Energy Regulatory Commission (FERC). Phase one, the Feasibility Study, consists of analyses of deliverability and short circuit reliability. PJM's FERC-approved tariff allows, as a guideline, that this phase be completed within three months of the end of the queue in which the project is submitted. For storage system requests below 10 MW, this would likely be the conclusion of the analyses, thus providing the developer with critical information on system impacts and costs, which it can consider in deciding whether to proceed with entering into a formal interconnection agreement. Larger and more complex systems would proceed to phase two, the Impact Study. Here the analyses are expanded to include stability and multiple contingency studies; with guidelines for completion in 150 days (30 days for signatures on an agreement to proceed and 120 days for analyses). There is a third phase, the Facilities Study, that would likely not be required for storage systems unless significant network upgrades are identified during the Impact Study phase. In short, although there is no separate expedited process for storage analyses and an interconnection agreement can be completed within a half-year of the close of the queue in which the application is received.

PJM does not believe that establishing a separate interconnection queue for energy storage would be beneficial to the development of innovative cost-effective solutions that benefit the grid and consumers. Specifically, a common queue allows for all resource solutions to be considered without artificially "choosing" one technology solution over the other. As directed by FERC, PJM maintains a common queue that is available to all resources and options including generation and merchant transmission, as well as energy storage solutions. This reflects the fact that all generators have a two-way flow of energy that must be considered. (In the case of traditional generation technologies, the two-way flow is represented by the energy used for auxiliary power and for unit start-up and shutdown). By considering all projects in a given queue, the value of each resource can then be recognized through the awarding of financial transmission rights to reflect the value, in the form of congestion relief, associated with the particular upgrade in question. A separate queue for energy storage would disrupt the analysis of various competing resources that is inherent in the existing queue process and would advance one technology over others

without the benefit of analysis of the site-specific facts and circumstances that are so important to the location of generation or energy storage devices.

The generator interconnection process was established by FERC based on the assumption that resources interconnecting to the grid should bear the costs of any grid upgrades needed to accommodate their request while maintaining system reliability in accordance with NERC standards. The FERC is presently considering whether to modify its present cost allocation policies. Proponents of socializing interconnection costs argue that the present system, which is grounded in principles of cost causation, may be an impediment to the development of renewable technologies. On the other hand, opponents of broad socialization of such costs argue that ratepayers should not bear the costs of facilities and resources that cannot be shown to be beneficial to them. Any changes ordered by FERC to its present cost allocation policies could affect whether energy storage resources remain subject to the cost allocation policies inherent in the queue process.

RESPONSE OF KENNETH HUBER TO QUESTION FROM SENATOR MURKOWSKI

Question 1. In your written testimony, you indicated that variable renewable energy sources present a reliability challenge. You also indicate that the lack of storage is already causing concern for PJM.

a. What is the current percentage of renewable electricity produced in the PJM region?

b. Will development and deployment of energy storage technologies in PJM proceed at a pace sufficient to match the need for meeting a federal renewable electricity standard or will the utilities in the PJM region utilize more fossil-based backup to renewable energy sources?

Answer. PJM embraces the growth of renewable generation as it satisfies a number of public policy goals, including existing state renewable portfolio standards which already exist in 10 of our 13 states. More than half of the new generation in the PJM Interconnection Queue can be categorized as renewable generation, with a particular heavy emphasis on wind generation. However, renewable sources such as wind and solar are a challenge and concern because of their intermittent nature — particularly in a region with the wind and weather patterns that we see in the PJM Mid-Atlantic and Midwest footprint. PJM is encouraging the installation of storage technologies to make the power generated by renewable resources available to consumers during times when it is most needed.

a. The current total generation capacity in PJM is 165,000 megawatts. Renewables including wind, runof-river hydro, pumped hydro and solid waste currently total 9,419 megawatts or approximately 6% of PJM's total capacity.

The 2008 annual energy produced in PJM is 735,244 gigawatt-hours. Renewables including wind, runof-river hydro, pumped hydro and solid waste total 28,635 gigawatt-hours or approximated 4% of PJM's total annual energy produced.

The chart* below shows the amount of megawatt-hours of renewable energy by fuel source produced in PJM for each year since tracking began in late 2005.

The future generation currently being proposed in the PJM generation queues is 82,151 megawatts with over 55% being renewable generation.

b. PJM is aggressively working with energy storage providers and our member companies to facilitate the delivery of energy storage systems in the PJM territory. We are actively pursuing and assisting in pilots of storage technologies that include flywheels, various types of battery systems, compressed air, large building controls, hot water heaters, plug-in hybrid electric vehicles and refrigeration. Renewable generation and energy storage systems are in their early adoption phase. The growth and maturity of both will depend on technology advances, economics and government policy. Forecasting the pace of these many variables is difficult. Current discussions with storage technology entrepreneurs, vendors and venture capitalists provide some insight of expected future storage systems to be installed in PJM: 1) near-term implementations, one to three years out, will likely be battery and flywheel systems with capacity amounts in the 500 MW to 700 MW range; 2) mid-term implementations, four to six years out, should see compressed air storage systems and the aggregation of building and residential energy systems in the 1,000 MW to 1,500 MW range; and 3) beyond 6 years PJM anticipates plug-in hybrid electric vehicle storage within PJM will be available in significant amounts that could provide an addi-

* Graphic has been retained in committee files.

tional 1,000 MW to 1,500 MW. If the storage systems are not available in the volume needed, PJM will utilize both its demand resources, as well as its fossil based resources to maintain system reliability.

APPENDIX II

Additional Material Submitted for the Record

STATEMENT OF THE COALITION TO ADVANCE RENEWABLE ENERGY THROUGH BULK ENERGY STORAGE ("CAREBS")

The Coalition to Advance Renewable Energy Through Bulk Energy Storage ("CAREBS") applauds the Committee on Energy and Natural Resources for its December 10, 2009 hearing on the topic of grid-scale energy storage and appreciates the opportunity to provide additional comments for the record.

CAREBS is a coalition formed to educate legislators, regulators, other policy makers, and the public about the enormous benefits that bulk energy storage—including compressed air energy storage ("CAES") and pumped storage hydroelectric facilities—can provide in facilitating the development of renewable energy resources and increasing the efficiency and reliability of the Nation's electric grid. As the Department of Energy's National Energy Technology Laboratory has noted, grid-scale energy storage, which balances large variations in load and generation, is essential if the Nation is "[t]o reap the full benefits of Smart Grid technologies. . . ." Specifically, bulk energy storage can:

- enable greater supplies of renewable energy to be incorporated into the grid, by converting these variable resources into firm, dispatchable resources;
- enhance grid stability by balancing large variations in load and generations; and
- increase overall efficiency by optimizing the use of existing and planned transmission infrastructure

CAREBS commends the Committee for focusing on how best to incent energy storage and strongly supports Senator Wyden's legislation, S. 1091, which would provide a 20 percent investment tax credit for grid-connected energy storage systems, This technology-neutral legislation would have a tremendous impact on accelerating the deployment of energy storage. Greater commercialization of bulk energy storage also offers the benefit of adding clean jobs to our existing domestic manufacturing base, solidifying the U.S. position as a leader in turbine and compressor equipment for bulk energy storage facilities.

CAREBS also concurs with comments made by several Senators that the regulatory challenges may be as significant as any technical challenges to energy storage. Bulk energy storage provides a lower cost solution to reliability problems than traditional approaches such as transmission upgrades or the construction of new generation. At two of the recent Federal Energy Regulatory Commission ("FERC") technical conferences, held on September 3, 2009 in Phoenix, Arizona and held on September 21, 2009 in Philadelphia, Pennsylvania, CAREBS representatives emphasized the importance of ensuring bulk energy storage solutions are considered on equal footing with new-build transmission and other solutions in the transmission planning process.

Other electricity organizations are recognizing the vital role bulk storage can play in our nation's electricity infrastructure. In its April 2009 report, "Accommodating High Levels of Variable Generation," The North American Electric Reliability Corporation, Princeton, NJ, concluded that "Additional flexible resources, such as demand response, plug-in electric hybrid vehicles, and storage capacity, e.g. compressed air energy storage (CAES), may help to balance the steep ramps associated with variable generation."

CAREBS is eager to work with the Committee and with regulators to advance the deployment of bulk energy storage to advance renewable resources, increase energy efficiency, optimize electricity infrastructure, and promote a self-healing energy grid.

About CAREBS: CAREBS supports policies that will accelerate the development and commercial deployment of CAES, pumped storage hydroelectric, and other bulk energy storage technologies. CAREBS members include: (1) Norton Energy Storage,

LLC ("NES"), which is developing a CAES facility at the site of an abandoned limestone quarry in Norton, Ohio; (2) Magnum Development, LLC ("Magnum"), which is developing a CAES facility in Milford County, Utah, as part of the Western Energy Hub Concept, which also includes a proposed natural gas storage facility; (3) Texas CAES, LLC ("Texas CAES"), which is evaluating several sites for a planned CAES facility in Texas; (4) Haddington Ventures, L.L.C., a private equity firm based in Houston, Texas that pioneered the development of high-deliverability natural gas storage projects and that is currently participating in the development of various CAES projects, including those being developed by Magnum and Texas CAES; (5) Dresser-Rand Corporation, a corporation based in Houston, Texas that is, among other things, a U.S. manufacturer of equipment that is used for CAES; (6) Iowa Stored Energy Plant Agency, an Iowa corporation formed by interested members of the Iowa Association of Municipal Utilities that is developing a CAES facility in Iowa known as the Iowa Stored Energy Park; and (7) HDR/DTA, a consulting firm based in Portland, Maine that provides hydropower and related renewable energy consulting services to utility, industry and government clients.

STATEMENT OF THE PENTADYNE POWER CORPORATION

Mr. Chairman and members of the Committee, Pentadyne Power Corporation appreciates your interest in energy storage by recently holding a hearing to discuss the role of grid-scale energy storage impact on energy and climate goals. Pentadyne Power Corporation encourages the Committee to also consider the role of smaller, non-grid energy storage systems in meeting energy and climate goals. We believe that smaller, non-grid energy storage systems also play a very important role in meeting energy needs.

Pentadyne Power Corporation would appreciate the opportunity to explain the role that smaller flywheels play in the energy storage arena. Our impact can provide immediate help to recycling energy for mass transit facilities that have outlasted their original life span, but are still counted on to delivery passengers. Many of this country's transit systems have exceeded the capacity of their electric systems and flywheels can help keep these systems operating by storing the energy and then sending it back into the system when it is needed.

While grid-scale energy storage plays an important role in a smart grid's system ability to meet energy goals, smaller energy storage systems like flywheel can also play a vital role in recycling energy in high electric use industries.

As mentioned at the hearing, Pentadyne Power Corporation encourages the committee to take an active role discussing and developing policy to promote energy storage. As you well know, energy storage is the key to developing the renewable energy industry. We encourage the committee to take a comprehensive view of energy storage to prevent a perception in the industry of a "two-tier pursuit".

As you heard from your panels at the hearing on December 10th, both government and industry officials agree for renewable energy industry to grow and help cut green house gas production, a wide variety of energy storage devices need to be developed. We would encourage the Committee to active push energy storage policy.

Start up companies, prevalent in new industry like energy storage, faces many hurdles in perfecting our technology and implementing a successful business plan. Under today's financial conditions, we face significant hurdles and would gladly come explain to the committee and its staff how those hurdles that prevent clean energy from breaking into the market.

Pentadyne is the world's leading manufacturer of flywheel energy storage systems. Designed to provide high power output and energy storage in a compact, self contained package, Pentadyne's flywheel products are a long lasting, low maintenance, lightweight, and environmentally sound alternative to lead-acid batteries, capacitors, and steel flywheels.

The company shipped its first commercial production flywheel in 2004, and has sold more than 725 since then. The company also has a multiyear direct supply agreement with a Department of Defense contractor for the purchase of more than 500 Pentadyne flywheel systems. Our flywheels have logged more than 4 million hours of reliable fleet operation. Pentadyne was recently named a "Global Cleantech 100" company by Guardian News and Media and Cleantech Group, LLC. We were also named to the 2008 "Inc. 500" list and a Technology Pioneer by the World Economic Forum in 2007. Our flywheels have won numerous awards, including being named a 2009 Top-10 Green Product by both BuildingGreen and GreenSource Magazine & Architectural Record.

That is why we were pleased by the many positive statements made by the two federal witnesses at this hearing:

Dr. Steven E. Koonin, DOE Under Secretary for Science:

[M]echanical kinetic energy storage via flywheels is particularly well suited to the short term requirements of power conditioning; and while flywheel systems can achieve very high energy densities2, the physical constraints on flywheel size limit energy storage for extended activities such as peak shifting."

* * *

Among the most important requirements for stationary utility storage, which ranges from half a megawatt to hundreds of megawatts, are storage technologies that are low-cost and have a high cycle life, meaning a large number of charge and discharge cycles. High reliability, efficiency, environmental acceptability, and safety are also important.

Mr. Jon Wellinghoff, Federal Energy Regulatory Commission Chairman:

[L]ocal storage is among the best means to ensure we can reliably integrate renewable energy resources into the grid . . . Regulation service is usually provided by combustion turbine gas-fired generators. But while such generators can generally follow the minute-by-minute variations in load to keep the system in overall balance, the frequency excursions that are the subject of Regulation service actually occur on even shorter time intervals. Indeed, it has been demonstrated that distributed resources such as storage are more efficient than central station fast response natural gas fired generators at matching load variations and providing ancillary services needed to ensure grid reliability. They are faster, generally cheaper, and have a lower carbon footprint than the traditional power-plant-provided ancillary service.

* * *

A newer technology for providing storage for the electric grid is the flywheel, which works by accelerating a cylindrical assembly called a rotor (or flywheel) to a very high speed with low friction components, and maintaining the energy in the system as rotational energy. The energy is converted back by slowing down the flywheel. Flywheels have been successfully piloted in the U.S., and their speed is particularly useful for regulation service. For example, for the past year, ISO-NE has been conducting a pilot program to test how alternative technologies such as flywheels are able to provide regulation service.

Both Dr. Koonin and Mr. Wellinghoff understand the role that flywheels can play in improving the efficiency of America's electric grids. We believe that significant hurdles exist to prefect energy storage and encourage the Committee to take a comprehensive review of the industry.

STATEMENT OF AUDREY ZIBELMAN, PRESIDENT AND CHIEF EXECUTIVE OFFICER, VIRIDITY ENERGY, INC.

DEMAND RESPONSE AS A STORAGE SOLUTION

My name is Audrey Zibelman. I am the President and Chief Executive Officer of Viridity Energy Inc. Prior to founding Viridity in 2009 I was the Chief Operating Officer of PJM Interconnection, the largest integrated electric grid in the world. My responsibilities at PJM included overseeing operations to insure that the grid remained in physical balance at all times. As such I managed operations involving the dispatch of thousands of generating units with different fuel types and different operating characteristics.

Viridity is a Curtailment Services or Demand Response Provider specializing in the integration of customer controllable loads and customer owned generation into grid operations. The service we provide transforms a customer's controllable load and owned generation into a virtual power plant which grid operators can rely upon and dispatch to maintain the grid in balance. The purpose of my testimony is to describe how Demand Response can function as an energy storage resource to be used in conjunction with intermittent generating resources such as wind power. The use of Demand Response with renewable power and storage capability allows the aggregation of many small, distributed resources into a new, powerful component of our energy strategy, which can deliver both economic and system stability benefits.

The principal responsibility of all grid operators is to maintain the physical balance between electric consumption (load or demand) and generation (supply). This balance must be maintained continuously and instantaneously. As the Committee is aware, energy storage was not feasible in significant amounts until quite recently. However, recent advances in technology and communications (generally referred to as the Smart Grid) have made storage and Demand Response a viable tool for maintaining the grid in balance. As described below, Demand Response is one of the storage techniques made possible by the Smart Grid.

Historically, grid operators have maintained balance by use of a protocol known as Security Constrained Economic Dispatch. Simply stated, this means that as load increased the grid operators would turn on (dispatch) more generating units so as to match the load. They would dispatch the least expensive unit available but not currently running. Thus, the newly dispatched unit is necessarily more expensive than the last unit that was dispatched before the increase in load. This regime of simply turning on the next generating unit in the queue is now giving way to a more sophisticated, environmentally-sound, consumer-friendly, approach to maintaining the grid in balance.

A key characteristic of any mechanism used to maintain balance is its ability to respond to directions from the grid operator; it must be dispatchable. This means that a generating unit must be capable of increasing or decreasing its output upon direction by the grid operator to do so. One of the issues associated with wind power for example is that it is not dispatchable. The power is available only when the wind is blowing, and the output of wind generation cannot be ramped up or down on command, as can generation from other sources such as storage resources or natural gas fueled generating units. The ability to be dispatched—to be capable of responding to signals—is an important attribute of a resource. Energy storage and demand response resources both have this important attribute. Many customer loads are dispatchable.

Many customers are ready and willing to reduce their consumption of electricity upon direction by the grid operator. Thus, increasing output from expensive or dirty generating units is not the only means available to grid operators to balance the grid. Customers can reduce their load upon a signal from the grid operator either by pre-arrangement or in real time.

Grid operators have traditionally maintained balance by arranging for sufficient generation to come on line as needed throughout the day, based upon the next day's forecast load. The supply is committed a day in advance. Generators who are advised that they will be running on the next day stay stand ready to respond to signals from the operator. The advent of the Smart Grid, sophisticated software, and telecommunications technology have now made it possible for customers to respond in the same way. Customers who are willing to reduce load in exchange for compensation can respond to a signal from the grid to reduce their consumption, or they can dispatch their storage resources. This 'demand response' can be pre-arranged on a day-ahead basis. Similarly, to the extent that demand exceeds the forecasted load, increased supply, in the form of storage resources, can be called for by the grid operator in real time. Again, however, those customers who are willing to reduce their consumption can also do so in real time, in response to an instruction from the grid operator. Storage and demand response can be called upon in tandem to maintain the grid in balance.

A Smart Grid enabled example of energy storage, renewable energy, and demand response working in tandem would be the use of Customer-owned solar power to charge a customer-owned battery when or where energy loads are low, and the discharge of that energy into the grid when/where the load is high. The discharge of the battery would allow the customer to reduce its load served by the grid; that is, to engage in demand response, and to provide power to the grid where and when it is needed.

Demand response can be a useful tool aiding in the integration of intermittent power sources, such as wind power, onto the grid. For example, fast-response customer load reductions can be called for as wind generation drops. This demand response will match the reduced level of wind generation and thus maintain the grid's balance. Similarly, to the extent reductions in wind power become increasingly predictable with improved remote monitoring, pre-arranged reductions in load can be relied upon to maintain the necessary balance.

Grid balance can be maintained either by increases in generation or by reductions in load and grid operators should be generally indifferent as to the source providing the balance. However, there are several clear advantages associated with maintaining balance via Demand Response that should be noted. First, Demand Response is a less expensive means of maintaining balance than is dispatch of greater quantities of electric generation. This has been demonstrated time and again in the

United States, most dramatically in PJM in August 2006. During that month, the dispatch of demand response instead of added generation, reduced the prices paid by customers by $650 million. The physical balance of the PJM grid was maintained by customers who reduced their consumption in response to a signal from the PJM dispatcher. This allowed PJM to avoid having to dispatch more expensive generating units. Hence, the savings noted above. Second, there are no green house gas emissions associated with Demand Response, unlike the emissions caused by dispatch of fossil-fueled generating units. The dispatch of coal or gas fired generating units necessarily results in emissions. The dispatch of demand response—that is, reductions in use by customers when called for by the grid—avoids emissions, much like all exercises in energy efficiency and conservation.

The provision of energy storage and demand response service to the grid by customers requires an investment by those customers. That investment constitutes a barrier to the deployment of these technologies. Customers will only make that investment if they can expect a reasonable return on their investment. However, an appropriate regulatory regime which provides fair, non-discriminatory compensation to customers who are willing to make that investment would constitute a regulatory policy that could eliminate the barrier to deployment. At present, the grid rules do not provide such compensation to customers willing to make the investment. A change in the rules such that customers were compensated for the service they provide through such investments would significantly enhance the level of deployment.

STATEMENT OF STEPHEN C. BYRD, PRESIDENT AND CEO, ENERGY STORAGE AND POWER, LLC

INTRODUCTION

Energy Storage and Power (ES&P) would like to thank the Committee for providing the opportunity to submit testimony describing how grid scale energy storage can meet the country's energy and climate goals, ES&P exclusively markets, designs, licenses and technically supervises the delivery of energy storage and power augmentation projects. ES&P's patented second generation compressed air energy storage, or CAES, technology enables the widespread deployment of renewable generation such as wind and solar, stabilizes the transmission grid and is the most cost effective storage solution available. ES&P is a joint venture between Public Service Enterprise Group, a Fortune 200 company with over a hundred years' history in the power industry and Dr. Michael Nakharnkin, the leading voice worldwide in the Compressed Air Energy Storage field for over two decades.

A number of power companies are pursuing the development of second generation CAES plants, most notably Pacific Gas & Electric (PG&E), which is developing a 300MW CABS plant, and New York State Electric and Gas's (NYSEG) which is developing a 150MW CAES plant. PG&E and NYSEG were recently awarded $ 25 million and $29.4 million, respectively, in grants from the Department of Energy for demonstration projects. These two projects alone are leveraging 73% of the total private capital associated with the 16 energy storage grants recently awarded by the Department of Energy.

ES&P recently won Platts 2009 Sustainable Technology Innovation of the Year Award for its second generation CAES technology. For a more detailed overview of ES&P, please see Appendix A.*

EXECUTIVE SUMMARY

Investments in energy storage at this time are absolutely critical. Energy storage will increase the usage of renewable generation and reduce greenhousegas emissions, will enhance grid reliability, and reduce overall customer power costs.

QUESTION 1: WHAT ARE THE PRINCIPAL GOALS OF STORAGE—LEAST COST GENERATION, GREENHOUSE GAS REDUCTIONS, OR GRID RELIABILITY?

Grid scale (i.e., large-scale) energy storage accomplishes a wide range of important objectives, namely the ability to (i) reduce greenhouse gas emissions, (ii) significantly enhance grid reliability, (iii) reduce the cost of power to customers and iv) reduces the need for additional transmission.

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*Appendixes A–C have been retained in committee files.

Firming Renewables and Shifting Their Output to Peak Demand Periods Will Reduce Greenhouse Gas Emissions

Incorporating energy storage solves the intermittent and unpredictable nature of renewable resources such as wind and solar and converts them into firm, dispatchable resources. Large scale energy storage enables the electricity generated from wind power to be provided when it's needed (on-peak), not when it's windy (predominantly off-peak)[1]. Without energy storage, substantial amounts of renewable generation, particularly wind power, will be unused because there will be insufficient demand for the product during off-peak power demand periods, when the majority of wind power is produced. Energy storage will enable renewables to be fully utilized, resulting in the displacement of fossil-fueled generation and the reduction in greenhouse gas emissions. The economics of a wind farm will improve as a result of energy storage, because the stored wind power output would be sold during peak demand periods, when powerprices are higher.

Significantly Enhances Grid Reliability

Another important goal of energy storage is to enhance grid reliability. This will become critically important as intermittent renewable resources such as wind and solar become an even larger portion of the power supply mix in the future. Because wind variability can be so extreme[2], substantial balancing reserves are required in the event there's a rapid drop in wind power output. In addition, existing power plants will have to cycle their output up and down to compensate for the changing winds; this constant cycling causes maintenance and operational issues for baseload power plants[3]. In addition, the range of options available to grid operators to enhance grid reliability is larger than what's typically understood. Grid operators require reliability service with response time within minutes, not milliseconds[4]. CAES technology meets grid operators' ancillary services requirements at a much lower cost than batteries.

Reduces Cost of Power to Customers

Large scale energy storage will reduce the cost of power to consumers because more costly peaking generation will not be utilized during the day.[5] Large scale energy storage will shift renewable generation output (that has no variable cost of production) from off-peak periods to peak demand periods, which will in turn avoid the need to run very high cost, high emission peaking generation. This role played by large scale energy storage is akin to "peak shaving" technologies designed to shift demand for power from peak periods to off-peak periods; energy storage is essentially shifting the supply side rather than the demand side. This will result in a reduction in system-wide power costs and a resulting reduction in customers' electricity bills. CAES is particularly effective in this role because its capital cost is an order of magnitude cheaper than other storage options such as batteries. Further, CAES consistently has a lower overall cost of power than conventional generation options, such as coal and natural gas, under a variety of market and commodity price scenarios.

Reduces Need for Additional Transmission

Large scale energy storage reduces the need for additional transmission and utilizes transmission more efficiently. Because second generation CAES can be built and integrated at various junctures in the delivery of electricity, transmission benefits can be realized. For example, a utility customer can build a CAES plant near load pockets to minimize the use of both constrained transmission lines and expensive local power resources. Also, a transmission grid operator (or wind farm owner) can build a CAES plant near generation to reduce or eliminate transmission conges-

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[1] The Midwest Model Building Subcommittee (a group formed by the Midwest Reliability Organization, one of eight regional entities in North America operating under their delegated authority from regulators in the United States and Canada) assumes that only 20% of nameplate wind turbine capacity will be available during peak time periods.

[2] Historically, the Midwest ISO has recorded a minimum and maximum output from wind power during peak periods equal to approximately 2 percent and 65 percent of wind nameplate capacity, respectively.

[3] "Cycling operations can be very damaging to power generation equipment." Stephen Lefton and Bill Besuner, *Power Plant O&M and Asset Optimization.*

[4] For example, in PJM, the largest Independent System Operator in the U.S., the ancillary service known as synchronized reserve (formerly spinning reserves) is defined as capacity (generation or usage reduction) that is available in 10 minutes.

[5] Dr. Robert Schainker, a Senior Technical Executive at the Electric Power Research Institute (EPRI), stated in October 2009 at the EESAT conference in Seattle, Washington that the addition of between 20% and 40% of anticipated future wind capacity in the form of compressed air energy storage would result in a reduction in overall customer power costs.

tion and increase efficiency of the grid because energy will be released when wind plants are at low output and transmission capacity is available.

QUESTION 2: HOW CAN ENERGY STORAGE TECHNOLOGIES HELP UTILITIES MEET STATE RENEWABLE PORTFOLIO STANDARDS (RPS) AND PEAK DEMAND REDUCTION TARGETS?

Energy storage will be critical for states to meet RPS requirements. Energy storage enables renewables to be used as a controllable, on-peak power source, improving renewable project economics and improving grid reliability. Energy storage also helps to avoid the usage of high cost, high emissions peaking generation.

By its very nature, energy storage enables renewables to account for a larger portion of the overall power generated. Energy storage will be critical to enabling states to meet their individual RPS and any federally instituted RPS requirements. For example, with wind power, storage will enable power produced by wind farms during off-peak periods to be used during peak demand periods; this will result in improved returns for renewable generation and provide an economic signal to build further renewable projects.

Energy storage shifts the generation of power away from high cost, high emissions peaking generation and towards more efficient, lower emission renewable power sources. In a similar way to demand response technology, large scale storage reduces the need for peaking generation; this ability is often referred to as "peak shaving." This reduces the cost of power to consumers because more costly peaking generation will not be utilized during the day.

QUESTION 3: WHAT IS THE TOTAL US POTENTIAL FOR ENERGY STORAGE?

The potential for energy storage in the United States is significant, and its deployment is in thevery early stages. If enough cost-effective storage is built, EPRI has indicated that the cost of power to consumers will be reduced.[6] Numerous parties have already begun making sizeable investments in energy storage.

Several sources have discussed the potential for large scale energy storage. Estimates of market size vary, but all agree storage is needed. . .and a lot of it. The American Institute of Chemical Engineers published a study in 2008 forecasting that if wind and solar accounted for 20% of the power generated in the United States, 114,000 MW of storage would be required. This represents a $342 billion market opportunity according to their calculations.[7] Others have more specifically defined the sizeable market opportunity for CAES. In a recent presentation, EPRI discussed a CAES to wind ratio of 20% to 40% reducing the overall cost of power for customers. Assuming the projected installed capacity for 2009 by the American Wind Energy Association of approximately 32,500 MW, a 30% CAES to wind ratio, 9,750 MW of CAES could be built in the United States. Whichever assumption is used to estimate the size of the large potential domestic jobs.

A number of utilities and merchant power generators have already recognized the potential for storage and have begun to make substantial investments. For example, Pacific Gas & Electric is developing a 300 MW CAES plant (expected cost: $356 million) and New York State Electric & Gas (NYSEG) is developing a 150 MW CAES plant (expected cost: $125 million). Both of these projects have received grants from the American Recovery and Reinvestment Act of 2009 ($25 million for PG&E and $29.6 million for NYSEG). In conjunction with the awards to PG&E and NYSEG, the Department of Energy recently made 16 grant awards for a total of $185 million to fund "utility-scale energy storage projects that will enhance the reliability and efficiency of the grid, while reducing the need for new electricity plants."

QUESTION 4: WHAT ARE THE MOST PROMISING TECHNOLOGIES?

There are a number of technologies available for electricity storage. However, some are better suited for large scale storage and are more economical. Technology like batteries, flywheels and supercapacitors are best suited for small scale storage in situations where instantaneous response is required. For large scale energy storage, CAES and pumped hydro are the technologies of choice.

Of these two alternatives, we believe that CAES holds advantages from the perspectives of cost,time required to deploy and number of suitable locations. Batteries, flywheels and supercapacitors are significantly more expensive on a capital cost basis and cannot be built at the scale required. Unlike CAES or pumped hydro,

[6] Dr. Robert Schainkera, Senior Technical Executive at the Electric Power Research Institute (EPRI), stated in October 2009 at the EESAT conference in Seattle, Washington that the addition of between 20% and 40% of anticipated future wind capacity in the form of compressed air energy storage would result in a reduction in overall customer power costs.

[7] "Massive Electricity Storage," Bernard Lee and David Gushee, June 2008.

these technologies are better suited for distributed storage or ancillary services that require an instantaneous response. It is rare to have a battery built bigger than 5 MW, but a CAES plant can be built up to 450 MW.

Overview of CAES

CAES stores low cost, off-peak wind energy in the form of compressed air primarily in anunderground reservoir, but it can also be stored in above-ground canisters. During peak hours,the air is released and heated with the exhaust heat from a standard natural gas-fired combustionturbine. This heated air is passed through expansion turbines to produce electricity. The exhaustair from the expansion turbines is then used to increase the output of the combustion turbine byapproximately 10% and create "free green megawatts." The second generation CAES technology has a "heat rate" (a measure of energy usage per unit of electricity output) that is three times as efficient as that of a coal plant or a combustion turbine when renewable generation is used as its power input. (See Appendix B for a graphical depiction and a detailed description of the technology).

Improvements to the CAES technology ensure that it is adjustable to meet specific customer smart grid requirements, utilizes standard, proven components, has a very low emissions design, and has significantly lower capital and operating costs than other storate technologies, and is a lower cost generator than coal and natural gas-fired power plants.[8]

There are several other characteristics of CAES that make it a straightforward technology to deploy on a widespread basis. Suitable geology exists in a large portion (approximately 80%) of the United States.[9] The CAES technology is proven and it works.

QUESTION 5: WHAT ARE THE OBSTACLES, TECHNICAL, REGULATORY AND LEGISLATIVE, TO COMMERCIAL DEPLOYMENT OF STORAGE TECHNOLOGIES?

There are numerous obstacles currently preventing the wide-scale deployment of storage technologies. However, we believe these obstacles can be overcome with coordinated efforts among industry, legislators and regulators. No technical obstacles have been identified relating to the construction and operation of CAES plants. Appropriate investment incentives should be instituted for storage. Storage is in the very early adoption phase, but further catalysts are needed to move from the demonstration phase to the mass deployment phase. Constrained financing environment is still limiting investment in storage. Certain parties have posited that energy storage isn't necessary as renewable penetration increases, contrary to consensus among grid operators and other entities responsible for grid reliability.

TECHNICAL OBSTACLES

There are no technical obstacles to the widespread deployment of second generation CAES plants. The technology and geology for CAES exists and it works. The first generation CAES technology has been in operation since 1991 and has had an availability factor above 95%. A variety of parties that have reviewed the second generation CAES technology have signed off on all technical specifications and agree it's a significant improvement over first generation CAES.

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[8] The Western sub-region of the Texas power market, known as Western ERCOT, provides an excellent example of how 2nd generation CAES can be (1) highly efficient relative to conventional fossil fuel fired generation and (2) enhance the value of renewable generation. As a result of substantial wind generation construction in Western ERCOT, wind generation economics have deteriorated in the region. Because there is so much wind capacity in Western ERCOT and its power is generated mostly at night when demand for power is low, off-peak power prices are often negative due to the utilization of the Production Tax Credit for wind. Wind generation in Western ERCOT is often being curtailed substantially at night because the volume of generation is greater than demand which obviously wastes a resource with no incremental cost. 2nd generation CAES enhances the value of wind generation while producing on-peak power at a cost lower than conventional natural gas-fired generation. The variable cost of generation is substantially lower than the most efficient combined cycle generation. In addition, 2nd generation CAES has a positive economic impact on wind generation by providing an incremental source of demand for the output of the wind generation.

To calculate the variable cost of generation, assume a $10 off-peak power price and a $5/mmBtu cost of natural gas. The 2nd generation CAES variable cost of generation would be $26 per megawatt-hour (($10 off-peak power price x .7 energy ratio) + (3,810 heat rate x $5/mmBtu/1000) + $2/MWh variable operations and maintenance cost). For the most efficient combined cycle generation the variable cost of generation would equal $38 per megawatt-hour ((7,000 heat rate x $5/mmBtu/1000) + ($3/MWh variable operations and maintenance)).

[9] EPRI.

REGULATORY AND LEGISLATIVE OBSTACLES

There are a number actions that could be taken by regulators and legislators that could acceleratethe adoption of storage. The successful deployment of energy storage technology requires regulatory and legislative certainty, (including passage of the energy and climate bills) and would be aided by the adoption of the Clean Energy Deployment Administration.. CAES investments currently receive no federal tax incentives. The institution of an Investment Tax Credit for storage would help spur investment. Additionally, energy storage can result in the loss of production tax credits otherwise available to certain non-CO_2 generators, such as wind generators. The tax code needs to be amended to ensure that there is no loss of the Production Tax Credit (PTC) for energy stored prior to delivery to grid.

A FERC technical conference on storage should be held to discuss integrating storage in competitive and regulated areas; the benefits of storage to the grid; quantifying energy storage required to maintain grid reliability and reduce system-wide power costs; and availability of FERC incentives depending on how storage is classified — whether as a transmission or generation asset, or some combination thereof.

Industry Obstacles

A very small number of industry players have said that with 20% wind penetration, storage is not needed.[10] We strongly disagree with that assertion. There are already issues with integrating wind in many regions, and wind accounted for only 1.3%[11] of the power produced in the United States in 2008. These issues will become far more severe and pronounced when wind becomes 20% of the energy mix, as some parties have suggested may occur. Based on the problems associated with the integration of wind in their respective regions, ERCOT and MISO strongly believe energy storage is needed. Terry Boston, CEO of PJM Interconnection, has stated that energy storage helps grid operators deal with the intermittency of renewable generation sources such as wind and solar. The intermittent nature of wind, with resulting negative effects on both grid reliability and the ability to deliver power when it is needed, will only be exacerbated as wind's share of the power generation mix continues to increase. Ignoring or downplaying the grid reliability issues caused by renewable generation, and the grid reliability benefits offered byenergy storage, is contrary to the thinking of transmission system operators, utilities, merchant power generators and Members of this Committee. In fact, large scale storage will increase the development of wind farms in the long run becauses toragew ill significantlye nhancew ind farmeconomics as wind evolves into a dependable power resource.[12]

CONCLUSION

ES&P would like to thank the Committee again for this opportunity. Investments in large scale energy storage at this time are absolutely critical. With the proper investment incentives in place, energy storage can play a critical role in helping the United States meet its renewable portfolio standards, enhance grid reliability, reduce greenhouse gas emissions, save consumers money and create jobs.

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[10] The American Wind Energy Association (AWEA) has stated that" [w]hile continuing advances in energy storage technology can make it more economically competitive as a provider of grid flexibility, it is important to remember that resources like wind energy can already be cost-effectively and reliably integrated with the electric grid without energy storage."

[11] Derived from data from the US Energy Information Administration.

[12] Richard Baxter, "A Call for Back-up: How Energy Storage Could Make a Valuable Contribution to Renewables."