REAL-TIME FORECASTING FOR RENEWABLE ENERGY DEVELOPMENT

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

SECOND SESSION

JUNE 16, 2010

Serial No. 111–100

Printed for the use of the Committee on Science and Technology

Available via the World Wide Web: http://www.science.house.gov

U.S. GOVERNMENT PRINTING OFFICE

57–178PDF WASHINGTON : 2010

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2104 Mail: Stop IDCC, Washington, DC 20402–0001

COMMITTEE ON SCIENCE AND TECHNOLOGY

HON. BART GORDON, Tennessee, *Chair*

JERRY F. COSTELLO, Illinois
EDDIE BERNICE JOHNSON, Texas
LYNN C. WOOLSEY, California
DAVID WU, Oregon
BRIAN BAIRD, Washington
BRAD MILLER, North Carolina
DANIEL LIPINSKI, Illinois
GABRIELLE GIFFORDS, Arizona
DONNA F. EDWARDS, Maryland
MARCIA L. FUDGE, Ohio
BEN R. LUJÁN, New Mexico
PAUL D. TONKO, New York
STEVEN R. ROTHMAN, New Jersey
JIM MATHESON, Utah
LINCOLN DAVIS, Tennessee
BEN CHANDLER, Kentucky
RUSS CARNAHAN, Missouri
BARON P. HILL, Indiana
HARRY E. MITCHELL, Arizona
CHARLES A. WILSON, Ohio
KATHLEEN DAHLKEMPER, Pennsylvania
ALAN GRAYSON, Florida
SUZANNE M. KOSMAS, Florida
GARY C. PETERS, Michigan
JOHN GARAMENDI, California
VACANCY

RALPH M. HALL, Texas
F. JAMES SENSENBRENNER JR., Wisconsin
LAMAR S. SMITH, Texas
DANA ROHRABACHER, California
ROSCOE G. BARTLETT, Maryland
VERNON J. EHLERS, Michigan
FRANK D. LUCAS, Oklahoma
JUDY BIGGERT, Illinois
W. TODD AKIN, Missouri
RANDY NEUGEBAUER, Texas
BOB INGLIS, South Carolina
MICHAEL T. MCCAUL, Texas
MARIO DIAZ-BALART, Florida
BRIAN P. BILBRAY, California
ADRIAN SMITH, Nebraska
PAUL C. BROUN, Georgia
PETE OLSON, Texas

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

HON. BRIAN BAIRD, Washington, *Chair*

JERRY F. COSTELLO, Illinois
EDDIE BERNICE JOHNSON, Texas
LYNN C. WOOLSEY, California
DANIEL LIPINSKI, Illinois
GABRIELLE GIFFORDS, Arizona
DONNA F. EDWARDS, Maryland
BEN R. LUJÁN, New Mexico
PAUL D. TONKO, New York
JIM MATHESON, Utah
LINCOLN DAVIS, Tennessee
BEN CHANDLER, Kentucky
JOHN GARAMENDI, California
BART GORDON, Tennessee

BOB INGLIS, South Carolina
ROSCOE G. BARTLETT, Maryland
VERNON J. EHLERS, Michigan
JUDY BIGGERT, Illinois
W. TODD AKIN, Missouri
RANDY NEUGEBAUER, Texas
MARIO DIAZ-BALART, Florida
RALPH M. HALL, Texas

CHRIS KING *Democratic Staff Director*
SHIMERE WILLIAMS *Democratic Professional Staff Member*
ADAM ROSENBERG *Democratic Professional Staff Member*
JETTA WONG *Democratic Professional Staff Member*
ANNE COOPER *Democratic Professional Staff Member*
ROB WALTHER *Democratic Professional Staff Member*
DAN BYERS *Republican Professional Staff Member*
TARA ROTHSCHILD *Republican Professional Staff Member*
JANE WISE *Research Assistant*
ALEX MATTHEWS *Research Assistant*

CONTENTS

June 16, 2010

Appendix 1: Answers to Post-Hearing Questions

Appendix 2: Additional Material for the Record

REAL-TIME FORECASTING FOR RENEWABLE ENERGY DEVELOPMENT

WEDNESDAY, JUNE 16, 2010

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE AND TECHNOLOGY
Washington, DC.

The Subcommittee met, pursuant to call, at 10:02 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Baird [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE AND TECHNOLOGY

SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6301
(202) 225–6375
http://science.house.gov

Subcommittee on Energy and Environment

Hearing on

Real-Time Forecasting for Renewable Energy Development

Wednesday, June 16, 2010
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Witness List

Ms. Jamie Simler
Director
Office of Energy Policy and Innovation
Federal Energy Regulatory Commission

Dr. Alexander MacDonald
Deputy Assistant Administrator
Laboratories and Cooperative Institutes
Office of Oceanic and Atmospheric Research
National Oceanic and Atmospheric Administration

Dr. David Mooney
Director
Electricity, Resources, and Building Systems Integration Center
National Renewable Energy Laboratory

Dr. Pascal Storck
Vice President
3TIER

Mr. Grant Rosenblum
Manager of Renewable Integration
California Independent System Operator

Dr. Robert Michaels
Senior Fellow
Institute for Energy Research

HEARING CHARTER

COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
U.S. HOUSE OF REPRESENTATIVES

Real-Time Forecasting for Renewable Energy Development

WEDNESDAY, JUNE 16, 2010
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Wednesday, June 16, 2010 the Subcommittee on Energy and Environment of the House Committee on Science & Technology will hold a hearing entitled "*Real-Time Forecasting for Renewable Energy Development*."

The Subcommittee will receive testimony on the roles that various Federal agencies as well as the private sector play in providing forecasting data and services relevant to expanding the availability of reliable, renewable power, and the extent to which these efforts are coordinated. The hearing will also explore any research, development, demonstration, and monitoring needs that are not currently being adequately addressed.

Witnesses

- **Ms. Jamie Simler** is the Director of the Office of Energy Policy and Innovation at the Federal Energy Regulatory Commission. Ms. Simler will testify on FERC's recent activities to survey the issues surrounding the utilization of intermittent renewable energy sources on the electric grid, as well as viable technical and policy options to address these issues.
- **Dr. Alexander MacDonald** is the Deputy Assistant Administrator for Laboratories and Cooperative Institutes in the National Oceanic and Atmospheric Administration's (NOAA's) Office of Oceanic and Atmospheric Research. Dr. MacDonald will describe the data, information, and services currently provided by NOAA in support of renewable energy, and how these capabilities could be further developed to better serve the needs of renewable energy developers and consumers.
- **Dr. David Mooney** is the Director of the Electricity, Resources, and Building Systems Integration Center at the National Renewable Energy Laboratory (NREL) in Golden, Colorado. Dr. Mooney will testify on NREL's activities with other Federal agencies as well as the private sector to identify and address issues with grid integration of renewable energy resources.
- **Dr. Pascal Storck** is the Vice President of 3TIER. Dr. Storck will provide testimony on the role that private renewable power forecasters play relative to and in collaboration with services offered by the public sector.
- **Mr. Grant Rosenblum** is Manager of Renewable Integration for the California Independent System Operator (California ISO). Mr. Rosenblum will testify on his experience in balancing intermittent renewable power with baseload power sources, and on ways to ensure the reliability of a transmission system with significant renewable energy components.
- **Dr. Robert Michaels** is a Senior Fellow of the Institute for Energy Research. Dr. Michaels will testify on economic and other challenges associated with renewable energy sources.

Background

A significant barrier to the widespread adoption of many forms of renewable energy, including wind, solar, and marine and hydrokinetic power (MHK), is that these sources are intermittent. Electric grid managers address this intermittency by adjusting the delivery of other sources of power based on expected changes in renewable power output. These expected changes are called power production forecasts. Such forecasts must take into account changing weather conditions in conjunction with the land's topography near a renewable energy device, along with the device's expected technical performance. The larger the uncertainty in these forecasts, the more baseload[1] power must be kept in reserve or stored to ensure the reliability of electricity to consumers, thus ultimately increasing the total cost of electricity generation. Several recent reports[2] have determined that improving the accuracy and frequency of these forecasts can have a major impact on the economic viability of renewable energy resources.

Wind, Solar and Marine and Hydrokinetic Power Forecasting Needs

Current observational networks in the United States are relatively sparse and widely spaced, and are therefore not well-suited to forecast wind energy generation. These networks emphasize data collection at a height of 10 m or less above the surface compared to today's typical wind turbine hub height of roughly 80 m. This makes it difficult to detect and forecast weather events such as large wind speeds over short time periods. The American Wind Energy Association's (AWEA's) detailed *Action Plan to 20% Wind Energy by 2030*, which is a follow-up to DOE's wind energy report, also notes that there is "currently a disconnect between wind forecasters and grid operators regarding what wind forecasting information is most useful for system operators." The plan recommends greater cooperation between these groups and enhanced system operator training, as well as a significant effort to integrate wind forecasting tools into energy management system applications. In addition, collaborative field and computational modeling research is considered necessary in strategic areas of the country to better detect and forecast complex flow regimes that lead to unexpected turbine outages, long-term turbine performance issues, and wind forecasting errors.

Forecasting needs for marine and hydrokinetic energy projects are similar to wind. High-resolution wind data, enhanced frequency in which data is collected, and increased local observation sites near potential MHK projects can improve long- and short-term power forecasts. Wave energy technologies also benefit from accurate ocean surface wind simulations. Although tidal and current energy are more predictable than wave energy, DOE's National Marine Renewable Energy Centers are currently developing numerical models to simulate the mechanics of flow around single turbines and full arrays with the goal of significantly improving their reliability and power forecasts. Finally, meteorological data focused on the surface boundary layer of the water, combined with the already collected astronomical tidal forecasts conducted by the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service, can assist in providing more accurate tidal power forecasts.

Solar power forecasting is heavily dependent on satellite data, much of which has a resolution that is a factor of 10 or more too course to meet the real-time needs of grid managers. The power output of utility-scale concentrating solar power systems also depends on the level of direct, as opposed to diffuse, sunlight incident on the systems' components, which in turn is dependent on the concentration of aerosols as well as cloud cover in the local atmosphere. This compounds the monitoring and modeling requirements to achieve an accurate forecast.

Public and Private Sector Roles in Renewables Forecasting

NOAA's capability to understand and predict changes in the Earth's environment enables the agency to support renewable energy at multiple scales. NOAA's weather forecasts support energy demand predictions today, and these forecasts are expected to be critical as sources which depend on real-time meteorological conditions such as solar, wind, and MHK power increase in importance. At the most basic level, most renewable energy sources depend on the atmospheric and oceanic data that NOAA provides. NOAA furthers the development and integration of renewable energy sources through models, analysis tools, and by providing reliable weather, hydrological[3], climatic, and ecological data and forecasts. To accomplish this, NOAA employs a diverse array of data collection tools and leverages internal and external partnerships. NOAA utilizes an integrated system of Earth observing networks supplied by such tools as remote sensing and satellite imagery and a surface network

[1] "Baseload" power refers to power that can be delivered continuously. Examples include coal, nuclear, natural gas, and power delivered from energy storage systems such as batteries, fuel cells, and compressed air energy storage (CAES).

[2] Examples include the National Renewable Energy Laboratory's *Western Wind and Solar Grid Integration Study* published in May 2010 and the Department of Energy's 2008 report entitled *20% Wind Energy by 2030*.

[3] Including researching, monitoring, and predicting ocean currents, tides, water levels, ocean circulation, and temperature.

of weather radars, upper air balloons, ocean buoys, ships, aircraft, and seafloor observations to enhance observation networks, improve weather forecasts, and incorporate climatic changes into long term resource forecasts for the energy industry and utilities. For example, the Earth System Research Laboratory (ESRL) and the National Weather Service (NWS) work to improve the sensing, characterization, and prediction of weather elements in the Planetary Boundary Layer (PBL) through advances in research and implementation of the next generation operational weather forecast model (called the Weather Research and Forecasting computer model, or more commonly WRF). NOAA leverages research capacities across the agency, as well as partnerships with other Federal agencies and national laboratories, cooperative institutes, universities, and international research organizations.

The National Center for Atmospheric Research (NCAR), sponsored by the National Science Foundation (NSF), conducts collaborative research in atmospheric and Earth system science, encompassing meteorology, climate science, atmospheric chemistry, solar-terrestrial interactions, and environmental and societal impacts. Since 2009, a priority of NCAR has been to develop its capacity to support a transition to renewable energy sources through its breadth of atmospheric science knowledge, experience with technology transfer, and access to university researchers. For example, NCAR entered into a partnership with DOE's National Renewable Energy Laboratory (NREL) and a regional utility company, Xcel Energy, to develop sophisticated, localized wind forecasts for operational use. These products aim to inform the siting of new wind turbine farms, to better integrate wind-generated electricity into the power grid, and to make critical decisions about powering down traditional power plants when sufficient winds are predicted. In addition, NCAR incorporates observations of current atmospheric conditions from a variety of sources, including NOAA models and meteorological data, satellites, aircraft, weather radars, ground-based weather stations, and sensors on the wind turbines into three powerful NCAR-based tools: WRF (referenced above); the Real-Time Four-Dimensional Data Assimilation System (RTFDDA); and the Dynamic Integrated Forecast System (DICast).

NREL has published several studies on the regional integration of intermittent renewables into the electric grid over the last several years. The laboratory currently works with private renewable technology developers and forecasters to test and supply relevant data on the effect that varying atmospheric conditions can have on particular types of renewable energy systems. NREL also works with NOAA and other relevant agencies to map and update its assessment of renewable energy resources throughout the United States, and it carries out modeling and simulation research activities to better inform the siting and operation of a variety of renewable energy projects. In addition to these ongoing efforts, on June 1st DOE announced funding for up to $6 million over two years to improve short-term (0–6 hour) wind energy forecasting—$2 million of which will be provided to NOAA this year to fund its technical support of the selected projects and $1 million will be awarded to one or two competitively selected teams. DOE anticipates providing an additional $3 million in fiscal year 2011 to NOAA and the recipient team(s) for completing the project.

Private sector companies, often called Forecasting Service Providers (FSP), have been in the business of producing site and technology specific renewable power forecasting products for over a decade. These companies are generally third-party vendors which provide confidential forecasting products. The power forecasting products are usually based on three main inputs. The first input is the foundational numerical weather prediction (NWP) models using NOAA, NASA and NCAR meteorological and atmospheric data. The second input is site specific observations collected from meteorological (or "met") towers and other on-site observation devices. Finally this information is combined with technical specs based on the energy output of the specific renewable technologies (i.e. a certain kind of wind turbine or solar panel). Then using advanced computational techniques, simulations and local scale specific models a power forecasting product is created.

Renewable energy project developers, financiers, energy generators, utilities, and electricity balancing authorities use power forecasts. Generally there are two kinds of products, one is used for long-term planning to build and site new renewable projects and the other is short-term (day-ahead or hour-ahead time frames) for optimization of renewable energy integration onto the grid. The long-term forecast helps assess the amount of energy a specific location may be capable of producing using a certain technology. This information helps determine characteristics of a project such as what technology to install and how large an installation should be. The short-term power forecasts are used for efficient scheduling of generation resources. This is important to energy generators as well as to balancing authorities such a Regional Transmission Organizations (RTO) and Independent Systems Operators

(ISO) which are charged with managing the flow of electric power on the grid. Accurate power forecast products help generators maximize profits by making their resources more reliable for scheduling as well as better at precisely predicting their energy output. Increased accuracy may reduce fines, penalties, and eventually the amount of reserve energy required to back-up or firm-up the same quantity of renewable resource. This is important to RTOs and ISOs because it reduces the risk of over or under loading the power grid, which can damage the grid and possibly lead to catastrophic blackouts.

FERC Notice of Inquiry on Variable Energy Resources

To gain further information on these issues, the Federal Energy Regulatory Commission (FERC) issued a Notice of Inquiry (NOI) in January on "the extent to which barriers may exist that impede the reliable and efficient integration of variable energy resources (VERs) into the electric grid, and whether reforms are needed to eliminate those barriers." The NOI goes on to state that:

> "[i]n order to meet the challenges posed by the integration of increasing numbers of VERs, ensure that jurisdictional rates are just and reasonable, eliminate impediments to open access transmission service for all resources, facilitate the efficient development of infrastructure, and ensure that the reliability of the grid is maintained, the Commission seeks to explore whether reforms are necessary to ensure that wholesale electricity tariffs are just, reasonable and not unduly discriminatory."

To date, FERC has received responses to this NOI from over 100 parties, including relevant government agencies and laboratories, electric utilities, RTOs, ISOs, and private forecasting companies.

Mr. TONKO. [Presiding] This hearing will now come to order.

Good morning, and welcome to today's hearing on real-time forecasting for renewable energy development.

The United States has tremendous potential to expand our use of renewable energy resources. According to a study by the Pacific Northwest National Laboratory, the accessible wind potential in just 12 states could power the entire country over twice. Lawrence Berkeley National Lab has also shown that if we took one percent of the total United States land area and covered just a quarter of it with currently available solar panels, we could meet all of our energy needs. In addition, the Electric Power Research Institute has found that we could more than double our electricity generation from waterpower just by harnessing our nation's ample marine and hydrokinetic energy resources.

But as we have often pointed out in this Committee, and it is a stunning observation, the wind doesn't always blow and the sun doesn't always shine. Now, the intermittency of these sources could eventually be addressed through the widespread adoption of energy storage technologies such as batteries, fuel cells and compressed air energy storage systems, and this Committee has passed significant legislation to accelerate the advancement of each of these options.

Right now, electric grid managers throughout the country are doing their best to integrate and balance several gigawatts of wind with baseload power options on an hour-by-hour and even minute-by-minute basis. To ensure a steady flow of electricity to their consumers, these managers rely on forecasts of power production, which take into account weather information provided by NOAA as well as energy technology research carried out by DOE or the private sector.

Recent studies led by the National Renewable Energy Laboratory have shown that improving the accuracy and frequencies of these forecasts can have a major impact on the economic viability of renewable energy resources. I look forward to learning more from this excellent panel of witnesses on how we should best be addressing this important issue.

[The prepared statement of Chairman Baird follows:]

PREPARED STATEMENT OF CHAIRMAN BRIAN BAIRD

The United States has tremendous potential to expand our use of renewable energy resources. According to a study by the Pacific Northwest National Laboratory, the accessible wind potential in just 12 states could power the entire country twice over. Lawrence Berkeley National Lab has also shown that if we took one percent of the total U.S. land area and covered just a quarter of it with currently available solar panels, we could meet all of our energy needs. In addition, the Electric Power Research Institute has found that we could more than double our electricity generation from water power just by harnessing our nation's ample marine and hydrokinetic energy resources.

But as we've often pointed out in this Committee—and it is a stunning observation—the wind doesn't always blow and the sun doesn't always shine. Now; the intermittency of these sources could eventually be addressed through the widespread adoption of energy storage technologies such as batteries, fuel cells, and compressed air energy storage systems, and this Committee has passed significant legislation to accelerate the advancement of each of these options.

Right now, electric grid managers throughout the country are doing their best to integrate and balance several gigawatts of wind with baseload power options on an hour-by-hour and even minute-by-minute basis. To ensure a steady flow of electricity to their consumers, these managers rely on forecasts of power production, which take into account weather information provided by NOAA as well as energy technology research carried out by DOE or the private sector.

Recent studies led by the National Renewable Energy Laboratory have shown that improving the accuracy and frequency of these forecasts can have a major impact on the economic viability of renewable energy resources. I look forward to learning more from this excellent panel of witnesses on how we should best be addressing this important issue. With that I yield to our distinguished Ranking Member, Mr. Inglis.

Mr. TONKO. With that, I yield to our distinguished Ranking Member, Mr. Neugebauer, for his comments.

Mr. NEUGEBAUER. Thank you, Mr. Chairman.

I appreciate you holding this hearing and bringing together the subject matter experts on not only energy, of course, but also the views of the national labs, the Federal regulator, and economists, as well as forecasting from the private sector.

At its most fundamental level, renewable power is about harnessing energy from the environment in some fashion. In that sense, being able to forecast the availability of those environmental sources, wind, solar, water, for example, at any one time is critical to knowing when and how much energy will be generated.

Because of its rich oil and gas resources, there has long been an impression that Texas is behind the times when it comes to pursuing renewable energy. To the contrary, though, Texas is firmly established as the country's leader when it comes to wind energy—almost 10,000 megawatts of installed capacity, more than double any other state. And I am sure many members have heard by now, because I never miss the opportunity to remind folks, that the highest concentration in wind energy in America is produced in my Congressional district.

Despite many years, even decades, of growth in subsidies and vast resources targeted toward research and development, renewable energy sources remain significantly more expensive than conventional counterparts: coal, gas and nuclear.

Yet still today, wind generation costs are averaging over $150 per megawatt-hour and solar over $250 per megawatt-hour compared to conventional costs of approximately $100 per megawatt-hour, to the frustration of many.

Nonetheless, the last decade has seen significant integration of renewable energy into the electric grid fueled by many of the subsidies as well as state-level renewable portfolio standard mandates. This growth has resulted in new and increasing challenges for both the industry and government, in particular because renewable energy sources such as wind and solar provide only intermittent contributions to the grid. They result in an increased reliability concerns, as they ultimately must be backed by baseload power from conventional resources.

The additional burden on baseload power supply to ensure overall grid reliability adds to the cost of delivering electricity. A key question that must be answered is: whom shall pay for this cost, the renewable energy companies that are being assisted, or the baseload providers that are doing the assisting? Regardless of the answer to the key question, there are potential reduced reliability concerns associated with integration of renewable energy with better weather forecasting and the incorporation of real-time information. As noted in today's testimony, improving forecasting accuracy by even just one or two percent can lead to millions of dollars in savings and can alleviate reliability concerns.

It seems the key to these improvements lies with NOAA, which has the responsibility for providing weather and water forecasts and developing computer models that are then used by the private sector to develop forecasting products for electricity suppliers. To this end, we need to make sure NOAA has the authority to pursue these activities through support of appropriately focused research and development and renewables-focused weather forecasting service.

I thank the witnesses for appearing before the Subcommittee today and I look forward to the testimony. Thank you, Mr. Chairman.

[The prepared statement of Mr. Neugebauer follows:]

PREPARED STATEMENT OF REPRESENTATIVE RANDY NEUGEBAUER

Thank you Mr. Chairman, I appreciate you holding this hearing and bringing together subject matter experts on not only energy of course, but also the views of the national labs, the Federal regulator, an economists as well a forecasting provider from the private sector.

At its most fundamental level, renewable power is about harnessing energy from the environment in some fashion. In that sense, being able to forecast the availability of those environmental sources—wind, solar, or water for example—at any one time is critical to knowing when and how much energy will be generated.

Because of its rich oil and gas resources, there has long been an impression that Texas is "behind the times" when it comes to pursuing renewable energy. To the contrary, though, Texas is firmly established as the country's leader when it comes to wind energy, with almost 10,000 Megawatts of installed capacity, more than double any other State.

And I'm sure members by now have heard it, but I never miss the opportunity to remind folks that the highest concentration of wind energy in America is produced in my district.

Despite many years—even decades—of growth in subsidies and vast resources targeted towards research & development—renewable energy sources remain significantly more expensive than conventional counterparts (coal, gas, nuclear).

Yet still today, wind generation costs are averaging over $150 per megawatt/hour and solar over $250 per megawatt/hour, compared to conventional costs of approximately $100 per mw/hour, to the frustration of many.

Nonetheless, the last decade has seen significant integration of renewable energy onto the electric grid, fueled by many of these subsidies as well as State-level Renewable Portfolio Standard mandates.

This growth has resulted in new and increasing challenges for both industry and government. In particular, because renewable energy sources such as wind and solar provide only intermittent contributions to the grid, they result in an increase of reliability concerns and as they ultimately must be backed by baseload power from conventional sources.

The additional burden on baseload power supply to ensure overall grid reliability adds to the cost of delivering electricity. A key question that must be answered is who should pay for this cost—the renewable energy companies that are being assisted, or the baseload power providers that are doing the assisting.

Regardless of the answer to that key question, there is potential to reduce reliability concerns associated with integration of renewable energy with better weather forecasting and the incorporation of real-time information. As noted in today's testimony, improving forecasting accuracy by even just one or two percent can lead to millions of dollars in savings and alleviate reliability concerns.

It seems the key to these improvements lies with NOAA, which has responsibility for providing weather and water forecasts and developing computer models that are then used by the private sector to develop forecasting products for electricity suppliers. To this end, we need to make sure NOAA has authority to pursue these activities through support for appropriately focused R&D and renewables-focused weather forecasting services.

I thank the witnesses for appearing before the subcommittee today, and I look forward to the testimony and discussion.

Thank you Mr. Chairman.

Mr. TONKO. Thank you, Mr. Neugebauer, and certainly with the increased pressure being felt by many to encourage alternate supplies of energy, I think today's witnesses will enable us to create that more effective, more efficient outcome out there, especially as we look at the situation in the Gulf today and the need to, I think, strengthen our entire comprehensive energy strategy.

With all that being said, it is my pleasure to introduce our first panel of witnesses at this time. We begin with Ms. Jamie Simler, who is the Director of the Office of Energy Policy and Innovation for the Federal Energy Regulatory Commission, or FERC. Seated next to Ms. Simler is Dr. Alexander MacDonald, who is the Deputy Assistant Administrator of Laboratories and Cooperative Institutes within the Office of Oceanic and Atmospheric Research at NOAA. Then Dr. David Mooney, who is the Director of the Electricity, Resources and Building Systems Integration Center for the National Renewable Energy Laboratory. Then we have Dr. Pascal Storck, who is the Vice President of 3TIER, and Mr. Grant Rosenblum, who is the Manager of Renewable Integration at the California Independent System Operator. And then finally, Dr. Robert Michaels, who is a Senior Fellow for the Institute for Energy Research. We welcome each and every one of you to the panel and look forward to hearing your testimony.

As our witnesses should know, you will have five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing, and when you have completed your spoken testimony, we will begin with questions. Each Member will have five minutes to question the witnesses.

Ms. Simler, you would begin, please.

STATEMENTS OF JAMIE SIMLER, DIRECTOR, OFFICE OF ENERGY POLICY AND INNOVATION, FEDERAL ENERGY REGULATORY COMMISSION

Ms. SIMLER. Good morning, Mr. Tonko, Mr. Neugebauer, and members of the Subcommittee. Thank you for the opportunity to appear before you today. My name is Jamie Simler and I am the Director of the Office of Energy Policy Innovation of the Federal Energy Regulatory Commission. I appear before you as a staff witness. My testimony does not necessarily represent the views of the Commission or any individual Commissioner. My testimony will cover the motivations of the Commission's January 21st Notice of Inquiry on the Integration of Variable Energy Resources and a summary of some of the more relevant responses to the forecasting issues in that notice.

The Commission regulates transmission and sales for resale of electric energy in interstate commerce. Its primary responsibility is to assure that the rates, terms and conditions of transmission service and wholesale power transactions are just and reasonable and not unduly discriminatory or preferential. As part of its ongoing responsibilities, the Commission issues public notices to solicit information on emerging issues that may affect jurisdictional rates and terms of service.

The Notice of Inquiry on the Integration of Variable Energy Resources sought comment on the extent to which barriers may exist that impede the reliable and efficient integration of variable energy resources into the electric grid and whether reforms are needed to eliminate those barriers. The Notice noted that while variable energy resources have many desirable characteristics, including low marginal energy costs and reduced greenhouse gas emissions as compared to conventional fossil fueled generation, they also present unique challenges. For example, because variable energy resources cannot store or control their fuel source, they have limited ability to control their production of electricity.

With regard to forecasting, the Commission sought comment on several issues. These include the current practices used to forecast power production from variable energy resources, and whether those practices would be adequate as the number of these resources increases. The Notice also sought information on whether additional data, tools and reporting requirements are necessary to accommodate state-of-the-art forecasting. A related question is whether safeguards need to be in place to ensure that commercially sensitive data remain protected.

As to the issue of current forecasting practices, commenters note the importance of understanding two aspects of variable energy forecasting, specifically, national weather forecasts and power production forecasts. National weather forecasts span large geographic regions and are developed by NOAA and associated government agencies. Power production forecasts are designed to predict the energy output of individual facilities. They build on the national forecasts by incorporating additional, site-specific information, such as local atmospheric phenomena and specific generator equipment, to then develop a more detailed forecast of the anticipated power output of a given facility. These power production forecasts are generally developed by commercial forecast service providers and are specifically tailored to the needs of their clients, which could be a variable resource owner, a local utility, or a regional transmission organization. Some commenters note that existing national weather forecasts are optimized for predicting temperature and precipitation and that additional data, models, and computing capabilities are needed to generate more detailed weather forecasts suited to the challenges of predicting the output of variable energy resources.

A number of commenters also encouraged the development of rapid-update national weather models that utilize data obtained and shared from variable energy resources. Many commenters indicate that such improvements to the underlying national weather forecasts could provide significant improvements to the ability of those in industry to predict the output of variable energy resources.

Additionally, because different market participants are often simultaneously engaged in predicting the output of the same variable energy resources, the notice included questions about whether the Commission should encourage centralized or decentralized forecasting protocols. Centralized forecasts are power production forecasts developed for system operators. The system operators use these forecasts and generator unit commitment process to ensure sufficient generation is online to meet load. Decentralized forecasts, on the other hand, are developed for individual variable energy resources and are used by them so that they can schedule their energy production.

Comments indicate that there is likely a role for both centralized and decentralized forecasts. The accuracy of these power production forecasts is ultimately affected by the data inputs that are used. Because different data sets are available to different market participants, some forecasts may include less than ideal information. The notice, therefore, sought comment on this, and the commenters provided information on what type of additional information may be needed. Some commenters also discussed the confidentiality of commercially sensitive data, and they suggested that meteorological data collected from individual generators could be reported to a centralized repository such as NOAA.

In summary, the Commission's Notice of Inquiry on the Integration of Variable Energy Resources brought forth a wealth of information on the topic of forecasting, much of which the Commission staff is still digesting. The full record, which is available through the Commission's document retention system, will be used by staff in making recommendations to the Commission for next steps. Thank you.

[The prepared statement of Ms. Simler follows:]

PREPARED STATEMENT OF JAMIE SIMLER

Introduction

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear before you today. My name is Jamie Simler, and I am the Director of the Office of Energy Policy and Innovation of the Federal Energy Regulatory Commission (FERC or Commission). I appear before you as a staff witness; my testimony does not necessarily represent the views of the Commission or any individual Commissioner. My testimony will cover the requested area of the Commission's Notice of Inquiry on Variable Energy Resources and filed comments of interest.

Background

The Commission regulates transmission and sales for resale of electric energy in interstate commerce to assure the rates, terms and conditions of transmission service and wholesale power transactions are just and reasonable and not unduly discriminatory or preferential.

The existing wholesale electricity supply function relies on the coordinated operation of transmission and generation resources. There exist two models to accomplish this. In some parts of the country Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs) coordinate the transmission and generation resources from a number of utilities and provide service to load serving entities through organized wholesale markets. In this model, the RTO/ISO uses day-ahead and real-time markets to assess the demand for electricity and to commit and dispatch generation and transmission resources to meet that demand. In other parts of the country (primarily western and southern regions), individual utilities use their own generation and transmission resources and may enter into bilateral arrangements with third-party generators and transmission providers to ensure that they have sufficient generation available to serve load reliably.

At all times, regardless of the model used to provide electric service, system operators must maintain a balance between the amount of energy put on the grid and the amount of energy being taken off of the grid. Complicating this task is the fact that there is a significant degree of variability in the moment by moment operation of the grid. For example, the demand for electricity (known as load) changes on a constant basis, and generation resources must be dispatched to meet this demand. Additionally, outages can occur whenever generation or transmission resources unexpectedly trip offline.

System operators have developed a set of tools that allow them to both plan for and react to these variations. In the case of load variability, system operators have significant experience in developing load forecasts, which rely on statistical analysis, temperature forecasts, and historical load patterns, to estimate the amount of load at any point on the grid in any given time period. These load forecasts are then incorporated into unit commitment and scheduling processes, in which system operators determine the generation and transmission resources needed to serve the anticipated load. Conventional generation resources, under normal conditions, are scheduled assuming precision in power production. However, variable energy resources cannot be scheduled with the same precision as conventional generation resources, so accurate power production forecasts play a more important role in allowing system operators to make accurate before-the-fact determinations of power production.

By their nature, load and power production forecasts are not perfect, and conditions such as weather can deviate from those forecasted. Accordingly, system operators have developed a variety of remedial actions that can be employed in real-time to maintain the balance between generation and demand for electricity and to react to unforeseen circumstances. For example, system operators deploy operating reserves, which are generation (or demand response) resources that stand ready to quickly increase or decrease power production or consumption as needed. Reserves are also available to accommodate what are called contingency events, such as the forced generation or transmission outages mentioned above. By forecasting anticipated conditions and having the tools in place to react to events as they happen, system operators maintain a balance in what is a constantly changing electric system.

As greater numbers of variable energy resources come online, system operators are increasingly faced with additional challenges. Variable energy resources have a limited ability to control their output. They can also experience significant increases or decreases in the amount of power they produce when a weather system moves through the area.

Notice of Inquiry

To gain a better understanding of the impact of increasing numbers of variable energy resources on the electric grid, the Commission issued a Notice of Inquiry (Notice) in January of this year. The stated purpose of the Notice was to seek comment on the extent to which barriers may exist that impede the reliable and efficient integration of variable energy resources into the electric grid and whether reforms are needed to eliminate those barriers. The Commission explained that it is taking a fresh look at existing policies and practices in light of the changing characteristics of the nation's generation portfolio. To that end, the Notice posed a number of questions on a wide range of subjects. Many of these questions explore ways in which existing operational practices or market rules may have the effect of imposing unnecessary costs or burdens on both variable energy resources and the transmission systems in which they are located. Thus, the Notice included a number of questions related to scheduling practices, unit commitment protocols, and reserve requirements.

Most relevant to the subject of today's hearing, the Notice included inquiries into existing power production forecasting techniques and data provision requirements. Among other things, the Notice posed questions about current practices used to forecast power production from variable energy resources, and whether those practices would be adequate as the number of these resources increases. The Notice also sought information on whether additional data, tools, and reporting requirements are necessary to accommodate state-of-the-art forecasting techniques, and whether safeguards need to be in place to ensure that commercially-sensitive data remain protected.

Commission staff is currently in the process of reviewing comments from more than 130 parties, and we are evaluating what future action may be appropriate. A consistent theme in many of these comments is that improved forecasts will play a critical role in facilitating the integration of variable energy resources into the grid. A few examples are provided.

National Weather and Power Production Forecasts

Several commenters noted the importance of understanding two aspects of variable energy forecasting: national weather forecasts and power production forecasts. National weather forecasts span comparatively large geographic regions and are developed by NOAA and associated government agencies. These national weather forecasts form the foundation for power production forecasts. Power production forecasts are designed specifically to predict the energy output of individual wind and solar facilities. They go beyond the national weather forecasts and incorporate additional site-specific information—such as terrain features, local atmospheric phenomena, and specific generator equipment—to develop a more detailed forecast of the anticipated power output of a given facility. These power production forecasts are generally developed by commercial forecast service providers and are specifically tailored to the needs of their clients, which could be a variable energy resource, a local utility, or an RTO or ISO.

Some of these commenters indicated that existing national weather forecasts are optimized for predicting temperature and precipitation, and that additional data, models, and computing capabilities are needed to generate more detailed weather forecasts that are suited to the challenges associated with predicting the output of variable energy resources. A number of commenters encouraged the development of rapid-update national weather models that utilize data obtained and shared from variable energy resources. Many commenters indicated that such improvements to the underlying weather forecasts, developed by government agencies like NOAA, could provide significant improvements to the ability of those in the industry to predict the output of variable energy resources in both the day-ahead and real-time operational time frames.

Different Uses of Power Production Forecasts

Additionally, because different market participants are often simultaneously engaged in predicting the output of the same variable energy resources, the Notice of Inquiry included questions about whether the Commission should encourage the development of either centralized or decentralized forecasting protocols. "Centralized" forecasts are power production forecasts developed for system operators. These forecasts are used in the generator unit commitment process to ensure that sufficient generation is scheduled to meet anticipated load. "Decentralized" forecasts are developed for individual variable energy resources and are used to create energy production schedules and offering strategies.

Comments indicated that there is likely a role for both decentralized and centralized power production forecasts. Commenters noted that different market participants use power production forecasts in different ways. Variable energy resource operators need accurate power production forecasts to submit bids to system operators that they are capable of meeting in real-time. By submitting bids they can meet in real-time, these resource operators mitigate their exposure to penalties as well as requirements to buy energy in spot markets to make up for any imbalances. System operators, on the other hand, need accurate power production forecasts to determine an appropriate commitment schedule for generation resources in advance of the operating hour and to deploy reserves as conditions change in real-time.

While different market participants use power production forecasts to different ends, the accuracy of these forecasts is ultimately affected by the data inputs that are used. Because different data sets are available to different market participants, some forecasts may include less-than-ideal information. The Notice therefore sought comments on whether there is a need for data reporting requirements among market participants. A number of commenters indicated that additional data reporting among market participants is needed. They provided various lists of the types of data and the frequency with which data are reported to support advances in power production forecasting capabilities. Commenters generally pointed to the need for additional meteorological, operational, and specifically generator outage and de-rate data in developing state-of-the-art forecasts. Some commenters, concerned about the confidentiality of commercially sensitive data, suggested that meteorological data collected from individual generators could be reported to a centralized repository such as NOAA because NOAA has no economic stake in the electric industry.

Conclusion

The Commission received over 2,800 pages of comments to its Notice of Inquiry; and Commission staff is in the process of analyzing how power production forecasts are used in existing electric markets and how potential regulatory reforms may achieve the Commission's goals of ensuring just and reasonable rates and result in benefits to market participants. Upon completing its analysis, the Commission staff will make recommendations to the Commission on possible courses of action on these issues. Thank you again for the opportunity to testify today. I would be happy to answer any questions you may have.

BIOGRAPHY FOR JAMIE SIMLER

Jamie L. Simler is Director of the Office of Energy Policy and Innovation at the Federal Energy Regulatory Commission.

Prior to heading the Office of Energy Policy and Innovation, Ms. Simler served from 2005 to 2009 as Deputy Director of FERC's Office of Energy Market Regulation. Ms. Simler has held several other positions at the Commission, including Director of the Western Division of the Office of Markets, Tariffs and Rates and Advisor to Commissioner Nora Mead Brownell. Before joining FERC in 1997, she was employed in private industry, working for the Interstate Natural Gas Association of America, Panhandle Eastern Pipeline Corporation and the Potomac Electric Power Company.

Ms. Simler earned a Bachelor of Science in Petroleum and Natural Gas Engineering from the Pennsylvania State University and a Masters in Business Administration from the George Washington University.

Mr. TONKO. Thank you, Ms. Simler.

Dr. MacDonald, please.

STATEMENTS OF ALEXANDER MACDONALD, DEPUTY ASSISTANT ADMINISTRATOR, LABORATORIES AND COOPERATIVE INSTITUTES, OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Dr. MACDONALD. Good morning, Mr. Chairman, Mr. Tonko, Congressman Neugebauer and other Members of the Subcommittee. I am Alexander MacDonald, Deputy Assistant Administrator of NOAA's Office of Oceanic and Atmospheric Research. Thank you for the opportunity to testify today.

The ongoing Deepwater Horizon spill in the Gulf of Mexico reminds us that there are indeed risks of producing and delivering energy. These events also emphasize the need as a Nation to look for new cleaner forms of energy. As we explore possibilities for new power sources, it is exciting to contemplate creating clean and renewable energy from the sun, wind and ocean. Today I will describe NOAA's current support of the renewable energy sector and how NOAA's data forecasts and information play a critical role in maximizing the potential benefits from renewable energy.

NOAA's current contributions to renewable energy include siting operation and support of management from our mission-driven and focused efforts. NOAA provides weather, water and climate forecasts and information over a full range of time and geographical scales. It accomplishes this through remote sensing and imagery from satellites, surface networks, weather radars, upper air balloons, ocean buoys, ships, aircraft, and subsurface ocean observations. It uses sophisticated weather and climate models running on supercomputers to make forecasts such as those that accurately predicted the East Coast snowstorms this past winter. NOAA also has expertise to effectively evaluate the impacts of coastal and ocean energy projects, thereby protecting our natural resources of our coastal communities that our national economy relies on.

With respect to hydropower, NOAA provides regular forecasts of precipitation, hydrologic forecasts of snow melt and runoff, as well as monthly precipitation outlooks. At the cutting edge of precipitation forecasting, NOAA's hydrometeorology test bed is researching how to forecast the most intense precipitation events.

In each of these instances, NOAA works in a partnership with other Federal agencies like the Departments of Energy and Interior, FAA, NASA and others. NOAA also works closely with the private sector and recognizes the contributions that private weather and climate service enterprise will continue to make in the Nation's renewable energy capabilities. NOAA understands that cooperation—and not competition with the private sector, academic, and research entities—best serves the public interest, and best meets the varied needs of individuals, organizations, and economic entities.

In light of the tremendous information that NOAA currently provides the renewable energy industry, the needs of the industry are relatively new compared to the evolution of NOAA's other products and services, and the pace of industry expansion is driving us toward developing new capabilities. The solar and wind energy sectors have generally highlighted that they require improved observations, global models, predictions across a range of time scales, and high-resolution forecasts to support the improved operational weather forecasts needed for their industry. Wind, for example, is typically not measured at the levels where wind turbines operate, over 300 feet above the ground. The lack of observations at these heights leads to inaccurate forecasts which are important for us to remedy. These inaccuracies drive added wind integration costs.

With respect to solar energy, there are relatively few high-quality, continuous, ground-based observations with which to evaluate current and future solar potential, and even fewer measurements of direct solar beam, which is essential for concentrating solar systems.

These are good examples of the new and emerging requirements from the renewable energy sector that NOAA must address. We are collaborating with DOE and the private sector on a planned 12 month field demonstration project to improve the efficiency of wind energy through enhanced modeling and forecasting. We are working with the private sector and would like to play the role of honest broker, which would allow us to collect data that would help improve the information we have.

Last night, President Obama framed the challenge of renewing America's energy system as similar to the challenges America faced in its industrial expansion in World War II and putting a man on the moon. In the future, the renewable energy sector will need observations, forecasts, and analysis in order to better integrate weather-driven renewable energy. NOAA has the experience and mission expertise to work in partnership to address these needs. This Nation can create a reliable, efficient energy system depending significantly on weather-driven renewable resources. The United States is big enough that if the wind is not blowing or if it is cloudy in one part of the country, it is most likely blowing and sunny in another part. Improved forecasts along with improvements in our national power transmission and storage would allow us to meet President Obama's challenge.

Thank you for the opportunity to testify today.

[The prepared statement of Dr. MacDonald follows:]

PREPARED STATEMENT OF ALEXANDER MACDONALD

INTRODUCTION

Good morning Chairman Baird, Ranking Member Inglis, and other Members of the Subcommittee. I am Alexander E. MacDonald, Deputy Assistant Administrator for Laboratories and Cooperative Institutes in the Office of Oceanic and Atmospheric Research at the National Oceanic and Atmospheric Administration (NOAA), in the Department of Commerce. Thank you for inviting me to discuss NOAA's science and research that has the potential to support the increased use and efficiency of renewable energy.

The Nation's renewable energy sources—solar, wind, and water—are largely driven by weather and dependent on climate. This fundamental connection of renewable energy to the atmosphere and oceans is at the core of NOAA's participation in today's hearing and explains our key role in developing renewable energy.

The U.S. energy sector is a $1 trillion-per-year enterprise [1] central to our Nation's economy. The Obama Administration has called for the expansion of our Nation's capacity to provide energy from renewable sources to help reduce our dependence on fossil fuels, increase our energy security, build the green jobs and economy of the future, and reduce greenhouse gas emissions. While numerous climate assessments completed by United States and international climate science bodies agree on the long-term impacts of greenhouse gases, the Deepwater Horizon/BP oil spill is a reminder of the potential catastrophic, short-term, and acute environmental impacts of a fossil fuel-based energy system. NOAA's scientific data, forecasts, and information can play a critical role in maximizing the potential benefits from all forms of renewable energy, and minimizing the environmental impacts of marine renewable energy.

Today, I will describe NOAA's current support of the renewable energy industry and the essential role of NOAA data, information, and services in sound renewable energy planning. Some of the challenges to increased use of renewable energy have the potential to be addressed by further developing NOAA's weather, climate, and ecological observations and predictions. While renewable energy sources offer a positive option, they are not necessarily environmentally benign. Therefore, I will also summarize NOAA's role in ensuring that renewable energy projects are developed consistent with NOAA's mission to conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs.

NOAA's CURRENT CONTRIBUTIONS TO RENEWABLE ENERGY

NOAA provides weather, water, and climate forecasts and information over a full range of temporal and geographical scales. NOAA accomplishes this through remote sensing and imagery from satellites, surface networks of weather radars and observing systems, upper air balloons, ocean buoys, ships, aircraft, and seafloor observations. NOAA's network of integrated Earth observing systems monitor changes in ocean, land, air, and space that are critical to siting decisions by the energy sector. NOAA provides the marine renewable energy industry with relevant ecological data to facilitate siting decisions and construction and operational requirements to minimize and mitigate adverse effects on living marine resources and ecosystems. NOAA also works to ensure that siting decisions and operations do not adversely impact other key NOAA missions, such as wind power facility impacts on weather radar installations.

NOAA's contributions to energy facility siting, operation, and management are based on a wide range of legal authorities, including energy-specific authorities, as well as authorities related to conservation, management, observation, and forecasting (see Appendix A for a list of authorities). In addition, although licensing authority for most energy projects resides with other Federal agencies, NOAA does have authority for licensing ocean thermal energy conversion (OTEC) facilities. Overall, NOAA plays an active and important role in the siting and management of energy facilities through legal authorities that direct NOAA to:

- Collect data on sensitive species and habitats, topography, tides and currents, and meteorological conditions. This data, along with information about protected areas and human use patterns, provides the basis for siting decisions.
- Evaluate potential environmental impacts of energy facilities on coastal and marine resources and recommend mitigation measures to minimize those impacts.
- Assess and predict the impact of oil spills and hazardous substance releases on natural resources, identify response strategies, and implement restoration.
- Forecast weather conditions. Based on the forecasts, energy facilities can adjust their operations to optimize energy production or minimize the negative impacts from inclement weather.
- Provide scientific expertise and technical and management assistance to Federal agencies, states, the energy industry, and other stakeholders.
- Determine energy-related content of state Coastal Management Plans, mediate Coastal Zone Management Act (CZMA) energy-related disputes and decide appeals of state CZMA objections to energy projects to the Secretary of Commerce.

[1] U.S. Energy Information Administration, Annual Energy Review 2008, Report No. DOE/EIA–0384 (2008). *http://www.eia.doe.gov/emeu/aer/overview.html*

While many of the authorities are NOAA-specific, NOAA implements some of the authorities in cooperation with other Federal agencies. The Federal agencies with energy-related authorities include Federal Energy Regulatory Commission, Department of Transportation, Maritime Administration, United States Coast Guard, Department of Energy (DOE), Department of the Interior (DOI), and Environmental Protection Agency. In an effort to focus on key authorities related to energy facility siting and management, this testimony does not cover the full scope of NOAA's legal authorities. Many other important authorities support the extensive work that NOAA does related to energy issues. For example, legal authorities related to climate are not listed in this testimony, but NOAA's climate change efforts provide valuable contributions to the advancement of renewable energy.

Additionally, in providing mission-relevant information and services in support of renewable energy development, NOAA works in partnership with and draws upon the data and information of other Federal agencies in this area, including but not limited to the DOI, DOE, the National Aeronautics and Space Administration, and the National Science Foundation. For example, NOAA and the Department of Energy's National Renewable Energy Laboratory together signed a Letter of Intent to allow the exchange of scientific resources, personnel, and technical knowledge to support the improvement or development of atmospheric and ocean sciences, instrumentation, climate modeling, and renewable energy. Furthermore, NOAA and DOE's Office of Energy Efficiency and Renewable Energy are exploring a Memorandum of Understanding to collaborate to achieve the necessary advancements in short-term environmental forecasts and long-term resource projections for the integration of renewable energy into the Nation's energy system.

NOAA also works closely with the private sector, and recognizes the contributions the private weather and climate service enterprise can make toward the Nation's renewable energy capabilities. NOAA's role in providing forecast data and information for the renewable energy industry will be guided by the 2006 NOAA Policy on Partnerships in the Provision of Environmental Information, based on the National Research Council's 2003 report, "Fair Weather, Effective Partnerships in Weather and Climate Services." The Nation benefits from government information disseminated both by Federal agencies and by diverse nonFederal parties, including commercial and not-for-profit entities. NOAA recognizes that cooperation, not competition, with private sector, academic, and research entities best serves the public interest and best meets the varied needs of specific individuals, organizations, and economic entities. NOAA will take advantage of existing capabilities and services of commercial and academic sectors to support efficient performance of NOAA's mission and avoid duplication and competition.

Observations and Forecasts for Operation of Renewable Energy Systems

NOAA's observations and forecasts are used by the renewable energy industry to efficiently operate its systems and plan for future sites. NOAA's historical climate records provide essential information required to optimize the siting of wind farms and solar energy plants. Not only are historical records essential to optimize the location of new production facilities, but accurate weather predictions are critical to renewable energy operations because they provide the information needed to ensure balance between electric supply and demand. For example, in order to increase operating efficiency, renewable energy operators must know how much energy a particular wind farm or solar energy farm will generate. Likewise, forecasts can help energy grid operators predict how much renewable energy will be available to distribute to the energy grid and inform the decision whether to supplement renewable energy with other generation sources, such as coal or natural gas plants. The more accurate the forecasts NOAA can provide, the more efficient the energy industry can become.

NOAA's predictions form the core of capability that is used by a thriving commercial weather industry to support the weather information needs of the Nation. In general, as NOAA's predictions have improved, the size and value of the commercial weather providing sector has grown commensurately, as it should for the improved renewable energy predictions discussed below.

Current Wind Observations

NOAA's wind observation capability includes surface measurements as well as measurements from aircraft, ships, satellites, Doppler radar, wind profilers, and radiosondes—instruments lifted through the atmosphere by weather balloons which provide wind data up to about 10 miles high. All of these data are critical for NOAA's success in forecasts and warnings, but wind is not typically measured at levels critical for wind turbine operators, about 100 meters above the ground. Also, none of these data sources provide information at the density that is needed by the wind industry. Even fewer observations are available offshore, and these data are critical for any offshore wind farms that are being planned.

While the observations at the 100 meter level are not available, NOAA's sophisticated computer simulations of the atmosphere can model and predict winds at 100 meters and some of these data are now becoming available to the private sector. However, these models were not designed to provide the information at the temporal and spatial resolution needed by the wind industry.

Current Wind Forecasts

The wind energy industry uses standard NOAA weather forecasts. These forecasts were developed to improve surface meteorological predictions and aviation needs. They have been extremely successful in addressing these goals but the weather models underlying these forecasts were never designed and optimized to provide the temporal or spatial resolution or the accuracy needed by the wind industry.

Solar Observations and Forecasts

NOAA's Surface Radiation network is a network of seven state-of-the-art Continental United States (CONUS) surface sites that measure diffuse, direct, and total solar radiation as well as surface reflectivity. NOAA also measures solar radiation at eight global monitoring sites. NOAA's Climate Reference Network measures total incoming solar radiation at about 140 sites in the CONUS and additional sites outside CONUS. These data provide a record of radiation coverage for CONUS.

NOAA has developed techniques to forecast solar radiation, and currently provides a forecast for ultra-violet (UV) radiation, which is used by the Environmental Protection Agency to warn the public of health risks. This product has the capability to be extended to address the radiation wavelengths relevant to solar renewable energy.

Precipitation Observations and Forecasts to Support Hydropower

NOAA's monthly and seasonal temperature and precipitation outlooks provide information for water management. In particular, NOAA hydrologic forecasts of seasonal snow melt and runoff are important to manage water flow feeding hydro-generation plants. Further, the National Integrated Drought Information System (NIDIS), a multi-agency effort which NOAA leads, provides information and early warnings of droughts while NOAA's Hydrometeorological Test Bed (HMT), a demonstration project, provides water information across a wide range of time and space scales with a focus on high precipitation events. HMT and NIDIS thus provide extensive expertise on water resources, helping the Nation design a future renewable energy system that maximizes our country's vast natural resources, while preserving water allocations to support our country's many needs.

Ocean and Coastal Observations and Forecasts to Support Ocean Thermal Energy Conversion and Marine Hydrokinetic Energy

Under the Ocean Thermal Energy Conversion Act (OTECA), NOAA has the responsibility for administering a consolidated licensing program for authorizing ocean thermal energy conversion (OTEC) facilities. OTEC is a technology which uses the differences between the temperature of deep, cold ocean water and warm ocean surface waters to produce electricity much like a heat pump. Although the technology has been proven to work, it has not been developed yet at a commercial scale. A substantial effort is underway by industry and the Navy to develop a commercial-scale OTEC facility with the most likely site being offshore of Hawai'i. Last November, NOAA brought together leading engineers in the offshore technology field to assess the feasibility of developing an OTEC technology at a commercial scale. The findings of that workshop are scheduled to be released this summer. Later this month, NOAA is holding a workshop in Hawai'i on the assessment of potential impacts from an OTEC facility. Both workshops are in preparation for a rulemaking for the licensing of OTEC facilities.

Marine hydrokinetic energy uses the energy of waves, tides, and currents in rivers and oceans to produce electricity. While these systems do not yet provide power to the electrical grid in the United States, a few tidal systems operate in other parts of the globe.

NOAA's observations and forecasts of the oceans, waves, tides, and rivers provide data critical for the development of OTEC and marine hydrokinetic energy. The U.S. Integrated Ocean Observing System (IOOS) generates and disseminates continuous data, information, models, and services on coastal waters, ecosystems, Great Lakes and oceans. NOAA is an integral partner in IOOS.

Observations and Forecasts to Support Biomass Energy

NOAA provides forecasts of precipitation, cloud cover, temperature, winds, and water flow that are important to biomass production. As these resources are developed, NOAA will work to improve forecasts of precipitation and temperature, which are critical factors in determining variation in U.S. biomass supply.

Predictions of Climate Variability and Change to Inform Siting of Renewable Energy Systems

Continued expansion of the Nation's renewable power capacity will require considerable infrastructure investments, whether in facilities or the grid that will be necessary to efficiently provide Americans with the power they need. To optimally plan tomorrow's energy system, the Nation needs information to understand how the influences of climate and climate change, including natural variability and large-scale climate-drivers, such as El Nino, may affect renewable energy resources such as wind, solar, and water in the future. In the same way, information about the location and likely intensity of weather- and climate-driven energy demand is needed by the industry, such as projections of climate and climate change effects on degree heating and cooling days. NOAA observation data, including wind, temperature, cloud cover, solar radiation, and climate variability and change predictions are critical pieces of information for forecasting the future availability and location of renewable sources of energy and the likely future demand for energy in the different regions of the nation. These forecasts in turn inform industry and public sector investment decisions about the best locations to build facilities like wind farms or solar energy platforms, as well as grid design.

For example, utilities need information about the likelihood of future increases in degree heating days to ensure ample power generation and distribution to meet cooling needs. In the same way, developers of coastal wind and hydropower need predictions of sea-level rise and the likelihood of increase in severe coastal storms to site, engineer, and design those facilities to withstand future conditions. And lastly, hydropower developers require information about the future timing and availability of water to adequately design reservoir and power storage capability and dam operation.

However, it is important to note that the optimal location for renewable energy production may not be the optimal location for social or environmental reasons. For example, an optimal energy production site may be in the heart of a prime fishing ground, in an important endangered species migratory corridor, or in a location that interferes with our Nation's important radar assets. Not only can NOAA assist by providing relevant information on these other factors to optimize site selection, but it also has regulatory and oversight obligations that are addressed below.

Evaluating the Environmental Impacts of Coastal and Ocean Renewable Energy

NOAA is also a regulatory agency with responsibilities under the National Environmental Policy Act, the Endangered Species Act, the Marine Mammal Protection Act, the Magnuson-Stevens Fishery Conservation and Management Act, and the National Marine Sanctuaries Act. NOAA ensures that coastal and ocean energy projects are conducted in compliance with these authorities. NOAA provides information on health, abundance, distribution, and ecological requirements of living marine resources to ensure industry and other regulatory agencies, such and the U.S. Army Corps of Engineers, Federal Energy Regulatory Commission, and Minerals Management Service have information to meet their obligations under these environmental statutes. NOAA also works with industry and other regulatory agencies to ensure that projects they fund or permit are reviewed and authorized consistent with the relevant environmental statutes.

In regard to providing ecological data relevant to environmental permitting or review of coastal and ocean renewable energy, NOAA conducts investigations of the status of various fish stocks that support commercial and recreational fisheries, threatened and endangered species, and marine mammal stocks. It also conducts ecosystem assessments that help define the ecological relations in the ecosystems of which these species are a part and upon which they depend. This information is critical to making sound siting decisions and accurately identifying effects of energy projects. NOAA's regulatory role can also facilitate the development of mitigation measures that will minimize environmental impacts; thereby potentially resolving conflicts with competing users of a location. NOAA's investment in studying and understanding our coastal and marine ecosystems is essential to the development of an environmentally sound renewable energy industry.

Avoidance of Radar Interference from Wind Energy

NOAA and other Federal agencies evaluate industry requests for turbine siting to minimize potential interference of turbines on our Nation's network of radars. NOAA is working with the Departments of Defense, Homeland Security and Transportation to develop software to model potential wind turbine impacts on radars in advance of turbine installation to better support the evaluation of industry siting requests. Turbines, when sited close to weather radars, can cause false returns that can disrupt forecaster situational awareness and weather radar algorithms. For example, a study has shown that when turbines are located within about 18 km (10 nm) of NOAA/NWS Doppler weather radars, the interference can cause tornado and severe thunderstorm detection algorithms to malfunction. NOAA is working with the academic community to develop radar software that mitigates the turbine interference in the weather radar's returned signal. The interference with air surveillance radars can be significantly different.

MEETING THE DATA AND INFORMATION NEEDS OF AN EXPANDING RENEWABLE ENERGY SECTOR

NOAA's observations, forecasts, and analyses are at the core of integrating weather-driven renewable energy in an efficient manner. NOAA has worked with the renewable energy industry, other Federal agencies, and academic partners to understand current and future observation and forecast needs to support renewable energy. For example, the wind energy sector identified its need for improved observations, global forecast models, predictions across a range of time scales, and high-resolution forecast models to support an improved operational weather forecast. In multiple public meetings, private sector weather service vendors, wind farm operators, utilities, and power balancing authorities have requested that NOAA provide these improved services. A strong collaboration with Federal partners and the industry would result in improved siting of renewable energy facilities, more accurate weather forecasting to support efficient operations, and an opportunity for growth in the renewable energy sector. In the end, advancements in observations and forecasts that help address the emerging needs of the renewable energy sector contribute to the broader national interest in reducing our dependence on foreign fuels, increasing our energy security, building the green jobs and economy of the future, and reducing greenhouse gas emissions.

In addition to the need for improved forecasts and observations from NOAA, the need for coastal and marine spatial planning (CMSP) in the U.S. is critical to the development of renewable energy resources. CMSP is a comprehensive, adaptive, integrated, ecosystem-based, and transparent spatial planning process, based on sound science, for analyzing current and anticipated uses of ocean, coastal, and Great Lakes areas. As the Nation's primary ocean agency, NOAA will continue to play a leadership role in advancing the implementation of CMSP throughout U.S. waters for purposes that include the development of renewable energy. To this end, NOAA brings a unique mix of: diverse legal authorities for place-based ocean stewardship; robust and cutting-edge scientific and technical expertise to understand and observe ocean and coastal ecosystems and their uses; effective ocean management programs with decades of expertise in spatial planning and meaningful stakeholder engagement; and long-standing partnerships with coastal states, regional ocean governance organizations, tribes, and other Federal agencies who share a common interest in sustainable, healthy oceans.

CMSP's comprehensive approach to planning the full range of human uses in the ocean provides many opportunities, and indeed imperatives, for substantive collaboration between Federal agencies, the private sector, and stakeholders on matters such as the siting and development of renewable energy sources. For these and other current and emerging ocean uses, private interests will play a key role in providing spatial data and insight into the requirements, plans and implications of siting decisions that maximize benefit while minimizing conflicts and impacts.

Onshore and Offshore Wind Energy: Forecasts and Observations

Since NOAA's current weather forecasts were not developed to support the wind energy industry specifically, and because there are limited observations that are publicly available where wind turbines reside, NOAA's forecasts do not provide information at temporal scales that the wind industry requires. Further, because the amount of wind energy produced depends on wind speed cubed, even small differences in projected wind speed can yield large differences in the predicted wind energy produced. Although such differences are addressed and overcome on a daily basis in the E.S. and everywhere wind provides electricity, power production based upon an intermittent resource adds additional elements of complexity when managing power production and delivery. For example, the Bonneville Power Administration imposed wind integration charges (WIC) of $5.85/MWh on wind producers due to scheduling discrepancies and the cost to maintain power reserves in the event that wind generation falls short of forecasts. The national electric system has evolved to support more temporally consistent energy sources like coal, nuclear, and natural gas, so integrating wind energy has presented some difficulties to system operators. NOAA can partner with the renewable energy industry to improve our understanding and predictions of wind energy and work together to provide better forecasts.

An additional challenge for wind energy forecasting is in the identification and prediction of so-called "ramp events." A ramp event is any large and sudden change in wind speed or direction that can significantly alter wind energy generation. NOAA's weather models were not developed to identify these features in such small scales and pose challenges to wind farm operators across the Nation. Power balancing authorities and system operators often "curtail" wind energy production when wind farms produce significantly different amounts of energy than what was expected, at least partly based on NOAA's wind forecasts. Better observations, forecast models, and wind forecasts (especially the timing and amplitude of ramp events) are a key to improving the ability to align electricity production from wind and other sources to meet demand most efficiently.

NOAA has the scientific expertise to partner with industry and help it to improve the understanding of atmospheric processes in the lower part of the atmosphere (called the boundary layer) where wind turbines reside and affect the operation, performance, and longevity of wind turbines. Finding out what is actually occurring in the boundary layer would entail the development of wind-energy demonstration projects, which would be research sites to study the lower part of the atmosphere. Based on NOAA's experience deploying atmospheric research demonstration projects, an array of industry-supported projects to advance an understanding of wind to support wind energy would: (1) collect observations of the boundary layer for studies of phenomena that affect wind resources; (2) provide data sets for weather-forecast model development and verification; (3) determine the most effective sensors for assimilation into weather-forecast models; (4) identify optimal sensors for a national observational network supporting wind energy. Off-shore turbine-height winds could be measured using buoy-based boundary layer profiling systems. Measurements of thermal-atmospheric eddies would support offshore wind energy. New observations that would inform the conditions that an offshore turbine tower will face include measurements of the vertical distribution of temperature in the ambient water, as well as of currents and waves.

These observations would advance the understanding of low-level winds and turbulence, which would allow the provision of forecasts of winds with greater accuracy in space and time. These observations also would help NOAA provide guidance to the developing national Network of Networks (NoN), called for by a recent National Research Council report, to ensure that the needs of the renewable energy industry are considered as this NoN is developed. With these observations, the wind energy industry would have the potential to meet its needs and contribute towards a national reference data set that would be managed by NOAA for the renewable energy industry that contains historical, real-time, and even projected/modeled data (discussed below), all of which have been subject to quality-control measures.

NOAA is currently collaborating with DOE to improve the efficiency of wind energy through improved models and forecasts on a small, regional scale. The area will be selected based on responses to a Funding Opportunity Announcement released earlier this month. A valuable part of this collaboration with DOE and the private sector is the request that the private sector (wind farm operators and balancing authorities) share proprietary atmospheric observations that they already collect. NOAA would act as an "honest broker" by keeping these data private and protected, but using them in our weather models to make our forecasts more accurate.

NOAA has fulfilled this "honest broker" role before in other sectors. A valuable example is seen within the airline industry, when during the 1990s airlines began to send their proprietary weather data from aircraft to NOAA to assimilate and provide improved forecasts for aviation. NOAA has improved its model forecasts, including those for aviation, significantly over the last 15 years. The improvements resulted from more observations, at all atmospheric levels, to better define the current 3-dimensional weather conditions; more frequent observations to allow models to be initialized more frequently; faster computers allowing higher spatial resolution in the models; and better understanding of weather phenomena. Over the last 15 years, the errors for 6-hr wind forecasts, used for air traffic management, have been reduced by 50 percent over the United States. These improvements also benefited many other NOAA programs which depend on better predictions (e.g., thunderstorms).

Solar Energy: Forecasts and Observations

NOAA's potential contributions to expanding solar energy could include building upon existing meteorological and climatological observation networks, such as the Historical Climate Network. The most difficult challenge in solar energy forecasting is providing precise cloud-coverage measurements. NOAA has the scientific expertise to design and deploy solar demonstration projects to make detailed and comprehensive measurements of cloud parameters and aerosols using remote-sensing instrumentation. Such research would allow an evaluation of weather forecast models by comparing their model output to the observations from demonstration projects. After pinpointing where inaccuracies arise in the models, the forecasts of clouds and aerosols could be improved.

To respond to industry identified needs, NOAA in partnership with other Federal agency and private sector partners could lend the scientific expertise necessary for the development of a national solar radiation and aerosol network. NOAA experience would contribute to the creation and maintenance of a national reference database of historical, real-time, and projected solar data. NOAA also has expertise in assimilating satellite solar radiation data to generate the best analysis fields for forecasting solar energy at various times scales, as well as for developing advanced methods for quickly and accurately computing net solar radiation under various weather conditions.

Ocean Thermal Energy Conversion (OTEC) and Marine Hydrokinetic Energy

As a source of renewable energy, OTEC has the potential to make a significant energy contribution in the locations where it is suitable. Islands that are currently almost entirely reliant on imported fossil fuel could take strides for self-sufficiency if the commercial development of OTEC proves feasible. However, while NOAA is working to develop a clear regulatory pathway for OTEC development, that pathway needs to include an assessment of the impacts, risks and mitigation requirements for OTEC facilities particularly in regards to the enormous volumes of water that will be required. Additional research will be needed to understand the environmental impacts of OTEC. This will provide greater regulatory certainty and confidence levels for OTEC developers, their financial backers and the public.

Marine hydrokinetic technologies currently depend on extensive testing of prototype devices on a pilot scale to guide technology design for eventual commercialization. Commercial scale projects will most likely have to compete with existing ocean user groups, but NOAA's potential contributions include resolving conflict by working with others under the Ocean Policy Task Force's Coast and Marine Spatial Planning Framework to develop regional coastal and marine spatial plans. Those plans, representing the best technological and spatial knowledge, should build on traditional mandates and agency roles.

Additional science, research and monitoring of coastal and ocean resources are needed to effectively inform siting of new renewable coastal and ocean energy projects. New observations of the vertical distribution of currents and of temperature in rivers and coastal areas, and of the living resources using those habitats, would also be needed for future siting and operations of marine hydrokinetic facilities. NOAA is well poised to provide this information by enhancing its current data gathering operations. In addition, NOAA requires comprehensive benthic habitat maps to fill gaps in current habitat characterization data that is needed to conduct essential fish habitat consultations.

Biomass/Biofuels

Improved and more geographically precise weather and climate forecasts of precipitation, cloud cover, temperature, winds, and water flow are needed for biomass/biofuel agriculture; improved vegetation index products; information about environmental impacts of land-use changes on coastal and ocean areas; and measurements and predictions of the distribution of atmospheric gases produced by biofuel production.

Climate Services for Renewable Energy

NOAA has a world-class scientific leadership in documenting and understanding climate variability and change, and in improving model forecasts of what the future climate will look like under different greenhouse gas emission scenarios. NOAA's capabilities and expertise in this discipline offer major contributions to the sound planning of a domestic renewable energy system by providing key climate services and information. NOAA also has the technical capability to provide the long-term data sets, the climatology, re-analyses (model-facilitated descriptions of past climate conditions), and projections into the future of wind and other renewable energy sources needed to support the private sector's decisions on selecting optimal locations for renewable energy facilities.

NOAA has the technical capability to conduct studies of how natural variability and anthropogenic climate change may affect renewable resources (wind, solar, water, marine hydrokinetic) in the future. The renewable energy industry has identified requirements for seasonal, annual, and longer-term predictions of renewable sources, as well as information about how renewable energy resources co-vary across time and space. NOAA's scientific expertise in weather and climate offer significant contributions to studies that would be necessary to optimize an electricity system based on weather-driven renewable energy, and address the advantages of increasing the diversity of energy sources, both in type and spatial location.

Little is known about the possible inadvertent impacts of deploying large numbers of renewable energy systems on the natural environment, across a range of time scales, including changes to local and regional climate. For example, wind farms could have the potential to cause small downwind changes in soil moisture or the number of frost days. NOAA could address these potential problems with targeted analyses in conjunction with academic and industry partners.

Providing meteorological observations, analyses, and forecasts is at the core of NOAA's mission. These needed products and services would fit appropriately within a NOAA Climate Service. Providing the atmospheric and oceanic research and services required for increased use of renewable energy is arguably one of the most effective ways that NOAA can support mitigation of climate change.

CONCLUSION

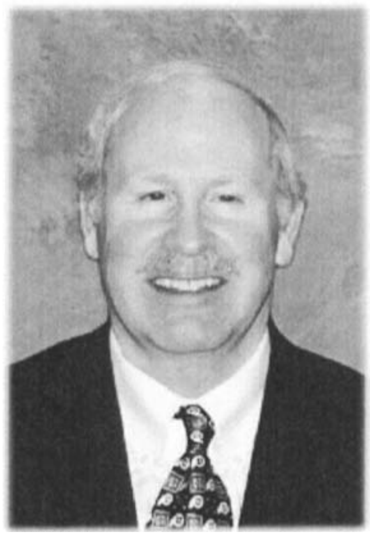
More detailed observations from the atmosphere, land, and ocean will feed into improved computer model forecasts for weather, water, and climate. This is at the core of NOAA's mission and it is well-positioned to partner with the private sector and support its efforts. These improvements offer substantial benefit not only for the renewable energy enterprise, but for the Nation as a whole. Thank you for inviting me to discuss NOAA's important current and potential roles in supporting this growing sector of our economy.

APPENDIX A. NOAA's Energy-Related Legal Mandates

Legal Authorities	Lead Federal Agency(ies)	Lead NOAA Office(s)	U.S. Code Citation
Energy-Specific Legal Authorities			
Federal Power Act (FPA)	Federal Energy Regulatory Commission	NMFS, Office of Habitat Conservation	16 U.S.C. §§ 791a-828c
Outer Continental Shelf Lands Act (OCSLA)	Department of the Interior, Minerals Management Service	NOS, Office of Ocean and Coastal Resource Management, Office of National Marine Sanctuaries, and Coastal Services Center; NMFS	43 U.S.C. §§ 1331-1356
Deepwater Port Act (DPA)	Department of Transportation, Maritime Administration; United States Coast Guard	NMFS, Office of Habitat Conservation; NOS, Office of Ocean and Coastal Resource Management, Office of National Marine Sanctuaries	33 U.S.C. §§ 1501-1524
Ocean Thermal Energy Conversion Act (OTECA)	Department of Commerce, NOAA	NOS, Office of Ocean and Coastal Resource Management	42 U.S.C. §§ 9101-9168
Ocean Thermal Energy Conversion Research, Development, and Demonstration Act (OTEC RD&D Act)	Department of Energy	NOS, Office of Ocean and Coastal Resource Management	42 U.S.C. §§ 9001-9009
National Methane Hydrates Research and Development Act of 2000 (MHR&D Act)	Department of Energy	OAR, Office of Ocean Exploration and Research	30 U.S.C. § 1902
Pacific Northwest Electric Power Planning and Conservation Act	Bonneville Power Administration	NMFS, Northwest Regional Office	16 U.S.C. § 839
Conservation and Management Legal Authorities			
Magnuson-Stevens Fishery Conservation and Management Act (MSA)	Department of Commerce, NOAA	NMFS, Office of Habitat Conservation; NMFS regional offices	16 U.S.C. §§ 1801-1884
Marine Mammal Protection Act (MMPA)	Department of Commerce, NOAA	NMFS, Office of Protected Resources	16 U.S.C. §§ 1361-1423h
Endangered Species Act (ESA)	Department of Commerce, NOAA; Department of the Interior, U.S. Fish and Wildlife Service	NMFS, Office of Protected Resources	16 U.S.C. §§ 1531-1544
Fish and Wildlife Coordination Act (FWCA)	Department of the Interior, U.S. Fish and Wildlife Service	NMFS	16 U.S.C. §§ 661-667e
Coastal Zone Management Act (CZMA)	Department of Commerce, NOAA	NOS, Office of Ocean and Coastal Resource Management	16 U.S.C. §§ 1451-1465
National Marine Sanctuaries Act (NMSA)	Department of Commerce, NOAA	NOS, Office of National Marine Sanctuaries	16 U.S.C. §§ 1431-1445c-1

Executive Order 13158 of May 2000, Marine Protected Areas (MPAs)	Department of Commerce, NOAA	NOS, Office of Ocean and Coastal Resource Management	Not applicable.
Oil Pollution Act of 1990 (OPA90)	Department of Commerce, NOAA	NOS, Office of Response and Restoration	33 U.S.C. §§ 2701-2762
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and National Contingency Plan (NCP)	Environmental Protection Agency	NOS, Office of Response and Restoration	42 U.S.C. §§ 9601-9675
Mapping and Observation and Forecasting Legal Authorities			
Coast and Geodetic Survey Act of 1947 (Provision of Data for Navigation of Marine and Air Commerce)	Department of Commerce, NOAA	NOS; NWS	33 U.S.C. §§ 883a-884
Hydrographic Services Improvement Act	Department of Commerce, NOAA	NOS	33 U.S.C. §§ 892-892d
Weather Service Organic Act	Department of Commerce, NOAA	NWS	15 U.S.C. § 313
Ocean and Coastal Mapping Integration Act	Department of Commerce, NOAA	NOS	Not applicable. P.L. 111-1, Title XII, Subtitle B
Integrated Coastal and Ocean Observation System Act	Department of Commerce, NOAA	NOS, Integrated Ocean Observing System Program	Not applicable. P.L. 111-1, Title XII, Subtitle C
Weather Service Modernization Act	Department of Commerce, NOAA	OAR	15 U.S.C. § 313
Research Authorities			
National Sea Grant College Program	Department of Commerce, NOAA	OAR, National Sea Grant College Program	33 U.S.C. §§ 1121-1131
Clean Air Act (CAA)	Environmental Protection Agency	OAR	42 U.S.C. §§ 7401-7671q
U.S. Weather Research Program (USWRP) Authorization Act	Department of Commerce, NOAA	OAR	15 U.S.C. § 313
National Climate Program Act	Department of Commerce, NOAA	OAR, Climate Research Program	15 U.S.C. §§ 2901-2908
The Federal Plan for Meteorological Services and Supporting Research	Department of Commerce	NWS	
Legal Authorities for All Federal Agencies			
Management of Federal Information Resources	All federal agencies.	NWS	
National Environmental Policy Act (NEPA)	All federal agencies.	PPI	42 U.S.C. §§ 4321-4375

BIOGRAPHY FOR ALEXANDER MACDONALD



Dr. Alexander E. (Sandy) MacDonald was named the first Director of the Earth System Research Laboratory and first Deputy Assistant Administrator for NOAA Research Laboratories and Cooperative Institutes on July 27, 2006. Dr. MacDonald served as Acting Director for the Earth System Research Laboratory and Director of the ESRL Global Systems Division during the consolidation of the Boulder Laboratories into the Earth System Research Laboratory in 2006. Prior to the consolidation, Dr. MacDonald led the Forecast Systems Laboratory.

Dr. MacDonald was the Director of the Program for Regional Observing and Forecasting Services (PROFS) from 1983 to 1988. From 1980–1982, he was Chief of PROFS' Exploratory Development Group and from 1975–1980 he was a Techniques Improvement Meteorologist in the Scientific Services Division, Western Region, National Weather Service in Salt Lake City, UT. He was an Air Force Officer while a member of the U.S. Air Force from 1967–1971.

Mr. TONKO. Thank you, Dr. MacDonald.

And we move to Dr. Mooney, please.

STATEMENTS OF DAVID MOONEY, DIRECTOR, ELECTRICITY, RESOURCES, AND BUILDING SYSTEM INTEGRATION CENTER, NATIONAL RENEWABLE ENERGY LABORATORY

Dr. MOONEY. Good morning, Mr. Chairman, Members of the Subcommittee. I appreciate the opportunity to appear before you today to discuss wind and solar resource forecasting. My name is David Mooney. I am the Director of the Electricity, Resources and Building Systems Integration Center at the National Renewable Energy Laboratory. NREL is the U.S. Department of Energy's primary laboratory for research and development in renewable and efficiency technologies.

I would like to emphasize three main points in my testimony today. First, high-accuracy, high-resolution wind and solar forecasts are critical for enabling reliable and cost-effective, large-scale deployment of wind and solar power generation. Second, while current state-of-the-art forecasts are very valuable to systems operators, there is considerable room for improvement. And third, there are important roles for both the public and the private sector in furthering forecasting technology.

As we all appreciate, forecasts are needed because we are unable to control the weather that is a source of uncertainty in wind and solar generating power plant outputs. The inability to dispatch wind and solar then becomes a significant integration challenge to systems operators in high-penetration scenarios. Therefore, reduction of uncertainty in renewable power plant output that can be achieved through forecasting is critical, and it serves two functions. First, forecasts allow the power system to be operated more reliably under high wind and solar generation deployment. Second, higher-resolution forecasts with enhanced accuracy significantly reduce the cost of integrating large amounts of renewable generation into the existing power system.

Renewable resource forecasts for utility operations have two main components. First is the prediction of the wind speed or the solar intensity at different times in the future, and second is the conversion of that data to power plant output. The first component has historically been the government's role. NOAA, through the National Weather Service, provides weather forecasts from which wind speed and solar intensity forecasts can be estimated.

Industry's role is to convert those weather forecasts into predicted power plant outputs that are then packaged into customized products for systems operators to plan their generation mix. Currently, for a single wind power plant, energy production forecast error varies from about 10 to 15 percent for hour-ahead forecasts and as much as 25 to 30 percent for day-ahead forecasts. At these accuracy rates, though, forecasts are very valuable. An example is shown in NREL's western wind and solar integration study which found that, for 27 percent wind and solar penetration across the 14-state western interconnection, the use of state-of-the-art day-ahead wind and solar forecasts in systems operations compared to not using any forecast at all would save $5 billion per year, which is about 14 percent of total operations costs, so a significant savings.

Even considering this impact, though, many improvements can be made to today's forecasts. To that end, the public sector should undertake simultaneous improvement on three fronts. First, there is a need to further develop weather prediction models that focus on the physical phenomena that impact wind speeds and solar intensity. This involves improved understanding and representation of the atmospheric conditions that impact those quantities. Second, there is a need to better observe those phenomena that are needed as inputs to the weather prediction models, and third, there is a need to operate these models at higher temporal and spatial resolution.

The public and private sectors currently work together very constructively. Private sector entities provide tailored renewable forecasts to systems operators using inputs to their models from the public sector. Given the substantial cost of conducting fundamental research in the areas of atmospheric physics, modeling, and observation, the acquisition and assimilation of that data from the observations and then running very computationally intensive models at high resolutions over vast geographic areas, the public sector is likely best positioned to undertake these challenges that are of common benefit to all private sector forecasting industry members. It is anticipated that the higher-quality data resulting from better understanding and modeling of fundamental atmospheric conditions will ultimately result in better forecasts that will enable more reliable and cost-effective wind and solar integration in support of our national objectives.

To make progress in this critical area on a time scale that supports our energy goals, both the government and the private sector have essential roles, and we are eager to support and actively participate in the advancement of this vital field.

I appreciate the opportunity to testify this morning and I will be happy to take questions.

[The prepared statement of Dr. Mooney follows:]

PREPARED STATEMENT OF DAVID MOONEY

Mr. Chairman, thank you for this opportunity to discuss important issues related to forecasting wind and solar resources, which are becoming increasingly vital to the nation's energy future. I am the director of the Electricity, Resource and Building Systems Integration Center at the National Renewable Energy Laboratory (NREL) in Golden, Colorado. NREL is the U.S. Department of Energy's primary laboratory for research and development of renewable energy and energy efficiency technologies. I am honored to be here, and to speak with you today.

Why is forecasting of renewables needed?

In many cases, renewable power generation technologies have operating characteristics that are unique when compared to the conventional generation technologies that utilities are accustomed to operating. Principal among these is that the generation of wind and solar plants (that do not include storage) cannot be controlled and depend on resource conditions to determine their output. While there are many techniques available to address the variability and uncertainly of the resources such as fast-response conventional generators and demand response, high resolution resource forecasting is recognized as a critical tool in allowing for the economic and reliable integration of variable generators.

Wind and solar renewable resources are inherently variable and uncertain—that is we cannot perfectly forecast what the weather will be like every hour of the day a day ahead. Because this adds to the inherent uncertainty in the load that utilities already manage, it can potentially become a significant issue for utility system operations at large wind and solar energy penetrations. In order to reliably and cost-effectively integrate large amounts of wind and solar power generation into the power system, accurate forecasts are critical. It is expected that the development of more accurate forecasts, for wind and solar power, at higher temporal and spatial resolution along with the adoption of those forecasts in utility operations will ensure that we can deploy wind and solar generation technologies in quantities that support our national goals of reduced greenhouse gas emissions and increased energy security.

The development and adoption of renewable resource forecasts reduce the uncertainty of renewable power plant output and serve two critical functions:

1) Forecasts allow the power system to be operated more reliably under high renewable generation deployment, and
2) Higher-resolution forecasts with enhanced accuracy significantly reduce the cost of integrating large amounts of renewable generation into the existing power system.

With both wind and solar, uncertainty has a greater impact than variability. If wind or solar power is over-forecast, a utility will likely experience higher costs due to using unplanned quick response conventional generation and possibly higher spot-priced fuel. If wind or solar power is under forecast, the utility may have excess electricity and need to sell at depressed market rates, or in extreme situations curtail "free fuel" wind and solar.

While today's state-of-the-art forecasts are proving to be very valuable in renewable generation adoption, there remains considerable room for improvement, and there are important roles in advancing this technology that both the public and private sectors can play.

Currently as wind turbines extend to 250 feet and higher and utility scale solar power plants are being developed, forecasters are challenged to predict with needed precision the electrical output from wind and solar plants for each season, day, hour and fraction of an hour ahead.

This challenge should be distinguished from another challenge, that of determining optimal sites for deploying turbines and solar plants to maximize production. Resource measurement and characterization is based on historic data and aids in locating plants to maximize their power output over time. Resource forecasting predicts resource availability in the future and aids in the integration and operation of the plants once they are constructed.

What is the state of the art of renewable resource forecasting today?

Forecasts of suitable quality for adoption in utility operations have two main components. First is the prediction of wind speed or solar intensity at different times in the future, and second is the conversion of that data to power plant output. Historically, the government has played the biggest role in providing generalized weather forecasts from which wind speed and solar intensity forecasts can be estimated, while it has been industry's role to convert those wind speed and solar intensity forecasts into predicted power outputs that individual utilities or systems operators can utilize to plan the mix of their power plant dispatch needed to meet demand.

The starting point for a state-of-the-art weather forecast today is provided by the National Weather Service (NWS), which is part of the National Oceanic and Atmospheric Administration (NOAA). These relatively coarse temporal and spatial resolution weather forecasts are produced using weather prediction models. These weather prediction models assimilate observations from ground and airborne instruments, as well as satellites for more accurate initialization of the weather models. Currently these weather prediction models and the observations they use are focused on weather prediction impacting life and property, but not necessarily on renewable power generation issues.

Although not of ideal temporal or spatial resolution, the private sector uses these NWS forecasts for the initialization of their proprietary models to provide tailored power prediction forecasts for utility and systems operators. To assist the industry in providing more accurate power production forecasts, it is critical that observational networks and the resulting weather forecasts provided by the NWS be of higher quality and accuracy, and that they be aimed at the unique requirements of renewable energy prediction in addition to the current focus of weather prediction impacting life and property.

Currently, for a single wind power plant, energy production forecast error varies from 10–15 percent for hour-ahead timescales, to 25–30 percent for day-ahead timeframes. This forecasting error diminishes when multiple plants (and their associated forecasts) across an entire region are considered. The table below summarizes these state-of-the-art forecast errors for both energy forecasts and capacity forecasts.

Average Wind Forecast Error by Timeframe

	Forecast Error	
	Single Plant	Region
Hour Ahead		
Energy (% actual)	10 – 15	6 – 11
Capacity (% rated)	4 – 6	3 – 6
Day Ahead		
Hourly Energy (% actual)	25 – 30	15 – 18
Hourly Capacity (% rated)	10 – 12	6 – 8

Source: J. Charles Smith, Sept 1, 2009, "Lessons Learned in Wind Integration", presented to FERC, Washington, DC.

Improvements in the error level of forecasts would benefit utilities immensely. Xcel Energy, for example, has released analysis that shows every percentage point improvement in accuracy saves Xcel Energy $1.2 million through a reduction in required spinning reserves [1].

[1] Keith Parks, "Value to Real-Time Operations", UWIG Spring Forecasting Workshop, Phoenix, AZ, Feb 18–19, 2009

Additionally, NREL's Western Wind and Solar Integration Study [2] (WWSIS) found that use of day-ahead wind and solar forecasts in operations, compared to not using a forecast at all, would save $5 billion per year across the 14-state, two-Canadian-province Western Electricity Coordinating Council. This savings was at a 27% wind and solar penetration across the region. Further, the WWSIS showed that if the forecast were perfect, those savings would increase by 10% or about $500M/year.

Studies [3] [4] [5] of the California Independent System Operator, the New York Independent System Operator and the Electricity Reliability Council of Texas systems also show significant costs savings when a forecast is used in power system operations and further incremental savings for a perfect forecast (i.e. a forecast with zero uncertainty).

The table below shows the impact on costs savings for these three system operators when no wind forecast is used, compared to implementing a state-of-the-art and a perfect forecast.

Impact of Wind Forecasts on Grid Operating Costs

			Annual Operating Cost Savings	
	Peak Load	Wind Generation	SOA Forecast vs. No Forecast	Perfect Forecast vs. SOA Forecast
California	64 GW	7.5 GW	$ 68M	$ 19M
	64 GW	12.5 GW	$ 160M	$ 38M
New York	33 GW	3.3 GW	$ 95M	$ 25M
Texas	65 GW	5.0 GW	$ 20M	$ 20M
	65 GW	10.0 GW	$ 180M	$ 60M
	65 GW	15.0 GW	$ 510M	$ 10M

Source: Richard Piwko, "The Value of Wind Power Forecasting", presentation at UWIG Workshop on Wind Forecasting Applications to Utility Planning and Operations, Phoenix, AZ, Feb 18-19, 2009.

It should be noted that there is approximately 30 times more wind generation installed in the USA than solar energy generation, making the demands on wind forecasting more critical than those for solar forecasting. The state-of-the-art for forecasting is therefore more advanced for wind than it is for solar. Additionally, development in capabilities for forecasting wind and solar resources differs because of differences in how these resources behave and how we measure and model them.

How can solar and wind forecasts be improved?

While wind and solar forecasts have been reasonably successful for small levels of deployment, it is becoming increasingly clear that higher accuracy levels need to be achieved to enable higher penetrations of renewable power generation on the grid.

While forecast error averaged over a year and across a wide region may not be too large, specific hours throughout the year can have significant forecast error. In

[2] GE Energy. May 2010. Western Wind and Solar Integration Study, NREL Report No. SR–550–47434, *www.nrel.gov/wind/systemsintegration/pdfs/2010/wwsis_final_report.pdf*

[3] New York State Energy Research and Development Authority. March 2005. "The Effects of Integrating Wind Power on Transmission System Planning, Reliability, and Operations," *www.nyserda.org/publications/wind_integration_report.pdf*

[4] California Energy Commission. July 2007. Intermittency Analysis Project Study. "Appendix B—Impact of Intermittent Generation on Operation of California Power Grid," *www.energy.ca.gov/2007publications/CEC-500-2007-081/CEC-500-2007-081-APB.PDF*

[5] GE Energy. March 2008. *Attachment A: Analysis of Wind Generation Impact on ERCOT Ancillary Services Requirements*. Prepared for Electric Reliability Council of Texas. Schenectady, NY: GE Energy. *http://www.ercot.com/content/news/presentations/2008/Wind_Generation_Impact_on_Ancillary_Services_-_GE_Study.zip*

the Western Wind and Solar Integration Study, these extreme over or under forecasts could be up to half of the installed capacity. It is these extreme events that create difficulties for system operators in maintaining system reliability. Improved forecasting to reduce the severity and number of these extreme events would be very helpful.

Among the most important reasons for wind forecast error is the lack of measurements in the Planetary Boundary Layer (PBL) as well as inherent uncertainties in modeling the atmospheric physics within the PBL. The resulting forecast uncertainty is also evident in the forecasting of ramp events—periods of rapid change in wind-farm production. Because ramp events drastically increase or decrease the wind energy available in a short span of time, an accurate ramp forecast is important for utility dispatchers who must address load balancing on a sub-hourly basis. The quantification of forecast errors for ramp events provides valuable information for improving wind forecast methods. This topic is not sufficiently understood or developed.

The errors in solar forecasting are primarily the result of forecasting errors in how clouds form and dissipate at different layers in the atmosphere. This involves complex physical processes, and better understanding and representation of these processes will lead to better solar forecasting. Because solar forecasting is not a priority of weather forecasting models, research and more accurate implementation of these processes in the weather prediction models do not typically get priority. Short-term solar forecasting capabilities can most probably be done using geostationary satellite imagery, but that methodology is not yet fully developed.

To improve forecasting of both wind and solar resources that will enable more accurate corresponding power production modeling, there is need for the public sector to provide more extensive measurements and improved weather models resulting in better resource forecasts for utilization by the sophisticated power production models used by the private sector. The provision of better resource forecast inputs will need simultaneous improvement on three fronts.

First, there is a need to develop weather prediction models that are tailored to producing accurate forecasts of wind speeds and solar intensity. This involves improved understanding and representation of the atmospheric conditions that impact their variability. As an example, cloud formation and dissipation need to be better characterized to improve solar forecast. Similarly the understanding of the dynamics of the wind in the lower levels of the earth's atmosphere (the PBL) needs to be improved for better wind prediction.

Second, there is a need to better observe the physical phenomena that are needed as inputs to the weather prediction models. Lack of proper observations to feed an improved prediction model will most likely result in a bottleneck to improved forecasts. Examples of observation tools and techniques needed are wind profiles from Light Detection and Ranging (LIDAR) and Sonic Detection and Ranging (SODAR) instruments. Also useful will be a significant increase in the number of sites where solar observations are taken by NOAA, which maintains only seven sites today.

Third, there is a need to operate these models at higher temporal and spatial resolution using enhanced observations as inputs. Higher temporal resolution provides information about variability that is missed when model output is only available at 3 or 6 hourly intervals. Also higher spatial resolution results in the capture of small-scale physical processes and the impacts of terrain that are missed when the spatial grid is coarse.

It should be noted that, even at today's lower resolutions, computers with high-end computational capabilities (teraflop range) are employed because of the computationally intensive nature of the model runs and the huge volume of observations from various sources they assimilate. To operate these models at higher resolutions over all of the U.S. would require the latest generation of supercomputers, which is another important capability and resource that is likely most appropriate for the government to provide.

It is expected that renewables-focused, higher quality wind and solar forecasts that are also available at higher temporal and spatial resolutions will result in a better forecasts of power output. These renewables-tailored forecasts could be provided by the NWS and available to all forecasting industry members. This is potentially an important role for government to play in accelerating the deployment and integration of wind and solar power production technologies.

What are Potential Roles of the Private and Public Sectors?

The synergistic relationship between the private and public sectors in forecasting of renewables is evident from how forecasting is currently done. Private sector entities provide tailored renewable forecasts to systems operators using inputs to their models from the public sector, while augmenting them with proprietary observations, mesoscale models, and statistical techniques.

Specifically, NOAA currently provides wind speed and cloud cover (from which solar resources can be derived) forecast products by running their operational weather prediction models. Given the enormous cost of

a) Conducting fundamental research in the areas of atmospheric physics, modeling, and observation;
b) Acquisition of observations over potentially thousands of sites that are input to the models;
c) Assimilating the observations for model initialization, and;
d) Running computationally intensive models at high resolutions over vast geographic areas;

the public sector is best positioned to undertake these issues that are of common benefit to all private sector forecasting industry members. NREL and the U.S. DOE have historically played an important role as an interface between the weather data and the forecasting industry. NREL and DOE have researchers with the domain expertise to understand how (and which) weather conditions impact the renewable generation technologies. DOE and NREL work to help NOAA better understand *which* resource characteristics impact technology performance, as well as support the industry in understanding *how* resource characteristics impact technology output.

Ultimately better, more renewable-tailored models run by NOAA will provide better initial conditions for the private sector to run their proprietary models for more time- and place-specific power-production forecast products. It is anticipated that these renewable-tailored, higher quality data resulting from better understanding and modeling of fundamental atmospheric conditions affecting wind and solar will ultimately result in better hour- and day-ahead power forecasts that will enable the integration of renewable generating technologies on a scale that will support our national objectives.

Another key government role is the role that DOE and its subcontractors have previously played in translating the needs of utilities to the forecasting industry and vice versa. For example, forecasters and the meteorological community previously used mean absolute error or root mean square error as a metric for their work. However, as understanding has improved, utilities have decreased emphasis on the average forecast error and focus more on whether forecasts correctly capture ramps, which directly and significantly impact operations and reliability. Through DOE's work, state-of-the-art forecasting has evolved to try to more accurately capture ramp forecasting.

Summary

High temporal and spatial wind and solar resource forecasting is critical for the deployment of large-scale renewable power generation technologies. High quality forecasting will enable integration of these technologies at lower costs, while maintaining the reliability of the power system.

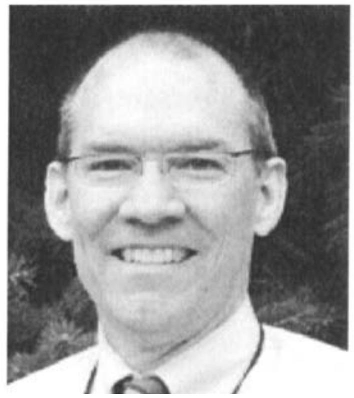
While state-of-the-art forecasting is already beneficial to wind integration, there is substantial room for valuable improvement in fundamental weather observations and models. Additionally, solar resource forecasting is in its infancy, and there are extensive requirements for the development of the fundamental science to improve the state-of-the-art for solar forecasting.

To make progress in this critical area on a time-scale that supports national objectives, both the government and the private sector have vital roles.

The government can improve fundamental weather forecasting techniques to include more accurate and timely forecasts tailored for wind and solar technologies. The government can provide the data required by industry power conversion models so that highly accurate power-production forecasts can be generated. More accurate power production forecasts will be crucial in maintaining the reliability of the power system and in improving the economics of wind solar power plants deployed at scale.

Mr. Chairman, thank you again for this opportunity to share our perspective on this important topic. I will be happy to address any questions you may have.

BIOGRAPHY FOR DAVID MOONEY



Dave is currently working at the National Renewable Energy Laboratory leading efforts to identify and address technical issues associated with the large-scale deployment and integration of renewable and efficiency technologies into the existing energy infrastructure. In this capacity, he leads 125 researchers conducting $65M in R&D annually. Dave is a 23-year veteran of the renewable energy industry.

From 2007 to 2008 he was assigned by NREL to support the DOE's office of the Assistant Secretary for Efficiency and Renewables. On the assignment he conducted analysis of EERE's technology portfolio to quantify energy, environmental, and economic benefits and served as technical counsel to the Deputy Assistant Secretaries. Principal among his activities at DOE was the development of a technology-based analysis for quantifying greenhouse gas reduction potentials for the EERE technology portfolio, which were used in international climate negotiations.

During his tenure at NREL Dave has worked as a physicist researching photovoltaic materials, as a project manager, and as Assistant to the Director implementing laboratory strategy.

Dave has also worked as the director of business development for a U.S. PV company where he was responsible for launching manufacturing and systems businesses, business planning, and raising investment capital.

Mr. TONKO. Thank you, Dr. Mooney.

Dr. Storck, please.

STATEMENTS OF PASCAL STORCK, VICE PRESIDENT, 3TIER

Dr. STORCK. Good morning, Chairman Tonko and the other Members of the Subcommittee. I appreciate the opportunity to be here today to testify on the issue of public and private roles and research needs in renewable energy forecasting.

Electricity generation from renewable sources such as wind and solar comes with the disadvantage that the output is variable and fluctuates as the weather does. As renewable energy generation has come to supply an increasing amount of the electricity consumed in our country, it has become clear that forecasting renewable energy output hours and days in advance is key to the cost-effective integration of this variable energy source.

The first point that I would like to make is that small- and medium-sized private businesses in the United States have assumed a leadership role in providing energy forecasting services. Our sector is vibrant, competitive and maturing and is creating high-paying technical jobs and exports. Our company, 3TIER, and our competitors routinely provide accurate forecasts of renewable energy output hours and days in advance to project owners, system operators, utility companies, and power marketers. Our company alone provides wind energy forecasts for over 12,000 megawatts of installed capacity representing over 100 individual projects and serving over 40 unique clients. 3TIER employs a staff of 60 in the production and delivery of these forecasts and other services for the renewable energy industry. To seize the opportunity of the global market, we have established offices in India, Latin America, and the Pacific rim for the export of our energy forecasting services.

As the renewable energy industry has grown, so has the experience level of the private sector in providing these forecasts. Our company was founded in 1999, and we have played an integral role in the improvement of forecast accuracy as we invest in our forecast systems to meet the demands of our clients. In fact, recent work overseen by NREL has demonstrated that the current state of the art technology provides 80 percent of the value of a perfect forecast. In short, the private sector renewable energy forecasting community is strong and well positioned to meet the demands of our clients worldwide both today and into the future.

The second point that I would like to make is that the government does have an important and fundamental role in supporting the private sector in our task of creating more accurate renewable energy forecasts. 3TIER and our competitors rely on accurate government weather forecasts as inputs to our more specialized energy forecast systems on both a regional and global scale. The government operates a reliable national network of routine surface and upper air weather observations. It also develops and operates sophisticated computer weather forecast models that ingest these data and produce weather forecasts. Improve the quality of these forecasts by improving the observational inputs, the models themselves, and the systems that create the forecasts, and the private sector will improve the quality of the renewable energy forecasts. Improving the accuracy of the Nation's fundamental weather forecasts is an enormous challenge. This charge falls squarely on the Department of Commerce where NOAA is uniquely positioned to accomplish these improvements through its Office of Atmospheric Research and other divisions. Doing so will not only improve the quality of renewable energy forecasts applied by the private sector, but will also aid the National Weather Service in its primary mission of protecting life and property. It will also provide benefits to transportation, agriculture and other economic sectors, ensuring that investments made here are not solely for the benefit of one industry.

The last point that I would like to make is that the roles of the government and the private sector in renewable energy forecasting need to be clearly defined. Fundamental research and infrastructure investments are required to improve the Nation's weather forecasts, but these should not be confused with applied research and product development for specific industries and end users. The public sector can and should provide the best possible scientific foundation upon which the private sector can do what it does best: drive innovation and deliver services nimbly and competitively to our customers. Confusion in these roles blurs the line between business and government, creates a distorted marketplace, and ultimately increases the tax burden while squeezing out the very companies that are effectively serving these markets. To be clear, it is essential that the Federal agencies provide fundamental research, data collection, and accurate foundational weather forecasts without then inserting themselves into the marketplace as an alternative to the private sector, thereby undermining a vibrant industry of small businesses like ours. In these times of strong renewable energy industry growth and Federal stimulus program funding, there is an opportunity, if not an obligation, for the public sector to work aggressively toward complementing the private sector's capabilities. Working together will allow American companies to continue to lead the world's clean energy revolution, but for these companies to lead, we need to make sure that they don't find that their biggest competitor is their own government, both at home and abroad.

Thank you for allowing me the opportunity to testify today and I look forward to any questions you may have.

[The prepared statement of Dr. Storck follows:]

PREPARED STATEMENT OF PASCAL STORCK

Good Morning, Chairman Baird, Ranking Member Inglis and the rest of the committee. I appreciate the opportunity to be here today to testify on the issue of public and private roles and research needs in renewable energy forecasting.

Electricity generation from renewable sources such as wind and solar comes with the disadvantage that the output is variable and fluctuates as the weather does. As renewable energy generation has come to supply an increasing amount of the electricity consumed in our country, with some regions (such as Texas/ERCOT) seeing 20% or more of hourly electricity demand satisfied solely by wind, the challenges of integrating this energy into our power system have been documented, studied and debated. One common theme that has emerged is that forecasting renewable energy output hours and days in advance is key to the cost-effective integration of this variable energy source.

The central importance of renewable energy forecasting has led to the establishment and growth of a vibrant and competitive private sector to provide these forecasts. Our company, 3TIER, and our competitors routinely provide accurate forecasts of renewable energy output, hours and days in advance, to project owner/operators, system operators, utility companies, and power marketers. Our company alone provides wind energy forecasts for over 13,000 MW of installed capacity and employs 60 staff in the production and delivery of these forecasts and other services for the renewable energy industry. As the renewable energy industry has grown, so has the experience level of the private sector in providing these forecasts. Forecast accuracy has improved significantly over the past several years as we invest in our forecast systems to meet the demands of our clients. In fact, recent work overseen by our colleagues at NREL has demonstrated that the current state-of-the art provides 80% of the value of a perfect forecast. In short, the private sector renewable energy forecasting community is strong and well-positioned to meet the demands of our clients, both today and into the future.

As I mentioned earlier, renewable energy output fluctuates as the weather does. This simple fact makes accurate weather forecasts a fundamental requirement of an accurate renewable energy forecast. 3TIER, as well as our competitors, rely on government weather forecasts on both the regional and global scale as inputs to our energy forecast systems. These government issued forecasts in turn rely on global and local observational networks as well as computer models that have been developed, implemented, and refined by countless individuals spanning government operational forecasting centers, our research universities, our national labs, and the private sector as well. Herein lies the best opportunity for collaboration between the private sector, government and academia. Improve the quality of the weather forecasts, by improving the observational inputs, the models themselves, and the systems that create the forecasts, and we will improve the quality of the renewable energy forecasts that the private sector can provide. Improvement of the accuracy of the nation's fundamental weather forecasts is an enormous challenge and one that our Federal agencies are uniquely positioned to achieve. Doing so will not only improve the quality of renewable energy forecasts supplied by the private sector, but will benefit transportation, agriculture and the other sectors that are affected by the weather, ensuring that investments made are not solely for the benefit of one industry.

In these times of strong renewable energy industry growth and Federal stimulus program funding, there is the opportunity—if not the obligation—for the public sector to work aggressively towards *complementing* the private sector's capabilities to provide the greatest benefits to the renewable energy industry's requirements for accurate energy forecasts. If this opportunity is not well planned and coordinated, there is the risk that federally-funded efforts could be redundant and in competition with services already provided by the private sector. Working together, we can ensure a robust and second-to-none U.S.-based weather forecasting infrastructure as well as a competitive renewable energy forecasting industry that enables the realization of the nation's full renewable energy potential.

Thank you for allowing me the opportunity to testify today and I look forward to any questions you may have.

Additional Material (see attached: Joint Statement on the Role of Government-Affiliated Renewable Energy Forecasting Activities Relative to the Private Sector, prepared by Bruce Bailey, Mark Ahlstrom and Pascal Storck on June 3, 2009)

Joint Statement on the Role of Government-Affiliated Renewable Energy Forecasting Activities Relative to the Private Sector

Prepared By:

AWS Truewind (Albany, NY); **3TIER** (Seattle, WA); **WindLogics** (St. Paul, MN)

June 3, 2009

The integration of wind energy generation into the country's transmission system has been greatly facilitated by the availability of advanced wind forecasting services developed over the past decade by the private sector. The three leading U.S.-based supplier firms are AWS Truewind, 3TIER, and WindLogics. The primary subscribers of wind forecasts are Independent System Operators, individual utility companies, wind plant owners/operators, energy traders, and wind turbine construction companies. Collectively these subscribers now obtain high-value forecasts for short-term (sub-hourly to 7-days) planning and decision-making for most of the country's installed wind capacity. Solar forecasting is also growing in demand and is being provided by the same firms. The quality of the forecast information and the tools used to develop forecasts are the best available worldwide. Ongoing investments in research and development by these firms and their clients are continually advancing the state-of-the-art and tailoring products to specific user needs.

In recent months, our firms—representing the private sector renewable energy forecasting community—have been engaged in preliminary discussions with government-affiliated entities about the appropriate roles for public and private sector organizations in the development and supply of short-term wind forecasts to fulfill the needs of the wind energy industry. These organizations can be placed into three categories:

- Government operational forecasting and research entities (NOAA/NCEP and NOAA/FSL)
- Government basic atmospheric research entities (NCAR, DOE labs, NASA, etc.)
- Government renewable energy research entities (NREL, DOE labs, etc.)

These discussions have been prompted by our concerns over the emergence of "new" government wind forecasting research and product development that replicates what commercial providers have been doing operationally for years.

In these times of strong wind industry growth and federal stimulus program funding, there is the opportunity—if not the obligation—for the public sector (encompassing the three government entity types) to work aggressively towards *complementing* the private sector's capabilities to provide the greatest benefits to the wind energy industry's requirements for accurate wind forecasts. If this opportunity is not well planned and coordinated, there is the risk that federally-funded programs for the government entities in support of wind forecasting could be duplicative and in competition with services already provided by the private sector. Our goal is to participate with the public sector in seizing the opportunity before us and to work collaboratively to ensure that the wind energy industry's needs are met in the most appropriate, sustainable and cost-effective way. In addition to wind, this initiative should be inclusive of other renewable energy technologies (e.g., solar, wave).

The following three broad points reflect our firms' recommendations for priority needs that federal entities can fulfill to the benefit of the entire renewable energy industry.

1. **Enhancing Publicly-Available Weather Data Networks** – The greatest opportunity for enhancing renewable energy forecasting skill throughout the United States is in increasing the number, quality, and reporting frequency of public weather monitoring stations. Current observational networks are relatively sparse and widely spaced and emphasize data collection at a height of only 10 m (or less) above the surface (compared to today's typical wind turbine hub height of 80 m). This situation makes it difficult to detect and forecast mesoscale weather events such as large wind speed or insolation deviations over short time periods (i.e., ramp events). Weather stations should also be upgraded with additional sensors (e.g., lidar, sodar, solar radiation instruments) to measure the portion of the boundary layer (up to heights of 200 m above ground) in which utility-scale wind turbines operate. The data distribution process must also be improved so that field observations are available to users in near real-time. This measurement enhancement program can be phased in over time, beginning with stations within and adjacent to concentrated renewable energy development regions. The benefits of this modernization program would be realized by all sectors of the economy that are vulnerable to severe weather events. A prerequisite and collaborative research component of this program would be to use numerical modeling techniques to identify what new locations would yield the best results for forecasting skill improvement (i.e., observational targeting).

2. **Research into Problem Flow Regimes** – Collaborative field and modeling research is needed in strategic areas of the country to better detect and forecast complex flow regimes, including low-level jets and stable layer flows, that lead to unexpected turbine outages, long-term turbine performance issues, and wind forecasting errors. Occurrences of these problem flow regimes often go undetected or under-detected because most wind monitoring towers are too widely spaced and shorter than the hub height of today's utility-scale wind turbines. A joint public-private research program should be initiated to identify and implement effective approaches to resolving this situation through innovative atmospheric measurement and modeling techniques.

3. **Improvements in NWP Models** – Numerical weather prediction models developed and run by NOAA for national weather forecasting purposes in general underperform European prediction models in terms of forecasting skill. All forecasting organizations, including ours, rely on the outputs of government-run weather prediction models to initialize their own customized higher-resolution models to produce accurate forecasts of local winds and other weather conditions. The inferior skill level of U.S. government-run models has given European firms a competitive edge in this country and is forcing our firms to become more reliant on the same European prediction models. Improving the combination of model performance, data assimilation and model output resolution should be a high priority for the benefit of both the public as a whole and the U.S.-based renewable energy forecasting industry.

While there are other areas of potential interest to advance the science and utilization of renewable energy forecasting, they are secondary in importance and would be fruitless without first accomplishing the essential advancements identified above.

What is the best way to proceed with defining and implementing government entity participation in providing the country's renewable energy forecasting needs? Framing the answer to this important question should begin with the recognition of the current role and accomplishments already established by the private forecasting sector. This sector is well engaged with both the majority of operating wind farms throughout the United States and the full array of forecast users. It best understands the renewable energy industry's needs and the forecasting challenges yet to be overcome.

The next step should be deliberate engagement between the public and private sectors to jointly define government initiatives that would have the greatest impact on the advancement of wind and solar forecasting while avoiding duplication of effort. We propose the initiation of government-sponsored meetings of representatives from the public and private forecasting sectors to formulate a roadmap for addressing the country's renewable energy forecasting needs and challenges. The roadmap would include a collaborative research plan that defines key priorities and problems, identifies geographic regions where to focus first, defines technology and model development paths as well as data assimilation approaches, proposes respective roles and relationships, and develops budgets and a timetable. Sound planning, coordination and implementation will optimize the assets existent within the public and private forecasting sectors. It will also ensure a robust and second-to-none U.S.-based forecasting infrastructure and forecasting industry that enables the realization of the nation's full renewable energy potential.

Respectfully,

Bruce Bailey, President/CEO AWS Truewind	Pascal Storck, President 3TIER	Mark Ahlstrom, CEO WindLogics

BIOGRAPHY FOR PASCAL STORCK

Pascal Storck serves as the Vice President of 3TIER and has been with the company since its beginning. During his tenure at 3TIER, Dr. Storck has played an integral role in the development and commercialization of all of the company's products and services. Dr. Storck is an internationally recognized expert on the topics of renewable energy forecasting and assessment and frequently presents at leading industry conferences. Dr. Storck received a bachelor degree in Civil and Environmental Engineering from Cornell University, a Masters in Civil Engineering through the University of Illinois-Urbana Champaign and a Ph.D. in Civil and Environmental Engineering through the University of Washington.

Mr. TONKO. Thank you, Dr. Storck.

Mr. Rosenblum, please.

STATEMENTS OF GRANT ROSENBLUM, MANAGER OF RENEWABLE INTEGRATION, CALIFORNIA INDEPENDENT SYSTEM OPERATOR

Mr. ROSENBLUM. Thank you. Good morning, Congressman Tonko and Members of the Subcommittee. I appreciate the opportunity to discuss the important function entity forecasting will play in our ability to successfully integrate increasing levels of variable renewable resources into the power system.

As a representative of a transmission system operator, my perspective is that of a consumer of forecasting services, and, in particular, one that has the responsibility for keeping the lights on for approximately 30 million Californians, and doing so in a manner as economically efficient as possible.

To provide a brief but hopefully unnecessary context to my comments, a fundamental but not exclusive requirement for keeping lights on is maintaining a constant and precise balance between electric supply and demand. Wind and solar resources add to the operator's balancing challenge by increasing the system's aggregate volatility, given their inherent variability and output and uncertainty as to the timing and magnitude of the fluctuations. Accordingly, the central issue operators confront with additional renewable resources is whether sufficient backup resources can be committed and maneuvered up or down fast enough to compensate for changes in variable renewable resource output.

While more flexible conventional resources such as pump storage, modern combustion turbines, and innovative technologies, including on- and offsite storage and demand response, will likely play a major role in managing renewable resource variability in the future, improvements in forecasting also offer potentially substantial and, importantly, more expeditious assistance in achieving continued grid reliability, market efficiency, and greenhouse gas reductions.

Based on this perspective, the California ISO offers three conclusions and recommendations. First, forecasting improvements appear to significantly reduce resource requirements for integrating renewable resources. A preliminary ISO analysis of a 33 percent RPS scenario consistent with current California policy direction indicates that if we were able to cut by nearly one-half our current forecasting error rates of approximately 15 percent in the day ahead and ten percent in the hour ahead, we could reduce the quantity of capacity that must be available for dispatch in our real-time energy market by approximately 25 to 35 percent, or nearly

2,000 megawatts. While the ISO has not completed its analysis of the potential cost savings on its system of this improvement, increases in forecasting accuracy will necessarily lead to more efficient and, therefore, less costly resource utilization.

Second, improvements in forecasting appear to rest in significant part on improvements by the Federal Government in the quality and quantity of data provided to the electricity industry and its private sector forecast partners. In particular, it is the Federal Government improvement in the underlying physics-based atmospheric models that form the baseline input for most resource forecasters that should be focused upon. As part of a recent RFP for forecasting services by the ISO, the ISO observed a high degree of correlation among the forecast errors committed by the participating private forecast service providers. This suggests that those Federal agencies responsible for developing numerical weather prediction models should tune their efforts by focusing on areas with concentrations of high renewable resources. In addition, it should be noted that the Federal Energy Regulatory Commission should be commended and should continue its efforts to address many of the root causes of poor data quality received from the generating facilities themselves. This includes improvement in the rules and requirements regarding reporting of meteorological data, equipment outage, and other critical factors.

Third, it should be emphasized that a transmission system operator must not only have accurate prediction of average production over a specified period, but it must also anticipate the speed, magnitude, and timing of changes over different operating periods. Therefore, forecasting improvement efforts must focus on increasing our ability to predict wind and solar ramp events and the underlying weather conditions that cause such events.

Thank you for this opportunity to come before you, and I welcome questions. Thank you.

[The prepared statement of Mr. Rosenblum follows:]

PREPARED STATEMENT OF GRANT ROSENBLUM

Mr. Chairman and Members of the Subcommittee, it is an honor to be here and I appreciate the opportunity to discuss the critical function energy forecasting will play in successfully integrating to the power system increasing levels of variable renewable resources. This hearing seeks to examine the roles the Federal agencies and the private sector play, and should play, in providing renewable resource forecasting as well as to explore means to enhance the efficacy of forecasting research, development, and monitoring. I intend to touch upon these topics from the perspective of a consumer of forecasts, which through its status as an independent transmission system operator, is responsible for "keeping the lights on" for approximately 30 million Californians and for doing so in as economically efficient manner as possible.

As I will elaborate further; my conclusions and recommendations are:

- Forecasting improvements are essential for maintaining reliable grid operation and market efficiency if we are to continue on a course of increasing reliance on renewable generation
- For a transmission system operator, forecasting improvement efforts should focus on increasing our ability to predict ramp events or abnormal weather conditions
- Improving forecasting requires collaboration between government and the private sector with the Federal Energy Regulatory Commission, National Weather Service, and the National Oceanographic and Atmospheric Administration, among potentially others, assisting to enhance the quality and quantity of

data available to, and, in the case of electricity generators, provided by, the private sector, which can perform the specific forecasting services

- FERC should continue its efforts to ensure adequate meteorological, production and other data is provided to those transmission operators that utilize a central forecasting structure or that reasonable and appropriate incentives exist for generation scheduling entities to provide accurate forecasts in those regions that may rely on decentralized forecasting.
- Those Federal agencies responsible for developing numerical weather prediction models should tune their efforts to focus on relevant weather patterns for areas with concentrations of renewable resources.

Brief Description of the California ISO

The California ISO is a non-profit, public benefit corporation regulated as a public utility by the Federal Regulatory Energy Commission. As an independent system operator (ISO), the California ISO impartially manages the flow of electricity across 25,398 circuit miles of high-voltage transmission lines that make up the bulk of California's power grid. While utilities still own the transmission lines, the California ISO acts as a "traffic controller," offering open access and maximizing the use of the transmission system and administering wholesale power markets. One of the most important responsibilities of any ISO is to maintain reliable bulk power system operations in real-time. We do this by, among other things, providing reliability services including outage coordination, generation scheduling, voltage management, ancillary services, and load forecasting. As noted, the California ISO, like other ISOs, coordinates competitive wholesale power markets in which energy providers submit supply offers and purchasers submit demand bids. A market clearing price balances supply and demand, selecting least-cost supplies until demand is met.

The Impact of Increasing Variable Energy Resources on Grid and Market Operations and the Benefits of Improved Forecasting

Power system operation requires the constant balancing of supply and demand to comply with mandatory reliability standards. Accordingly, all power systems historically have been designed to manage a certain degree of demand volatility and supply unpredictability. The inherent variability and uncertainty of wind and solar generator output present challenges to grid operators by increasing the system's aggregate volatility. Variability refers to the fact that, in the absence of supplemental storage capability, the output from wind and solar resources changes according to fluctuations in its primary fuel source. Uncertainty refers to the greater unpredictability in the magnitude and timing of the production variations in comparison to more traditional generator technologies. In short, the central issue operators confront with additional renewable resources is ensuring there are sufficient other resources available for timely commitment that have the ability to be maneuvered up or down fast enough to compensate for the expected and actual changes in output from variable renewable resources.

How a particular power system manages the increase in volatility due to renewable resources will depend on a myriad of factors, including the quantity of installed renewable capacity, the technological and geographic diversity of the renewable capacity, and the flexibility attributes of other available resources to call upon to alter their output. Despite potential differences, virtually all regions with an independent system operator administer a day-ahead market for energy and ancillary services and a reliability commitment process to ensure sufficient resources are available the next day to meet anticipated demand and satisfy other reliability criteria. Since all power systems are highly dynamic from moment to moment, the day-ahead system set-up will necessarily require refinement as the operating time becomes closer. This refinement is accomplished, as a general matter, through the procurement of "regulation" ancillary services, short-term supply commitment and real-time market redispatch of energy every five minutes from committed resources through sophisticated optimization software.[1] Thus, added variability and uncertainty from renewable resources generally results in:

- Less efficient unit commitment both in the day-ahead and real-time periods

[1] Regulation is generating capacity under automatic generation control that is dispatched on a four-second basis to continuously balance instantaneous deviations between supply and demand that occur within the five-minute periods between each economic dispatch of energy through the ISO's real-time market software applications. The market dispatch of energy is often referred to as "load-following." It is the dispatch of energy in the real-time market to address longer-term imbalances that are not addressed by regulation.

- Unanticipated and higher system ramps in the upwards and downwards direction
- Increased load/renewable resource following requirements
- Increased regulation requirements
- Increased frequency and magnitude of minimum generation or over-generation events.

Each of these impacts will likely impose costs on the system. Inaccurate unit commitment triggers additional costs because either an underestimate of the renewable output results in the unnecessary commitment of alternative resources or an overestimate of the renewable output requires the commitment of a faster starting, often less efficient, unit closer to real time. The increase in ramping and load following capabilities requires the system operator to have capacity available to convert the capacity to energy as needed to maintain the balance between supply and load. This may lead to the commitment or reservation of less efficient units than would otherwise be required to ensure the balance of more predictable and stable net load. In addition, load-following may require the dispatched resources to move from their most efficient operating point to a less efficient operating point.

Reliability problems can also occur when an erroneous forecast either underestimates or overestimates the amount of load-following or regulation service that must be available. For example, in the case of an underestimate, if the system operator is required to commit additional capacity at minimum load to be ready to make up for a shortfall in supply due to an inaccurate prediction of expected renewable output, that commitment will increase the possibility of there being too much generation on the system during low load periods, when wind power tends to be produced at its highest level. The operational and market consequences of over-generation include, but are not limited to, acceleration in system frequency, violation of control performance standards established by NERC, and an increase in excess energy flows to neighboring balancing authority areas as inadvertent energy, which can cause control performance problems for the receiving balancing authority areas. In the case of an overestimate, insufficient load-following capacity can result in a need to convert resources reserved for contingencies to energy in order to satisfy load requirements or, at worst, an inability to serve load.

Accurate forecasting will mitigate many of these potential inefficiencies of increased reliance on renewable resources. Better wind power forecasts in the day-ahead unit commitment process minimize the potential to over- or under-commit other generation resources to meet forecast load when renewable generation, which is generally not required to offer into the day-ahead market, shows up in the real-time. The real-time forecasts are, or will be, used to update short-term unit commitment decisions to ensure sufficient maneuverability or ramping capability exists to manage changes in renewable output as well as part of the real-time security-constrained economic dispatch program to ensure the most efficient resources are moved to provide the necessary system balancing.

There have been several studies that I am aware of, but there are probably others that I am not aware of, that have attempted to quantify the benefits of more accurate forecasts. Links to a few studies are provided. An example of one effort was conducted by Richard Piwko of GE Energy. Using a production simulation program for the Texas system, GE Energy evaluated three levels of wind energy—5,000 MW, 10,000 MW and 15,000 MW—and found there to be an annual savings of $20 million, $180 million and $510 million, respectively, from moving from no forecast to a state of the art forecast. A similar result was reported as part of the Western Wind and Solar Integration Study prepared by GE Energy for the National Renewable Energy Laboratory.[2]

The California ISO is conducting, but has not yet completed, its own quantification of the financial impact of improved forecasting on its system. However it has completed the first part of its analysis, which focused on the potential reduction in regulation and load following needs. The results are as follows:

---

[2] "Western Wind and Solar Integration Study" (May 2010) at *http://www.uwig.org/wwsis_final_report.pdf*.

Table 1 – Reduction in Requirements for 33% RPS Case between Current Forecast Errors and Improved Forecast Errors*

	Spring			Summer			Fall			Winter		
	2006	2012	2020	2006	2012	2020	2006	2012	2020	2006	2012	2020
Maximum Regulation Up Requirement (MW)	277	502	1,150	278	455	1,156	275	428	1,323	274	474	1,310
			1,135			1,144			1,308			1,286
Maximum Regulation Down Requirement (MW)	-382	-569	-1,112	-434	-763	-1,057	-440	-515	-1,278	-353	-442	-1,099
			-1,097			-1,034			-1,264			-1,076
Maximum Load Following Up Requirement (MW)	2,292	3,207	6,797	3,140	3,737	7,015	2,680	3,326	6,341	2,624	3,063	6,457
			4,423			4,841			4,565			4,880
Maximum Load Following Down Requirement (MW)	-2,246	-3,275	-6,793	-3,365	-3,962	-6,548	-2,509	-3,247	-7,303	-2,424	-3,094	-6,812
			-5,283			-5,235			-5,579			-5,176

*Improved forecasts are approximately 50% reduction from current levels

Consequently, while I cannot provide an estimate of the savings to the California market from improved forecasting accuracy, it is likely to be material based on the reduction in services that otherwise must be acquired by the California ISO to manage increased renewable resources. The California ISO would be happy to submit the results of its ongoing study efforts as they become available.

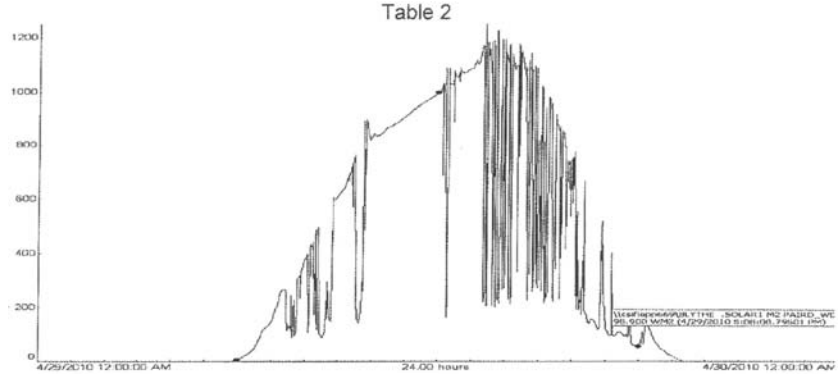
Transmission System Operators Need the Focus of Forecasting Science to Shift to Prediction of Significant "Ramp Events"

Until recently, renewable power production forecasting focused mainly on predicting the average power production for a series of upcoming time intervals. This focus reflects the need of market participants to minimize the potential economic impacts of energy imbalances over the corresponding time period. The quality of these forecasts is usually measured with metrics such as mean absolute error (MAE) or root mean square error (RMSE). Currently, this is the type of forecast produced by private forecasting service AWS Truepower, as the California ISO's centralized forecast provider, for use in California ISO market applications. For this type of forecast, the California ISO is observing an aggregate day ahead forecast error of less than 15%, calculated as the root mean square error (RMSE). This level of forecast error represents a substantial improvement over past California ISO experience with day-ahead forecasts. The aggregate hour-ahead forecast errors was reduced to less than 10% RMSE, which represents a 20% improvement in forecast accuracy over the CAISO's prior hour ahead forecast methodology. This forecast improvement was based on changes to the algorithm used to manipulate NWS forecasts, not an improvement to the base NWS forecast.

As noted, these more deterministic forecasts were largely developed to meet the needs of market participants, not transmission system operators. Transmission system operators are more sensitive to the need for a forecast product that provides an advanced warning of situations with a high probability of a large change in wind or solar production over a relatively short period of time. Unexpected large wind or solar ramps can have a large impact on the transmission operators' ability to keep power systems within their operating range and avoid catastrophic events. Because small errors in forecasting the timing of a ramp event produce large power errors, approaches that focus only on minimizing power error over an hour are not appropriate for ramp forecasting.

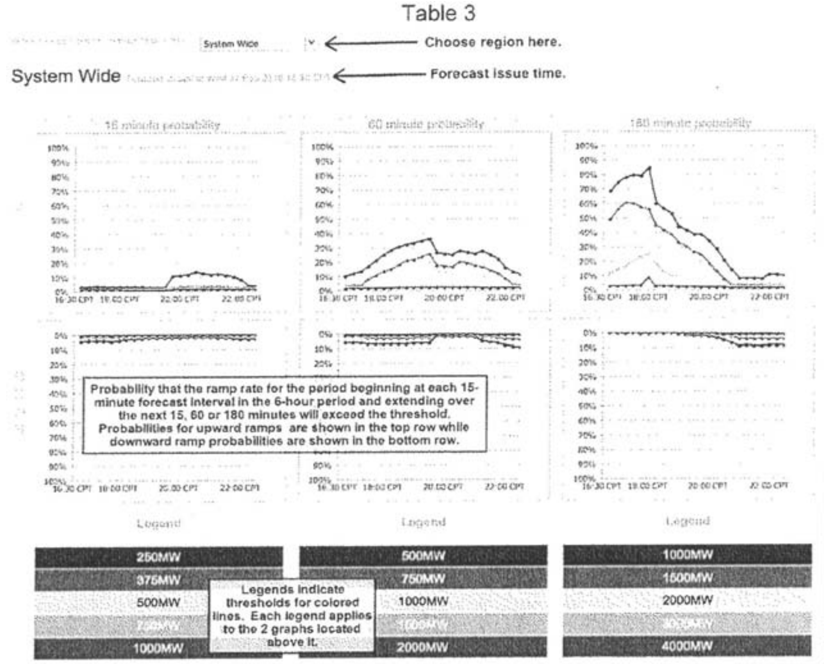
The severity of renewable resource ramping events is highly dependent on both the weather causing the ramp and geographic diversity of renewable resources within the ISO. For example, wind generators shut down when wind speeds exceed safe operating limits. As a result, a big storm front with high wind gusts can first result in a substantial spike in output, followed by the loss of hundreds of megawatts energy from wind generation over a short period of 10 to 20 minutes. Also, wind shear conditions at a wind facility may result in the units going from zero to full output within a few minutes when the wind shear condition changes and the wind hits the turbines instead of passing above the units. While solar power may not fluctuate as regularly as wind, most solar generation technologies will suffer significant variation in output due to transient cloud cover or other atmospheric conditions, such as ambient moisture or aerosols. The following provides a graphic example of the changes in solar production.

Table 2



Several ISOs, including California ISO, NYISO, and ERGOT, are pursuing the development of ramp prediction forecasts through relationships with private forecast service providers. The California ISO is working with AWS Truepower to implement a ramp forecast tool that includes both a probabilistic ramp rate forecast and a deterministic ramp event forecast with probabilistic confidence bounds. It is contemplated that when complete and tested, the probabilistic ramp rate forecast will be a primary driver of grid management decision-making, including incorporation into market systems. Given the nascent status of ramp forecasting, there is considerable opportunity for public/private collaboration in enhancing data inputs and methodologies, as I will discuss next. An example of a graphic representation of the proposed ramp tool for the California ISO is provided for your review in Table 4.

Table 3



This view gives a grid operator a graphical forecast page that displays a probabilistic ramp rate forecast. The ramp rate thresholds in MW, the time window over which the ramp rate is defined (15, 60 and 180 minutes in the above example) and the number and composition of the regional aggregates is customized for the operator.

Regardless of the Nature of the Forecast, Improvements Hinge on Increased Quality and Quantity of Weather Data

The California ISO obtains its forecasts through AWS Truepower and therefore is most familiar with its methods and needs. Other private forecasters may have a different set of methods, but all seem to agree on the need for high quality input data. Based on our knowledge of the process, the forecast service provider develops the forecast using

ensemble forecasts techniques that rely on input from regional-scale and global-scale numerical weather predictions models, statistical models and plant output models. For these prediction models to improve, more strategically located and high quality data inputs are necessary and for simplicity, I will focus on data from the renewable resources and the needs of numerical weather prediction models (NWP) that are largely within the purview of the NWS and NOAA.

Data from the renewable facility is critical for statistical and plant output models. ISOs generally require renewable resources to provide a range of real-time meteorological data, such as wind speed/direction, barometric pressure, humidity and ambient temperature as well as current MW output, along with physical data such as location and hub heights to forecast providers. FERC should be commended for facilitating the collection of such data and their continued investigation of data needs through its recent Notice of Inquiry.

In general, the California ISO has observed data issues in three areas and has taken remedial action in each with FERC's support. Forecasts rely on high quality data made available in a timely manner to the forecast providers for use within their models. In 2008 and 2009, the California ISO conducted a one year head to head forecast service provided competition. The central objective of the competition was to ensure the California ISO was receiving the most accurate forecast possible. During the competition there were several instances when data quality was an issue and forecast quality suffered as a result. Improving telemetry data and reliability from wind sites has been an ongoing focus of the California ISO to improve forecasting performance.

In early 2008, AWS Truepower provided California ISO with data detailing the relationship between poor data quality from renewable resources and the degradation of energy forecast accuracy. The study showed forecast errors ranged between 11% to over 15% MAE due to data availability and data quality issues. Based on the finding of the report, California ISO engineers investigated the root cause of poor quality data. The California ISO found three basic causes for errant data. Those causes are:

- Unreported Outages
- Communications Failure
- Equipment Failure

The CAISO recommended and has implemented the following:

- Outage/Availability Reporting—The Scheduling Coordinator is responsible and must report all data anomalies and outages to the CAISO. These anomalies include MW availability and all telemetry problems with the site.
- Independent Power Supply—electrical interruption of telemetry equipment causes errant data which must be eliminated and therefore an independent power supply should be mandatory. All telemetry equipment must have a backup power source that is independent of the primary power source for the station (e.g., station power, battery or solar panel). The backup power source must provide power until primary power is restored.
- Data Redundancy—Receiving anemometer data from multiple sites within the wind or solar park will add two important components to the meteorological data streams. Those components are redundancy of data from the site along with a more representative collection of data from the site to develop an energy forecast.

Barriers to obtaining high quality data (i.e. more sensors per wind project or area and higher sampling frequency) are mostly driven by economics and relate to installation and maintenance of sensor equipment, but FERC has done a commendable job of weighing the benefits to system operation against the potential hardship for smaller renewable projects.

NWS and NOAA provide the numerical weather prediction models that are currently used by forecast service providers, but tuned to providing temperature and rain forecasts for the entire United States. These models form the baseline inputs to the forecasters' wind and solar predictions. At the 2010 UWIG Wind Forecasting Workshop in Albuquerque, New Mexico, a representative from NOAA delivered a presentation outlining the need and a plan for NOAA to improve renewable energy forecasts. One of the most important points made was the need for "interaction between NOAA, DOE, NREL, other government, energy industry [and] other private sectors." The California ISO firmly believes NOAA should follow up on the promise and is willing to be an active participant with NOAA and other balancing authorities. In this regard, the California ISO understands that much of the improvement is likely to come from strategically located three dimensional atmospheric sensors to cover the 'boundary layer" or at or above wind turbine hub height, For California's Tehachapi wind area, initial guidance on observation targeting has been accomplished through work supported by the Department of Energy's Lawrence Livermore National Laboratory under the WindSENSE project. This work should come to completion. To the extent there is a sense that those areas utilizing the power in specific renewable regions should fund the infrastructure for better forecasting, the California ISO suggests that it may be appropriate for the FERC to establish mechanisms to require utilities to construct, and recover the costs of, any necessary observation equipment.

Thank you. That concludes my testimony.

BIOGRAPHY FOR GRANT ROSENBLUM

Grant is the Manager for the California ISO's renewable resource integration efforts. The position was created in August 2008 to oversee a multi-disciplinary team of engineers and economists who have been directed to ensure the California ISO can integrate increasing levels of variable renewable generation in a manner consistent with market efficiency and grid reliability. This encompasses evaluating electric system infrastructure needs and necessary modifications to California ISO markets and operating practices.

Prior to assuming the position of Manager, Renewables Integration, Grant spent four years as an attorney for the California ISO, addressing a broad range of regulatory matters, including generator interconnection, transmission planning and market reform. Grant came to the California ISO from the Electricity Oversight Board, where he represented the State in litigation before FERC on the enforceability of long-term power purchase agreements entered into during the height of the 2000–2001 energy crisis. Grant also has eight years of experience in private practice in the area of environmental and commercial litigation. He received his JD from University of California, Hastings College of the Law, and his undergraduate degree from Pomona College.

Mr. TONKO. Thank you, Mr. Rosenblum.

Dr. Michaels, please.

STATEMENTS OF ROBERT MICHAELS, SENIOR FELLOW, INSTITUTE FOR ENERGY RESEARCH

Dr. MICHAELS. Thank you. I am honored to be here.

Given the recent record of economists and forecasting about everything, one might wonder why I am here. The answer is fairly straightforward. This is a committee on both science and technology. Science is about forecasting atmospheric motions, but the technology that matters for us is the technology of wind power, and they are interrelated in economic terms.

Renewables now contribute approximately three and a half percent of the Nation's electrical energy. A few years ago, they were doing about two percent. Essentially, all of that growth in renewables has been due to the growth of wind power. If you are committed to renewables given the technologies that are on the horizon, you are committed to wind. Wind is going to be the dominant renewable probably for the foreseeable future. If so, then what this Committee must do as it evaluates the funding of this improved forecasting is to ask itself what is going to be the future role of wind. Is it going to be worth the public investment, given wind's track record and given wind's likely prospects? Wind now is a very special source of energy—essentially the only renewable that is really easy to build now—but it still lives on subsidies. It lives on renewable energy mandates. It lives on the production tax credits. We know that. We have got lots of statistical records of that. There may be rationales for some of these subsidies. In my testimony, I say I don't find them very convincing, but that is another story.

The question that matters to us is that we are accumulating evidence on the viability of wind and we are accumulating a lot of practical questions about whether we should rethink its future or not. We know, for instance, that now states even with renewable mandates are having trouble building transmission, having trouble siting such plants. We are understanding now that the way they interact with the rest of the electrical system has very interesting consequences, sometimes adverse consequences for carbon emissions and emissions of criteria pollutants. We have a lot of evidence to still accumulate and a lot to learn. The practical questions are, then, how are you going to interface this? You must be in the process of making your decision today. You are implicitly saying something about the future desirability and the future evolution of wind power in this country. You have a tremendous number of developments taking place that are changing everything we know about the energy picture. You now have a revolution in the natural gas industry, which may well guarantee us clean, economical energy independence with it. If that is so, then again, we may rethink wind. There are questions mounting about climate policy and what exactly will happen if climate policy changes in either direction.

So we have a set of questions which are really the kinds of questions economists ask. They are questions that, off a word from elementary economics, they are "marginal questions." What is going to be the value of what you do? What will be the value of funding this work, supporting this work, given the current state of the wind industry and given its many possible futures? And when you make a decision here, you are implicitly saying something about what you believe the future of the wind industry is going to be. The question would be, what if all wind construction stopped today? What would you be doing? Would this be funding that was worth engaging in, or wouldn't it be? That is the question that this Committee must decide; I can't.

What you are doing is a simultaneous determination of how to handle the forecasting models and support them and the future role of wind. That role is going to need, I think, to be rethought in light of the accumulating evidence. But in any case, it's critical that we think about it in connection with what is before this Committee today. Thank you.

[The prepared statement of Dr. Michaels follows:]

PREPARED STATEMENT OF ROBERT MICHAELS

I. Introduction

My name is Robert J. Michaels. I am Professor of Economics at California State University, Fullerton and an independent consultant. I hold an A.B. Degree from the University of Chicago and a Ph.D. from the University of California, Los Angeles, both in economics. My past employment as an economist includes the Institute for Defense Analysis and affiliations with consulting firms. I am also Senior Fellow at the Institute for Energy Research and Adjunct Scholar at the Cato Institute. I attach a biography to this testimony. The findings and opinions I am presenting today are entirely mine, and they are not the official views of any of my professional or consulting affiliations.

For over 20 years I have performed research on regulation and the emergence of markets in the electricity and gas industries. My findings have been presented in peer-reviewed journals, law reviews, and industry publications and meetings. I am Co-Editor of the peer-reviewed journal *Contemporary Economic Policy*, an official publication of Western Economic Association International with a circulation of 2,500. I am also author of *Transactions and Strategies: Economics for Management* (Cengage Learning, 2009), an applied text for MBA students and advanced undergraduates. My consulting clients have included state utility regulators, electric utilities, independent power producers and marketers, natural gas producers, large energy consumers, public interest groups and governments. My services have at times entailed expert testimony, which I have presented at the Federal Energy Regulatory Commission, public utility commissions in California, Illinois, Mississippi and Vermont, the California Energy Commission, and in two previous appearances before other House committees.

II. Background on renewables

A. Purpose of testimony

The Committee today explores questions pertinent to the fuller integration of renewable generation into regional power grids. The achievement of important energy and environmental policy goals may require additional research within this Committee's jurisdiction to support new technologies and operating practices that may be necessary if grids are to operate efficiently and reliably. I intend that my testimony provide the Committee with guidance on factors that it should consider when evaluating the research that others are presenting today, and its relevance for future policy. The most important such research is contained in a study completed last month by General Electric Energy for the National Renewable Energy Laboratory (NREL).[1] Its authors claim that new technologies and changed operating practices could enable some regions (in particular, the area covered by WestConnect, an association of transmission-owning utilities that cover parts of seven western states) to obtain as much as 35 percent of their power from wind (30 percent) and solar (5 percent) generators. Reliability considerations currently put considerably lower limits on the power that grid operators can safely obtain from such sources. Most of the witnesses on today's panel are probably strong supporters of increasing renewable resources and integrating them more strongly into existing grids. I hope that my testimony will bring some balance to the discussion, and perhaps strike a cautionary note. At the outset I wish to make clear that I do not object in principle to Federal support of research in this or other areas. There may well be cases in which such support is economically warranted. My testimony will instead put the recent rush toward renewables into perspective, and conclude that recent experience in the U.S. and elsewhere requires rethinking their role in our electrical future.

B. Generation: history and choices

The desirability of integrating wind and solar resources on a large scale depends on both the costs of new infrastructure and the costs of the resources themselves. Those of renewables continue to disappoint the long-held expectations of their advocates. Instead of passing market tests that would indicate their worth, wind and solar continue to live on subsidies and state-level requirements that require utilities to procure increasing percentages of their power from renewables. In 2009, 44.6 percent of the nation's power was generated from coal, 23.2 percent from natural gas, 20.0 percent from nuclear, and 3.6 percent from renewables, generally defined as including biomass and waste conversion, geothermal, wind and solar sources.[2] Until very recently, their percentage contribution to the nation's power supply was even less important. In 1990 they produced 2.0 percent of it, and 2.2 percent in 2005, before beginning their recent growth to 3.6 percent in 2009. The reasons for the change are important. In 1990, 95 percent of renewable power came from biomass, waste burning and geothermal sources. These were viable power sources because, then as now, their unsubsidized costs made them competitive against fossil fuel generation in some markets. These resources had the added virtue of dispatchability—they could be run when they could lower the system's costs and left idle when they could not. Their fuel could be stored in anticipation of when their power would be most useful.

[1] GE Energy, *Western Wind and Solar Integration Study*, May 2010.

[2] All figures are from various documents of the U.S. Department of Energy's Energy Information Administration. A set of graphics and data are available upon request from the author.

For the next 20 years, biomass, waste and geothermal power remained viable but their outputs did not grow. In 1992 they produced 70.5 gigawatt hours (gwh or million kilowatt-hours) of power, and in 2009 their output was about the same, 69.5 gwh. The growth of solar power has been surprisingly modest. In 1993 it produced 0.45 gwh, which by 2009 had grown to 0.81 gwh (below the 2008 figure). This was 0.6 percent of all renewable power in 2009, and one-fiftieth of one percent of all U.S. power. The growth in renewables since 2000 has been almost entirely in wind, to the point that by 2009 it accounted for over half of all renewable generation.

Intermittent power is expensive power, and official expectations are that it will remain so. The accompanying figure shows the U.S. Energy Information Administration's projections of the levelized cost per megawatt-hour output of the most common electrical technologies. They apply to plants expected on-line in 2016, and are expressed in 2008 dollars. The four most costly sources are, by rank, solar photovoltaic ($396/mwh), solar thermal ($256), offshore wind ($191) and onshore wind ($149). Compared with a conventional (not an advanced) combined-cycle gas plant ($83/mwh) the cheapest intermittent source is 80 percent more expensive. Nor are intermittent resources necessarily good investments if a carbon tax or cap-and-trade system is on the horizon. Adding carbon capture and sequestration (CCS) technology (whose cost is still quite uncertain but is likely to fall) to a combined cycle gas plant still leaves it 32 percent less expensive per mwh than the cheapest wind plant. At prices for carbon predicted by many models, the wind plant still loses. Note also that biomass and geothermal are expected to remain competitive with gas on a cost basis.

Subsidies explain investment in wind generation. Although the 20 percent production tax credit on wind energy is now (probably) permanent, earlier in this decade it was on-again off-again. In 2000 (off) 67 MW of wind capacity were built, rising to 1,697 MW in 2001 (on). Between 2002 (off) and 2003 (on) the figures are 446 and 1,687 MW; and between 2004 (off) and 2005 (on) they are 389 and 2431 MW.[3] Many other factors influence investment, but total investment in years with the tax credit was 544 percent greater than in years without it. There is no evidence that the costs of wind turbines have fallen sufficiently since 2005 to invalidate this relationship. The American Wind Energy Association (AWEA) is aware of the importance of subsidies. As recently as last week (June 8) it explained a recent upswing in installations of small wind turbines as due to the 2009 American Recovery and Reinvestment Act (ARRA), which expanded the Federal Investment Tax Credit (ITC) for small wind turbines to 30 percent.

> "The ITC was perhaps the most important factor in last year's growth . . . [it] helped consumers purchase small wind systems during a recession when other financing mechanisms were hardest to obtain. The enactment of the ITC [was] the industry's top priority . . ."[4]

The issue of subsidies is a sensitive one, with problems that hinge on what a subsidy is, etc. About the most comprehensive study of U.S. energy subsidies is a 2007 document by the U.S. Energy Information Administration. The document is unique in that its authors took the pains to examine how they applied to fuel actually used to produce electricity, which is the issue before this Committee. Thus a subsidy to the oil and gas industry, for example from some particular tax rule, is only relevant to the extent that it affects the oil and gas used to generate electricity. Specializing to fuels used in electricity, the attached graph presents the basics. Per megawatt-hour of power it produces, wind receives a subsidy of $23.37 and solar receives a dollar more. Wind gets 53 times more funds per mwh than coal, and 93 times more than gas and oil.

Note that these facts do not by themselves say much about the desirability of these transfers. Since renewables are a relatively newer industry than fuels, there might be an economic rationale for subsidies that fund basic research in them that if successful could render them truly competitive. A subsidy that simply discounted prices to purchasers of renewables or reduces their taxes would be harder to rationalize. According to the Energy Information Administration, "tax expenditures" (i.e. reductions) to the coal industry (including those for coal not used to produce power) were $264 million in 2007, while R&D subsidies (possibly necessary if we are to

---

[3] U.S. Department of Energy, Energy Efficiency and Renewable Energy (DOE/EERE), GPRA07 Wind Technologies Program Documentation (2007), App. E at E–6. *http://www1.eere.energy.gov/ba/pdfs/39684_app_E.pdf*

[4] AWEA Small Wind Turbine Global Market Study, Year Ending 2009, 4. *http://www.awea.org/smallwind/pdf/2010_AWEA_Small_Wind_Turbine_Global_Market_Study.pdf*

have "clean coal") were $522 million.[5] Tax expenditures for renewables were $724 million, primarily the production tax credit for wind, while the R&D that might make them truly competitive was only $108 million.

III. U.S. renewables, present and future

As the U.S. and other nations accumulate experience with wind generation, its virtues and its shortcomings are becoming evident. Small amounts of wind power are easily integrated into existing grids because a sudden calm is operationally no different from a small outage. Wind, however, blows the most when it is not needed, and increasing grid sizes and wind resource concentrations will not completely resolve the basic problems of intermittency. In 2006, California had 2,323 MW of wind capacity and was operating under record loads in early summer. Wind's average on-peak contribution (scattered over the diverse northern and southern climates) was 256 MW.[6] For system planning purposes, ERCOT, the Texas grid operator, currently sets a wind turbine's "effective capacity" at 8.7 percent of its nominal amount.[7] The costs of more wind will include that of transmission that links it with consuming areas, which will usually operate at only a fraction of its capacity. When it is fully loaded, however, however, markets supplied by wind behave oddly. Texas' wind capacity is mostly far from load centers, and its power is priced by market bidding. As they compete for access to the constrained transmission lines, prices are bid to lower levels. In Texas, however, those prices are quite frequently becoming negative, 14 percent of all hours in 2008.[8] This growing problem is indicative of both a need for transmission and strong evidence on the effects of subsidies. Wind generators will pay to put power into the grid because subsidies are high enough that they retain a small profit after making that payment.

Some might view negative prices in Texas as curiosities, or as an embarrassing consequence of an otherwise desirable subsidy system. Newer research has found that increasing the scale of wind operations sometimes produces a strikingly perverse outcome. Gas marketer Bentek Energy examined a seeming paradox in Texas and Colorado: Large increases in wind power production were responsible for decreases in the output of coal-burning generators, but emission of pollutants from those plants had had actually increased, and CO_2 emissions were unchanged.[9] Operating data showed how wind's variability meant that coal units had to make many quick output adjustments, and that those adjustments were responsible for the added pollution. Bentek's controversial conclusion was that the total load in the area could have been produced with lower total emissions had the wind units never existed.

Another possible problem for wind's expansion stems from the country's dual regulatory system for power. State regulators have the lion's share of authority over permits for and siting of generation and transmission that move power between states. An increasing number of them are unwilling or politically unable to ensure that construction of renewable generation and transmission will take place. Local intervenors who formerly blocked the construction of conventional generation and transmission are becoming adept at doing the same for renewables. Utilities in a growing number of states are becoming unable to comply with their own "renewable portfolio standard" (RPS) requirements. Once lauded for its progressive policies, California now exemplifies how to obstruct them. A 2002 law required its large utilities to obtain 20 percent of their energy from renewables by 2010. All of its utilities are currently out of compliance, and now expect to meet the standard by 2014 or later. In 2008, California got a smaller percentage of its power from renewables than it did in 2001. Other states are encountering similar problems, and these will become more stringent as compliance levels increase.[10] Through all of the questions

---

[5] Federal Financial Interventions and Subsidies in Energy Markets 2007 (2008), 105. *http://www.eia.doe.gov/oiaf/servicerpt/subsidy2/pdf/subsidy08.pdf*

[6] Robert J. Michaels, "Run of the Mill, or Maybe Not," *New Power Executive*, July 28, 2006, 2. The calculation used unpublished operating data from the California Independent System Operator.

[7] Lawrence Risman and Joan Ward, "Winds of Change Freshen Resource Adequacy," *Public Utilities Fortnightly*, May 2007, 14–18 at 18; and ERCOT, *Transmission Issues Associated with Renewable Energy in Texas, Informal White Paper for the Texas Legislature*, Mar. 28, 2005 at 7. *http://www.ercot.com/news/presentations/2006/RenewablesTransmissi.pdf*

[8] Peter Hartley, Some Preliminary Comments on Wind Generation in ERCOT, presentation graphics, Rice University, n.d. *http://www.rice.edu/energy/research/carbonsolutions/Hartley%20Presentation%20Aug09Workshop-SECURE.pdf*

[9] Bentek Energy, How Less Became More: Wind, Power and Unintended Consequences in the Colorado Energy Market (April 10, 2010).

[10] Massachusetts utilities have largely complied with their state's RPS by obtaining generation credits from biomass plants in Maine (which has no RPS), and difficulties in siting the Cape

about renewable investment, the U.S. Department of Energy's National Energy Modeling System has demonstrated that for at least the next several decades the preponderance of new generation will continue to be in fossil-fuel plants.[11]

IV. Operations and economics

A. Operational realities

Any possible increase in U.S. commitment to wind power should be viewed in light of recent European experience, and it should be viewed in both economic and political terms. Denmark's vaunted ability to obtain 20 percent of its electricity from wind helps make its power costs the highest in Europe, and they can use only about half of that output. The country can maintain its mix of power sources only thanks to geography. It owns a small part of a large, centrally dispatched grid that covers Scandinavia, whose power sources are mostly hydroelectric and nuclear, and whose systems always have capacity to handle imports from or exports to Denmark, whose wind facilities are a minor part of the regional total. Denmark is relevant here not only for its economics, but for the underlying politics. The WestConnect region is only a fraction of a considerably larger grid that covers the western U.S. The bulk of the nation's hydroelectric capacity is in the Pacific Northwest, and is equivalent to approximately 22 nuclear powerplants. The ability to redirect some of this power out of that region appears to be of great importance if NREL's plan is to be feasible. As practical politics, the Pacific Northwest has long fought tenaciously to keep as much cheap hydropower as possible for its own use, and governments in that region appear unlikely to cede control over it to facilitate NREL's scenario.

B. Economic realities

America's economic performance over the past two years gives little encouragement to those who believe that government spending can generate substantial and sustained increases in employment. But even if one believes in the efficacy of a stimulus package renewables are probably a poor choice for the creation of job slots. Most jobs in that industry are in the production and construction of durable equipment and installations, with relatively few long-term operating positions. Wind advocates and critics have produced many studies on the stimulus approach, but there is a fundamental flaw in one of the most widely-used models that favor job creation. As an example of a critical study, a recent one from Spain purports to show that governmental support for renewables actually destroys jobs rather than creating them, because renewables have surprisingly high capital requirements per worker. If so, investing elsewhere will create more employment slots, although not necessarily better-paying ones.[12] For uncertain reasons, NREL subsequently took the initiative in critiquing this study, documenting how its "JEDI" computer model showed that that pro-renewables policies in fact created new employment.[13] Calzada's study is open to criticism, but ironically NREL's model cannot possibly be the tool to make those critiques. NREL admits that JEDI is constructed in a way that renders job destruction mathematically impossible, i.e. it preordains a pro-renewables finding of job creation regardless of the data being analyzed.

V. Summary and Conclusions

The value of funding the changes that the Committee is considering depends critically on an assumption that requires far more thorough examination than it has thus far received—that wind power will be an economic choice for the nation's electrical future. Almost all of the evidence points in the opposite direction. There are two types of renewable resources: ones like biomass, waste and geothermal generators that have long occupied a small niche in markets where they have long stood

---

Wind project have become national news. Many other states have maintained compliance in the same way. Maryland's utilities have done so with small hydro projects in Pennsylvania, but the start of that state's RPS will eliminate this alternative. Arizona is 25 percent compliant with its RPS, Nevada 35 percent, and similar records are appearing elsewhere.

[11] See any recent volume of the Energy Information Administration's Annual Energy Outlook. I and others have criticized the model elsewhere, but the text is a consensus finding that does not depend on details of its assumptions.

[12] Gabriel Calzada Alvarez, Study of the Effects on Employment of Public Aid to Renewable Energy Sources, Universidad Rey Juan Carlos, March 2009. Calzada's non-peer reviewed study concluded that since 2000 each "green job" created in Spain cost €571,000, with subsidies of over €1 million for each wind industry job.

[13] Eric Lantz and Suzanne Tegen, NREL Response to the Report *Study of the Effects on Employment of Public Aid to Renewable Energy Sources* from King Juan Carlos University (Spain), White Paper NREL/TP-6A2-46261 (Aug. 2009).

on their own. The other resources, primarily wind, have yet to pass market tests and instead thrive because of subsidies and regulatory requirements that utilities purchase their output. Official data show clearly that the costs of electricity from wind and solar units are well above those of every fossil fuel, and are expected to remain high. We have seen wind's sensitivity to subsidies in the pattern of investments with and without its production tax credit, and in the statements of its trade association about the importance of those subsidies. Further, claims that all energy sources are subsidized can be quite misleading. Looking at fuel actually consumed in power production, a megawatt-hour of wind power receives 90 times the subsidy of one produced from natural gas. Most of wind's subsidy takes the form of tax breaks for producers rather than direct allocations of funds for research.

Other problems are still matters for research, but as they arise they suggest that government think twice before it continues to rush electricity into heavier dependence on wind power. Wind's useful contributions to capacity are weather dependent, and wind often produces the least when it is the most needed. Integrating wind into regional markets will require substantial transmission investments, and preliminary results of work on wind power's actual impact on fossil fuel emissions are not encouraging. Regional political factors and electrical geography may further render some planned operational changes difficult or impossible to implement. Finally, as an engine of "job creation," wind power is probably a poor choice.

It is always hazardous for a non-expert (or for that matter an expert) to predict policy trends. Unfortunately, this Committee will have little choice but to do so when considering the GE/NREL study. Public opinion is in flux, but absent national carbon control and/or renewables requirements, the value of implementing its recommendations will fall precipitously. Markets are also changing in ways that bring up further questions. Over the past few years wind power has grown strongly, largely fueled by subsidies and regulatory requirements. Over that same period a revolution in fossil fuels has taken place, but without such subsidies or regulations. The technologies to access natural gas in shales, tight sands and coal seams have come of age. They can now reach hitherto unimagined volumes located all around the Nation at current prices, and with what most agree are minor environmental impacts. The nation's gas reserves are massively increasing, and the history of oil and other minerals strongly suggests that early estimates of reserves will turn out to have been far too low.[14] America can probably look forward to literally centuries of its own clean, safe, competitively produced, and truly secure fuel. Looking forward also means looking backward. Abundant gas means less need for power from coal and uranium, and from uneconomic renewables as well. Gas-fired generation is cost-effective, fuel-efficient, environmentally acceptable almost everywhere, and already an integral part of almost every utility's power supply. The future belongs to the efficient, and it is time to abandon the mistaken belief that efficiency and renewable are synonyms.

I thank the Committee for the opportunity to present these views, and welcome any questions or comments.

Biography for Robert Michaels

Robert J. Michaels is Professor of Economics at California State University, Fullerton and an independent consultant to the electricity and natural gas industries. He holds an A.B. from the University of Chicago and a Ph.D. from the University of California, Los Angeles, both in economics. His past positions include Staff Economist at the Institute for Defense Analyses and affiliate of various consulting firms. He is Senior advisor to the Institute for Energy Research and Adjunct Scholar at the Cato Institute.

His research on regulation and competition in electricity and gas has appeared in peer-reviewed journals, law reviews, and industry publications. He is also Co-Editor of the peer-reviewed journal Contemporary Economic Policy. He has advised state regulatory agencies, electric utilities, independent power producers and marketers, consumers and producers of natural gas, public interest groups, and governments on aspects of regulation and competition. He has provided expert testimony at, among other venues, the Federal Energy Regulatory Commission, the California Public Utilities Commission, the Illinois Commerce Commission, the Vermont Public Service Board, and in two prior appearances before committees of the U.S. House of Representatives.

[14] Proved U.S. gas reserves rose from 4.74 trillion cubic meters in 1999 to 6.93 million in 2008. *BP Statistical Review of World Energy*, June 2010, 22.

DISCUSSION

Chairman BAIRD. Thank you, Dr. Michaels. I thank all the witnesses. I am glad to be able to join the hearing at this point. I will recognize myself for five minutes.

Ms. WOOLSEY. Mr. Chairman, could I ask a favor of you?

Chairman BAIRD. Of course.

Ms. WOOLSEY. We are the Energy and Environment Subcommittee. Can we save some energy by turning down the air conditioning in this room? It is freezing.

Chairman BAIRD. If we can't, I will loan you my jacket, but I agree with you——

Ms. WOOLSEY. Well, no, I mean——

Chairman BAIRD. No, I agree with you entirely. Let us have staff try to work on it.

Mr. HALL. I am about to burn up.

Ms. WOOLSEY. That is your problem.

Chairman BAIRD. Wait. There is a solution. May I borrow your jacket? Then I will give it to her.

Ms. WOOLSEY. That is not the point. The point is, we are wasting energy.

Chairman BAIRD. I agree with you. Thanks, Ms. Woolsey. I appreciate your observation. I share that. We cool this place down to outrageous levels.

POTENTIAL ECONOMIC SAVINGS

So, in the Pacific Northwest, we have a great deal of potential hydropower. We are putting in an awful lot of wind, and one of the things that people at Bonneville, and I know some of you have testified about this issue in general, talked about was the challenge of integrating the grid, and I know that has been much of your testimony. If I missed it, forgive me. What are the estimated savings if we can more precisely tell a concentrated solar plant or a wind farm to expect this amount of wind, which should lead to X amount of output? In our region, that might mean you have to put less energy through the turbine or lower the—you know, or you could maybe use your baseline somewhere else, et cetera? How much do we save if we can make better predictions of this?

Dr. MOONEY. Mr. Chairman, we have recently completed a study called the Western Wind and Solar Integration study, the National Renewable Energy Laboratory, that is, and we showed as one example, and there are a number of studies that I cite in my written testimony that give specific quantifications of those savings, but, just as an example, in the Western Wind and Solar Integration Study, we compared for 27 percent wind and solar penetration in the 14-state western interconnection region. We compared operating that system with no forecasting compared to state-of-the-art forecasting, and then compared that to perfect forecasting. Going from no forecasting to state-of-the-art forecasting, there was a savings of approximately $5 billion annually, which is about 14 percent of the total operations cost. The savings going from state-of-the-art to perfect is somewhat incremental, an additional roughly ten percent savings, but still a significant sum of money of about $500 million.

Chairman BAIRD. That is a tremendous amount, and it would seem that it also allows your baseload to maybe be channeled into different other possible uses. Especially as you get smart grids up, and maybe certain industries with high demands, they would run their high-demand operations during periods of abundance on the renewable side to take advantage of excess baseload.

Any others wishing to comment on that? Mr. Rosenblum.

Mr. ROSENBLUM. Yes, I would. Thank you, Mr. Chairman. We are currently engaged in a 33 percent RPS analysis within the California ISO. The first part of our study has tried to quantify what the benefits would be for different portfolios of renewable resources, and part of the sensitivities that we ran were what happens if we were able to reduce the level of error that we are currently experiencing with wind. We extrapolated for solar to the experience in Germany, which has much more solar PV penetration than we do, and reduced those approximately in half. What we found was that, under those scenarios, we would essentially reduce the amount of capacity that we would need in a real-time environment by approximately 2,000 megawatts or more in the spring and summer months, and that equates to the commitment of multiple combined cycle turbines. So we think that we would see a significant—we haven't translated that to dollars, and we are doing so—but we think that will translate to significant operational and cost savings to consumers.

POTENTIAL BURDENS ON ENERGY RESOURCES AND TRANSMISSION

Chairman BAIRD. Now, this issue of more precise predicting, you know, I grew up in farm country, and I remember if it was time to bring in the hay, gosh, you would watch to the hour whether the rain forecast was coming, because if it was going to rain you couldn't bring in the hay, and if it was going to rain, we would work round the clock to get it in and get it into the barn before it got wet, if we could. So now we are applying the same kind of fairly precise microforecasting but to the energy sector.

Ms. Simler, in your discussion, you state in your written testimony that existing operational practices or market rules have the effect of imposing unnecessary costs or burdens on both variable energy resources and transmission. Can you elaborate on that a little bit?

Ms. SIMLER. I can try. We don't have any quantitative studies. We rely on studies that others have done. But the idea there is similar to what was—what you have heard so far. It is that, if we can have better forecasting that would allow better forecasting for better predictions, you would free up other resources to provide energy. You wouldn't have to have as many resources committed for reserves.

Chairman BAIRD. I appreciate that, and I may be drilling down too much, and we can get to it later if we want because I am almost out of time. But you mentioned specifically market rules. Are there market rules that particularly come to mind that may be somehow in conflict with the issues we are discussing here?

Ms. SIMLER. That is part of what the Notice of Inquiry was supposed to do was to explore what the market rules—if there are market rules, and if there are, then the Commission can take action to remedy them.

Chairman BAIRD. I see. So you are not saying you have an answer to that; you are trying to say this is a question we need to ask.

Ms. SIMLER. Right.

Chairman BAIRD. Okay. Good.

With that, I recognize my friend Mr. Hall.

ALLOCATING COSTS FOR RENEWABLES

Mr. HALL. Thank you. I may touch a little in your question, Mr. Chairman, from Dr. Michaels, but first I want to ask Ms. Simler: your testimony noted the need for baseload electricity suppliers to back up renewables when the wind doesn't blow or the sun doesn't shine or you don't have some of the benefits that you would expect and anticipate, and by the way, I read the other day where some of the women out in west Texas were objecting to T. Boone Pickens' towers because it was blowing their hair. I don't know how serious that is, but something happened to it. Some of them think it is cold when the weather and temperature is normal, you know. I am picking a fight I can't possibly win.

But, obviously, the unpredictable nature of weather presents some kind of a burden and adds cost to the baseload supplier support, and these costs are going to increase as we add more renewables to the grid. I guess my question is, how significant are these costs? I think you have touched on it, and will FERC make that determination as to who ought to pay for them and could you give us some kind of an idea as to the responses to your Notice of Inquiry about this issue?

Ms. SIMLER. Yes. To the extent that variable resources impose additional costs on the grid due to having to have other generations standing ready to provide reserves, and, as I said, that generation standing ready to provide reserves can be reduced with better forecasting. But to the extent that that occurs, customers will have to pay a portion, a share of that. At the end of the day, customers pay. And the Federal Energy Regulatory Commission, to the extent that those are part of the wholesale rates, would decide which customers pay.

Mr. HALL. Well, let me ask Dr. Michaels, you referenced DOE electricity cost data in your testimony and noted that renewables are significantly more expensive than conventional sources on a levelized basis. I guess, Dr. Michaels, my question would be, do you expect this to change the future as more renewables are added to the electricity mix as a result maybe of subsidies or mandates or some other unknown or undetected aid? Are subsidies driving technology advances, and, in the current economic environment, how much is too much to provide in subsidies or renewables?

Dr. MICHAELS. I think the way to look at it is, if that is so, what is the form that the subsidies are taking? Because, for wind in particular, the subsidies are in the form of production tax credit, basically just a cash flow in the industry. It is not a subsidy for research. Wind is progressing. Wind has progressed, but at this point, we know that the rate of productivity increase is slowing down, and that is somewhat taking place all over the world. It is an international industry. There is still improvement, but it is a much slower improvement than before. Beyond that, I can't extrapolate.

Mr. HALL. Any others want to make any suggestion along that line?

WIND POWER IMPACTS ON POLLUTANTS AND EMISSIONS

I will ask Dr. Michaels. You note in your testimony that in Texas and Colorado, it has been found that large increases in wind power production resulted in increases in pollutant emissions and unchanged CO_2 emissions because the baseload electricity required to support the wind power operations forced coal generators to make unusually quick adjustments that increased pollution. Has this problem been studied more in depth to determine its significance, if any, and its impact?

Dr. MICHAELS. At this point, this is the only study that is outstanding and it is a study that came as a fairly complete surprise to the entire industry. It may well be that Texas and Colorado have some degree of uniqueness, because they are more dependent on cycling coal units than many other parts of the country, so how it generalizes is not clear and whether its quantitative importance will be the same again we don't know. I am putting it forward as another question that you should think of, though, if you are intending to encourage the further development of wind.

Mr. HALL. I am just going to ask how much, or are such quick adjustments necessary?

Dr. MICHAELS. They have to—these are the people who are the experts in it but the basic answer is, its because wind is intermittent. For small problems, it is no different from the outage of an ordinary electrical generator.

Mr. HALL. I think my time is up. Thank you.

Chairman BAIRD. Thank you, Mr. Hall.

Ms. Woolsey.

ROLES FOR THE FEDERAL GOVERNMENT AND PRIVATE INDUSTRY

Ms. WOOLSEY. Thank you, Mr. Chairman.

Who would ever have anticipated that the NOAA Weather Service would become part of our daily news and entertainment cycle in the United States of America? I mean, I have a friend who would rather watch the weather station than any of the other television stations, and we also know that people follow storms like a sporting event. I mean, this is really something that we have accomplished through NOAA—knowing ahead of time what could be coming. Sometimes it doesn't come, but forecasting is really something. There is an economic benefit to the media for bringing viewers and readers because of NOAA's product, I mean, so what a service that is. But we want to improve on this. That is what we are talking about today. So we want to meet the President's goals, many of us, and we want to save the $5 billion a year—at least—that has been reported. So, I mean, why aren't we already doing this, and what do we really need to do? That is my question. I mean, each one of you has said we can, we must, you know, and we should. What will be the Federal Government's role? What will be private industry's role?

Dr. Storck, you talked on that, so let us hear from the others. You did get to that slightly, but I want to know what you think our role is and what private industry's role is. Do you have a thought on that, Ms. Simler?

Ms. SIMLER. I will let others speak to that.

Ms. WOOLSEY. Okay. Thank you.

Dr. MacDonald?

Dr. MACDONALD. Thank you. NOAA is always trying to improve its weather forecasts, and most people do recognize they have gotten a lot better, and I appreciate your comments about—I actually do have friends whose favorite channel is The Weather Channel. That is because I am in weather.

Ms. WOOLSEY. Well, they need to get a life.

Dr. MACDONALD. We are improving our forecasts. They partly improved because we understand the weather better and because, as computers get faster, our models get better. But there are some unusual things about renewables. For example, you really care about the winds, you know, fairly high above the ground, about 300 feet is where the power is. We used to kind of say partly cloudy, but partly cloudy is not good enough when you can have clouds sort of go over an entire city and change the amount of photovoltaic energy available. So what we want to do is improve our networks and improve our models really going specifically after those things needed for renewable energy. We need a way to do that. It is at a higher resolution and it is observing using things like we have—things like SODARs—that actually can measure the winds 100 meters above the ground. So we have some great ideas to go after it and we are going to keep working on it.

Ms. WOOLSEY. So, okay, you have the ideas. Do you have the technology and do you have the equipment, or are we depending on private industry to provide this?

Dr. MACDONALD. Well, I see us as depending on private industry for some of the new technology. I mentioned some of these new wind measuring tools. It is going to require, I think, some investments to improve our systems, but, in any case, we are going to be working on it because improved weather helps everything. It helps aviation. It helps renewable energy. But there are some specific things for renewable energy that we really do need.

WIND POWER

Ms. WOOLSEY. Dr. Michaels, you hate wind. Poor wind. But isn't wind just part of the solution? I mean, it is not the whole thing.

Dr. MICHAELS. The Nation is undergoing yet another energy transition of the same sort that it has made in the past from wood to coal to oil to electricity, and it may well be a transition that has a greater role for wind. I do not hate any particular source of energy, and I also do not hate efficiency. But it is important to think about what wind's role really is because some facts are coming to light, and its role in the system is, I think, in need of a little more rethinking. That is my major point.

MORE ON PRIVATE INDUSTRY

Ms. WOOLSEY. Dr. Storck, what do you think will be private industry's role in this? We just have 10 seconds.

Dr. STORCK. Private industry's role is fairly clear, as I see. Private industry relies on the forecasts that NOAA creates. We take those forecasts, forecasts of the weather, and we make them very specific and relevant to a wind farm. Regardless of how many computers and scientists NOAA employs, it can never get into the details of every particular wind farm in the United States. And, remember, we export our technologies globally, as well. So we need NOAA to produce better weather forecasts and we can take it from there.

Ms. WOOLSEY. Thank you, Mr. Chairman.

Chairman BAIRD. Thank you, Ms. Woolsey.

I wouldn't expect the panelists to be aware of this, but the gentleman now about to ask questions is probably the leading authority in the Congress on some of this because he is virtually off the grid, if not entirely off the grid, and has been doing renewable energy in his home walking the talk for many, many years. So with that, I am pleased to recognize Dr. Bartlett.

STORAGE AND THE LIMITED AVAILABILITY OF FOSSIL FUELS

Mr. BARTLETT. Thank you very much. You know, in thinking about these alternative energies, we need to think about them in a different context. The context in which we ordinarily consider them is the present context where about half of our electricity comes from coal, and if you are comparing these renewables with fossil fuels, they aren't going to look very good because the quantity and quality of energy in fossil fuels is just unsurpassed. Where else can you find that quantity and quality of energy?

The general statement is that we have 250 years of coal at current use rates. Be careful with that phrase "current use rates", because an increase of just two percent doubles in 35 years, gets four times bigger in 70 years, eight times bigger in 105 years, 16 times bigger in 140 years. I hope we will still be here as a country 140 years from now. The National Academy of Sciences says that we probably have 100 years of coal at current use rates, but even if we have the 250 years and you increase its use only two percent, and we will increase its use more than that as we have to turn to coal for gas and liquids, but even if you increase it only two percent, the 250 years now drops to 85 years. That is the power of compound interest, which Albert Einstein says was the most powerful force in the universe, and now if you take some of the energy from that coal to produce a gas or a liquid, now it shrinks to 50 years, and there is an inevitability that few people understand, and that is that you will share it with the world out of necessity because if we are getting oil from coal, then the Saudi oil goes to somebody else, so in reality, you have no choice but to share it with the world. What that means is that 50 years now shrinks to 12.5 years. So if you make two assumptions, one is that the use of coal will increase just two percent, and the other is, the inevitability that you will share it with the world, we have 12.5 years of coal left.

So the context in which we need to be thinking about these alternative energies is a world in which we do not have the abundance of fossil fuels that we have today. Then they start to look a whole lot different, don't they? But we have huge problems with the intermittent production of energy by wind and by sun, and so we need hugely increased focus today on storage, do we not? Because you can get all the energy that you need from solar, you can get all the energy you need from wind but, boy, is it sporadic. And we have grossly inadequate ways of storing it today. Where are we in this balance between looking at the renewables and looking at ways of storing the energy? Because don't you think that the utility of these renewables in the future will be largely dependent on our ability to quickly store and release the energy we get from them?

Dr. STORCK. Congressman Bartlett, can I first address that? I think one of the first things before we engage wholly in the idea of storage, which I do think is important, is we need to look at other market structure improvements such as larger geographic areas in which we transact energy because I think that may be a more a direct way to increase the flexibility of resources that we utilize to balance the variability——

Mr. BARTLETT. You really can't——

Dr. STORCK. —that you were talking about.

Mr. BARTLETT. —stretch this stuff too far, can you? Unlike oil, you put a gallon in here and a thousand miles away a gallon comes out. You put electrons in a wire at this end, and a thousand miles away nothing may come out as a result of line loss. Aren't there some limitations to equalizing, to normalizing the production if you just include the whole country?

Dr. STORCK. Well, I would say that is something we need to study, but one of the things that we have observed is that the broader the geographic area that you can use to balance, there probably are benefits and we need to look at transmission associated with that. You are correct.

Dr. MOONEY. Congressman Bartlett, I think you raise a very important point, and just as wind or any single technology is not the solution, in addition to forecasting there are many things that we can do to address the variability of wind and solar generating plants. Storage, I think, is certainly one, and will likely be a part of the solution. As was discussed here earlier, there are market structures that could be changed to make integration easier. There are operational techniques that can be implemented, for example, looking at wider geographic areas for integrating renewable generating technologies, and that is on top of potential efficiency and demand response technologies and techniques. So there is a whole portfolio if we look at this as an entire system that will help to address that variability.

Mr. BARTLETT. Thank you. I yield back.

Chairman BAIRD. Thank you, Dr. Bartlett.

Dr. Ehlers.

MORE ON THE NEED FOR RENEWABLES

Mr. EHLERS. Thank you, Mr. Chairman, and I apologize for the delay in being here. I have two committee meetings going on simultaneously.

On the storage issue, of course Michigan, my state, has more experience than most with the pump storage facility that consumers power put in, and which has worked remarkably well outside of killing a lot of fish initially, but they have managed to put up a net that is good enough to keep the fish from getting in and it has worked rather well. Every night the otherwise idle plants are sending electricity up there and pumping water, I think, about 200 feet up the hill into a lake and during the day let it flow down. The same turbines turn the other way and produce electricity. Unfortunately, that is a geographic scarcity to have a situation like that, but nevertheless, they have proved it works and so that can be a model, and I worry. Mr. Bartlett and I are much in the same vein on this issue. We very much support the renewable industry in whatever form it manages to survive. That is a very good direction to go, but that is only part of it. I really don't like that term "renewable" because it is not renewable. I mean, sunlight is always there, but it is not really renewable. Not much we can do about it.

But, at any rate, all those alternative forms of energy—which I think, is probably a better way of saying it—are essential for us. We have to use them, we have to develop them, we have to make them work well, and here, as in so many cases including automobiles, the biggest stumbling block is having a good method of storage, and particularly in homes. My fond dream is that eventually every home in America will have solar shingles at not much greater cost than ordinary shingles. That makes solar power very economically feasible. But again, where do you store it? Buying batteries can be expensive and erratic, but nevertheless, that appears to be the best thing at this point, and I would be delighted if someone can develop really good batteries or better methods of storage than we are used to having.

So that is not a question, Mr. Chairman. It is more an editorial, but I really appreciate what you are doing and what you are working on. It is absolutely essential, I think. As the spill in the gulf is pointing out, we have problems with every source of energy, and energy by its very nature creates some of its own problems because you need ways of containing it, preserving it, shipping it and so forth. So thank you for what you are doing, and I yield back at this point.

Chairman BAIRD. Thank you, Dr. Ehlers.

Mr. Rohrabacher.

POWER PLANT SITING

Mr. ROHRABACHER. Thank you very much, Mr. Chairman, and as a preface to what I am about to say is that of course again for the record state that I think that the global warming CO_2 theory is nonsense and those of us who have found ourselves in combat on this, quote, global warming issue realize that there is more to the energy argument and the energy issue than simply trying to say that we are not going to put more CO_2 in the air, which I might add as we all know, over the Earth's history there has been many times more CO_2 in the air at wonderful times in the world's history.

But beside that, back to energy, and that is, those of us who have that disagreement don't disagree that we need to be developing our energy resources to the maximum degree so that America can benefit both economically and in terms of our national security. With that, I have been very active in supporting various alternative energy sources rather than just oil and gas, and I happen to have bought on to the theory that we should be moving towards electrifying America, that we should be looking at electric energy as a source of transportation, et cetera.

With that said, I have also been dismayed that quite often those people who are supposedly dedicated for the global warming theory or whatever motivates them to producing clean electricity that in California at least they seem to be putting up roadblocks, and I think this is true in other places as well, to actually putting in place solar energy installations, and I have a bill, H.R. 964, which would facilitate the development and the building of solar installations in the desert, and what apparently we have now is 205 or at least over 200 applications at the Bureau of Land Management that have been sitting there for years for people who would like to build solar plants in the middle of the desert but can't get the Bureau of Land Management to give them a permit to build. Now, something is wrong there. Something is wrong with that equation and I would like to ask the panel, what is going on here? I mean, are we committed to it to the point that lizards and insects and their habitat is more important than developing the energy or can we say that yes, developing electric solar power in the desert is worth eliminating the habitat for a small number of insects and lizards, who can then scurry someplace else, I might add. So I would like to ask the panel that. What about siting of solar plants and other alternative plants, I might add?

Dr. MICHAELS. The issue of siting these plants is being very interesting in California for a lot more reasons than just that. Among other things, even if they get sited, nobody is going to be able to build transmission to them. The question——

Mr. ROHRABACHER. I will have to tell you that I am personally involved with several sitings that the transmission lines go right through and it is right there, so I would like to say that yes, that is true. We don't have any electric lines or any way to get it onto the grid in many of these but in many of them they do have access to the grid and access to transmission lines. Go ahead. Sorry.

Dr. MICHAELS. But if this is the case, this is the question that has always had to be looked at. We have only relatively recently in our history become aware that much of what we do does have consequences for the environment. The real question is always a rule of reason. How do you value the environmental amenities, the value of species biodiversity against the value of the power? Is there in fact an easier way to get it, a cheaper way to get it, a cleaner way to get it? Those are the questions about the relationship of markets and regulation. The question of how the solar units are getting built, how they are being financed, are they getting some sort of subsidies, tax breaks, questions like those. You have got to look at all those aspects of them. It may well be that these are intrinsically uneconomic and you wouldn't want them in the desert were it not for certain special treatment that they get.

Mr. ROSENBLUM. As a transmission planning entity, we do see that there is a definite chicken-and-the-egg problem in California.

Do we build the transmission and have them come to it, or do we wait for siting to take its course and then build the transmission out there? We are trying to be proactive, but also take into consideration the environmental limitations that are occurring. So it is a difficult process, as you point out.

Mr. ROHRABACHER. Would any of you be supportive of legislation that said on its very face building a solar plant is positive towards the environment and thus they should be—their grant process with BLM should be facilitated? Would anyone support that on the panel? Okay. Thank you.

Chairman BAIRD. Shall we let the record show that there was no——

Mr. ROHRABACHER. Show there was no great response to that question.

INFORMATION GATHERING AND SHARING

Chairman BAIRD. I don't know if we want a lengthy second round, but there is a topic that I don't think has been addressed and I just want to raise it with my colleagues' indulgence. It has to do with, Dr. Storck, your model is a private entity providing forecasting or predicting—I am not sure of the proper term—information for the purpose of renewable energy entities, I think predominantly wind, as I understand it. Two main questions come to mind. One, we have heard a little bit about the economic benefits that could be achieved if we had more precise forecasting. I want to learn what we need to do to get that achieved, what has to be added to the system or done better from what we already do. But secondly, this interface, you know. There are some really bright folks out there doing little iPhone apps for free, but they need public access to information, and the question I would have is, do we really need a Federal investment in certain information-gathering infrastructure that then becomes open source so that then private entities can use it? What do we need to do to make this better and how do the private enterprises work with government agencies?

Dr. STORCK. Thank you. I will start with that question. First, to capture the value of renewable energy forecasts, you do need a stem that can allow you to extract that value. You need a market. Continuing with your analogy of sort of making hay, if I tell you that it is going to rain in another hour and you know that perfectly, what you really need is someone to help you make hay. You don't need to know that it is going to rain within the next hour. That is just a piece of information. So it is what you do with the information. So markets and systems allow renewable energy to be moved from one location to the next and they allow that value to be captured. In the NREL study that was referred to, the fundamental assumption with looking at the value of forecasts is that markets behaved rationally and that you were able to move power from one area to the next. It didn't consider things like $100 per megawatt hour in balance penalty. That would be what I would call an irrational market.

Secondly, to your issue of observations and open source, it is a very important point. To really predict wind energy on an hour-ahead basis, we need more than just a weather forecast. We need access to those observations that ring the wind farms and perhaps that our clients at the wind farms have installed themselves. So providing these observations that NOAA might put in and not just feeding those observations into their supercomputing models but making those observations available to the renewable energy industry and not just wind. We heard the last two Congressmen talk about solar. We need to think beyond just wind here because once we do get to your vision of shingles as PV panels, we are going to be having a hearing about solar forecasting and cloud tracking. Thank you.

Chairman BAIRD. Dr. MacDonald?

Dr. MACDONALD. Chairman Baird, I think NOAA and the private commercial sector have really grown in our ability to work together. There was a report called the Fair Weather report done back in 2003. NOAA worked on policies, and I agree with Dr. Storck that NOAA should put out the best possible forecasts but the private commercial sector can work with the very specific needs of something like the renewable energy industry to tailor the forecasts that they need, so I think there is an excellent cooperation and it says that, as we improve NOAA's observing networks and NOAA's computing and forecasting, we improve everything. We improve aviation. We improve public forecasts like the blizzard forecasts this winter. So it is something where I liked your words "open source." We operate, we sort of get the best forecast, make it available. And the better our forecasts get, the more companies like Dr. Storck's company make money.

Chairman BAIRD. Let me ask a slightly different variation of that. So forecast is some degree distant from raw data. Is the raw data open source as well?

Dr. MACDONALD. It is, right. We make it all available, and nowadays on the Internet, it is quite easy. There is one distinction on that, and that is, sometimes there are proprietary data. For example, one wind farm and one company may say, I don't want my neighboring one to have it, and we have proposed that NOAA be kind of the honest broker, where we would get the data and have it, but we would use it to improve the forecast.

POTENTIAL SAVINGS VERSUS INSTRUMENTATION AND DATA GATHERING COSTS

Chairman BAIRD. The other question then would be, and I don't know that we have time to answer it here, but we have heard estimates in the billions of dollars of savings through increased productivity and efficiency. I am wondering what the cost would be to realize those billions of dollars in terms of new instrumentation, available data.

Dr. Storck, you allude to a few new subsets of information-gathering technologies and if there are others who want to speak to that?

Dr. STORCK. Real quick. The billions of dollars of savings is what is realized with the current state-of-the-art forecasts that are available to the industry today. That is a very important point to make. We have come a long way and we already provide tremendous value to the industry. The incremental improvements on a day-ahead forecast time horizon, which is what the NREL study looked at, was another $500 million for the wind energy industry. That is significant money, but I wouldn't spend $500 million just to get there.

Chairman BAIRD. Okay. So you feel with existing technologies and data used more effectively, we can already realize substantial savings, and that is your business model?

Dr. STORCK. Yes, and the fundamental question we have in integration is forecasting wind energy changes in the next hour to next five minutes. and that is going to require thinking a little bit outside the box of just supercomputers and weather forecast models and really getting into the details of more advanced weather observation systems. The question becomes who pays for that. Is that the owner/operator of the wind farm or is that the taxpayer?

Chairman BAIRD. I will give my colleagues, if there any colleague dying for a second round? Dr. Bartlett.

ADAPTING ENERGY DEMAND TO INTERMITTENT SOURCES

Mr. BARTLETT. Of course, an alternative to storage is simply to try to match an intermittent production of electricity with an intermittent use of electricity, and there are many uses that we have for electricity that could be inherently intermittent. When your air conditioner comes on, whether it was five minutes ago or five minutes from now, it makes little difference in how cool your house is going to be, and there are many manufacturing processes where you simply could stockpile some material when you had energy available and use it when the energy is not available. Of course, there are always going to be some inefficiencies in doing that but there are also inefficiencies in storing it if you have a constant load and an intermittent production.

To what extent are we investing in these kinds of studies so that we can create a more flexible load to match an intermittent production?

Dr. MICHAELS. You already have the growth of an industry which essentially makes—what they call the product themselves—is virtual power plants. There are companies like one called EnerNOC, which essentially signs up people and tells them that they are going to control their loads in exchange for certain rewards in order to help the power system cope with its operating problems. So these industries already exist and they apparently are able to make a profit off it and the question is possibly how to grow them.

Ms. SIMLER. I would like to comment on that, if I may. The Federal Energy Regulatory Commission has due to Congress this month, I think by June 19th, a national action plan on demand response, and Dr. Michaels just referred to with EnerNOC, they are providers of demand response and demand response can complement the variability of wind energy resources. So FERC last June did a study on the assessment of the potential of demand response in the country and, like I said, the report should be going to Congress on the action plan which talks about support for states and others about how to achieve the potential identified in that assessment. Thank you.

Mr. BARTLETT. Yes, sir.

Dr. STORCK. Yes, and also just recently DOE has made hundreds of millions of dollars of funding available for what is called smart grid demonstration projects. We are a member of one of those projects in the Pacific Northwest, and the idea is to look at demand response and basically information services that support the electric grid to match supply, particularly from renewables, and in the Pacific Northwest, we have got a lot of wind and it is all in one spot. So when the wind is blowing, we really want something on the power system to consume that resource, and these are large-scale, five-year-duration demonstration projects that are currently getting underway, so there is a lot of interest there, and funding.

Mr. ROSENBLUM. The ISO has recently submitted to FERC a modification to its ancillary service market requirements to try to facilitate the participation of demand in those markets.

Mr. BARTLETT. As a small example of what one might do, if you have a well-insulated hot water tank in your home and you are heating it electrically, it will make little difference when you heat that water. It could all be heated at two a.m. in the morning, for instance, and last you for the whole day if it were large enough and well enough insulated. So there are enormous opportunities out there for varying the load, and I suspect that that may be simpler and cheaper than storage in many cases, and I am glad that we are pursuing this with some vigor apparently. Thank you all very much for your answers and yield back.

Chairman BAIRD. Dr. Bartlett, I think that is an excellent line of questioning. One of the issues we discovered in the Northwest and I think elsewhere is for communities, when you try to look at conservation, there is a risk that they lose their access to load. When they start using less, then they are entitled to less in the future. So one of the issues we have to deal with with FERC and other management entities is to make sure that demand management doesn't cost you guaranteed access, because that is a disincentive that is built in to some of our current agreements.

Ms. Woolsey.

POTENTIAL FOR JOB CREATION

Ms. WOOLSEY. Thank you, Mr. Chairman.

Dr. Mooney, we talked about saving money and increasing energy. We haven't talked about renewable energy creating and investing in more jobs in this country. Has your lab taken that on as one of your measurements?

Dr. MOONEY. We do have a group at the Laboratory that is called the Strategic Energy Analysis Center. That center has a focus, among other things, of looking at the economic and job impacts of various renewable energy and efficiency deployment scenarios. So we do that, and I am happy to get you additional information on what we do there. But——

Ms. WOOLSEY. Mostly I would like to know what they have concluded.

Dr. MOONEY. Well, generally, I will say without being able to quote specific numbers is that there is an economic benefit, job creation benefit, to renewable energy and energy efficiency development, manufacturing and deployment in the United States.

Ms. WOOLSEY. And would anybody else like to comment on that?

Dr. MICHAELS. Yes.

Ms. WOOLSEY. Dr. Michaels.

Dr. MICHAELS. The record is decidedly mixed on whether there really is such. There have been studies in the United States, studies abroad. The problem that you have in the United States in particular is the type of computer modeling that they engage in. There was a study in Spain. It is a controversial study but they found out that renewable energy was actually a destroyer of jobs because it had such high capital requirements per worker relative to other potential sources of stimulus. The NREL did a study to refute this study, and they used the standard model, and in the process it came out, NREL's model created jobs. NREL's model mathematically must create jobs. It has to give them the answer that they want. In other words, I don't think that much of this has really been studied to the degree that it should, so I am concerned about that.

Ms. WOOLSEY. Would anybody else like to respond to that? I mean, do you buy this that going into the new energy-saving technologies in this country, we are not going to have more jobs?

Dr. STORCK. Well, I could offer a small example. Renewable energy has created 60 very high-paying jobs in Seattle, and a lot of the people that we employ are atmospheric scientists and they remark to me, you know, it sure is nice to have an alternative to go to other than to work at NOAA. No offense to NOAA. Because, without the private sector having a role, that was their option. It was either academia or it was to go work for the government, and now they can roll up their sleeves and they can do something useful supporting renewable energy in this country. We are just one country. Multiply that by all the companies that are out there and, yes, renewable energy creates jobs.

Ms. WOOLSEY. Thank you, Mr. Chairman.

Chairman BAIRD. Dr. Ehlers, do you have any additional comments?

Mr. EHLERS. Not at this time, Mr. Chairman.

Chairman BAIRD. Dr. Mooney, my staff tells me it looks like you wanted to respond to that last one, and with that, then we will finish up.

Dr. MOONEY. I just wanted to offer to the Subcommittee that I am happy to make available to the Subcommittee our response to the Spanish jobs report, and I will make that available to you if you would like.

Ms. WOOLSEY. Thank you very much.

Dr. MOONEY. Our intention, though, let me just conclude by saying, our intention in any type of study like that is to objectively look at the issues and provide honest information as best as we can determine it. We don't set out in those studies with a predetermined agenda.

Ms. WOOLSEY. So Mr. Chairman, would it be appropriate at this time to ask when we receive it to have that information entered into the record?

Chairman BAIRD. I think it certainly would, and Dr. Mooney, we would welcome that, especially if you have a response to the assertions of Dr. Michaels, and Dr. Michaels, feel free to add your explanation for the assertion that the NREL model produces—you know, is guaranteed to appear that it produces jobs, so we would be happy to look at both of those analyses.

Dr. MICHAELS. The Institute for Energy Research has authored a study about the Spanish study and the NREL response to it, and we will be happy to give it you.[1]

Chairman BAIRD. We would appreciate that.

CLOSING

Before we bring the hearing to a close, I want to thank our panel of witnesses for testifying before the Committee today, and I thank my colleagues for very important and informative questions as well. The record will remain open for 2 weeks for additional statements from the members and for answers such as we have just discussed to any of the follow-up questions the Committee may ask the witnesses.

With that, the witnesses are excused with our gratitude, and the hearing stands adjourned.

[Whereupon, at 11:27 a.m., the Subcommittee was adjourned.]

[1] Dr. Mooney and Dr. Michaels submitted supplemental testimony regarding modeling procedures at the National Renewable Energy Lab (NREL). See Appendix.

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ms. Jamie Simler, Director, Office of Energy Policy and Innovation, Federal Energy Regulatory Commission

Question submitted by Representative Ralph M. Hall

Q1. Dr. Michaels noted in his testimony that, in Texas and Colorado, it has been found that large increases in wind power production resulted in increases in pollutant emissions, and unchanged CO_2 emissions, because the baseload electricity required to support the wind power operations forced coal generators to make unusually quick adjustments that increased pollution.

Please provide FERC's reaction to this concern. Given that integration of renewables onto the grid is a top priority for FERC, will the Commission be examining this issue in further detail to determine its significance and consider potential policy changes related to it?

A1. As I explained in my testimony, with respect to electricity, the Commission regulates transmission and sales for resale of electric energy in interstate commerce to assure the rates, terms and conditions of transmission service and wholesale power transactions are just and reasonable and not unduly discriminatory or preferential. In the study noted by Dr. Michaels, there were claims of increased pollutant emissions resulting from the practice of cycling coal fired generation in lieu of reducing wind power generation. The Commission does not have the statutory authority to address power plant emissions and has not sponsored such a study.

The Commission's economic regulatory focus with respect to the integration of renewable resources centers on the variability of these resources, and how that variability is addressed by the rates, terms and conditions of transmission service and wholesale energy markets. The Commission seeks to ensure that all power supplies have comparable access to the grid.

As I mentioned in my prepared testimony, the Commission is currently engaged in an effort to examine the extent to which barriers may exist that impede the reliable and efficient integration of variable energy resources into the electric grid, and whether reforms are needed to eliminate those barriers. Several areas of this inquiry are focused on electric utilities' ability to deal with the variability and intermittency of wind power production. These include information and data exchanges between wind generators and interconnected transmission operators, wind power production forecasts, and unit commitment procedures. Reforms in these practices should enhance the ability of the electric power system to efficiently integrate wind power resources. For instance, the Commission noted in the Integrating Variable Energy Resources Notice of Inquiry that improvements in transmission scheduling procedures may offer the potential for greater efficiency in dispatching all energy resources if the degree of variability can be reduced, better anticipated, and/or planned for more precisely.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Alexander MacDonald, Deputy Assistant Administrator, Laboratories and Cooperative Institutes, Office of Oceanic and Atmospheric Research, National Oceanic and Atmospheric Administration

Question submitted by Representative Ralph M. Hall

Q1. In his testimony, NREL noted that the Department of Energy (through NREL) acts as a sort of "middleman" in supporting renewable-related weather forecasting. Specifically, the testimony states that DOE serves "as an interface" between NOAA and the forecasting industry.Does NOAA need an "interface" to communicate effectively with the forecasting industry? What is the unique value added by this "interface" step, and does NOAA need it to communicate effectively with the forecasting industry? If so, would NOAA be capable of carrying out this activity if directed to do so?

A1. NOAA has been working directly with the weather forecasting industry since the industry began in the middle of the 20th century. NOAA communicates directly with the private forecasting industry to understand their requirements and provide observations; weather, water, and climate forecasts; and other forecast information that is used to respond to the renewable energy community's needs. NOAA also provides historical climate information (e.g., long-term yearly averages of climate variables such as solar radiation, wind speed, etc.) that is used for siting new renewable energy facilities.

When working with private weather forecast providers to respond to the information needs of specific sectors—e.g., renewable energy, emergency management, agriculture, and aviation—relevant Federal agencies such as the Departments of Energy (DOE), Homeland Security, and Agriculture and the Federal Aviation Administration are key partners and play an important role in bringing their knowledge and experience to the discussion. In the renewable energy arena, DOE and NOAA have formed a productive collaborative relationship to identify strategic efforts that NOAA could undertake to improve its products to better address industry needs. NOAA is working directly with the renewable energy community, as well as in collaboration with DOE, to understand the needs and to develop programs and capabilities to provide the needed information for the renewable energy industry.

NOAA does not, however, provide specific forecasts for any private companies or industries—but all can use NOAA's information as a starting point to produce more tailored, higher resolution, and industry-specific forecasts. In working with the private weather forecasting industry, NOAA follows its Policy on Partnerships in the Provision of Environmental Information (*http://www.noaa.gov/partnershippolicy/*). Adherence to this policy enables a healthy and productive public-private enterprise relationship. The NOAA policy was developed in response to the *Fair Weather Report: Effective Partnership in Weather and Climate Services* (National Research Council of the National Academies of Science, National Academies Press, 2003), which examined the roles of the private sector, the academic community, and the Federal sector in the provision of weather and climate services.

NOAA believes public sector prediction models and observation networks can be improved to meet the needs of the renewable energy industry. As the information and forecasts provided by NOAA continue to improve, forecasts developed by private industry will also improve. The renewable energy industry is growing rapidly, and its needs and requirements continue to be developed and refined.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. David Mooney, Director, Electricity, Resources, and Building System Integration Center, National Renewable Energy Laboratory

Questions submitted by Representative Ralph M. Hall

Q1. 3Tier appended to its hearing testimony a statement expressing "concerns over the emergence of "new" government wind forecasting research and product development that replicates what commercial providers have been doing operationally for years." NREL activities appear to be at least partially at issue with respect to this concern, please provide NREL's response and reaction to the 3Tier, et al statement. What steps does NREL take to ensure its activities do not interfere with those of the commercial sector?

A1. Commercial wind power forecast providers rely on government agency weather forecasts and public weather data to develop their specific operational products, so there is an inherent Federal role. The issue raised in the appended statement, a letter dated 6–6–09, points to a concern regarding public funded research that contains elements of applied, operational wind power forecasting. NREL is committed to participating in the advancement of forecasting in order to most cost effectively integrate wind generation in the nation's electric systems. The DOE Wind Program funds our activities in this area, as well as the efforts of other Federal labs and industry led collaborations. NREL has played a positive role in resolving differences by facilitating exchange of information and ensuring any research results funded by DOE are publicly available and can benefit future private sector commercial endeavors. As discussed in the response to question 2, the Utility Wind Integration Group (UWIG) has been key in this coordination.

NREL fully agrees with the three priorities outlined in the 6–3–09 statement: Enhancing Publicly-Available Weather Data Networks, Research into Problem Flow Regimes, and Improvements in NWP models. The DOE Wind Program has recognized the research issues as well, and recently issued a competitive funding opportunity titled "Enhancing Short Term Wind Energy Forecasting for Improved Utility Operations", funding opportunity announcement number DE–FOA–0000343. This opportunity is specifically targeted at fostering collaboration with the National Oceanic and Atmospheric Administration (NOAA), the private forecasting industry, and utility grid operators. DOE has increased its interactions with NOAA, and supports expansion of the NOAA mission to include weather driven renewable energy issues, including forecasting.

NREL believes these recent efforts are fully in line with private sector priorities and the private sector's views on appropriate roles based on collaborations with the American Meteorological Society, UWIG, NOAA, the National Center for Atmospheric Research (NCAR), the Office of the Federal Coordinator for Meteorological Services, and others. This work, and likely related future collaborations, will advance understanding of wind forecasting, enhancing the commercial sector's products, and ultimately benefiting the public by facilitating integration of renewable power generation into electric systems.

Q2. You note in your testimony that the Department of Energy, through your laboratory, acts as a sort of "middleman" in supporting renewable-related weather forecasting. Specifically, you state that DOE serves "as an interface" between NOAA and the forecasting industry, and that DOE plays a role in "translating the needs of utilities to the forecasting industry and vice versa."

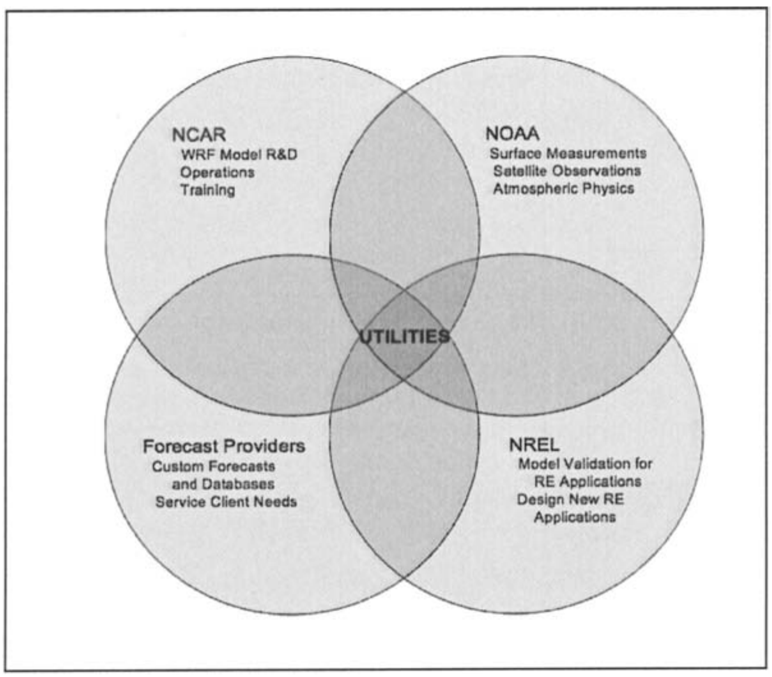
Please describe in further detail what these interface and translational activities entail and why they are necessary, What is the unique value added by DOE/NREL that cannot be fulfilled directly by NOAA and the forecasting industry, or by utilities and the forecasting industry?

A2. DOE/NREL has played, and continues to play a critical role in bringing relevant forecasting stakeholders together to help them understand the technical issues associated with renewable resource forecasting, translating this information into power plant output, and the potential of renewable plant generation.

The main forum for this interaction is led by the Utility Wind Integration Group (UWIG) and UWIG's partnership with DOE/NREL. Twice yearly, UWIG meetings bring utilities and the forecasting industry together to discuss forecasting needs and develop deeper understanding of how forecasting products should be tailored. For example, DOE/NREL/UWIG sponsored a workshop in 2008 (*http://www.uwig.org/Update/uwigupdateMarch08.htm*) to bring the government meteorology research community together with the forecasting industry to discuss how existing weather models could be improved to address wind and solar power forecasting. In June of 2010, UWIG sponsored a workshop (*http://www.uwig.org/abpwindforework.html*) that brought together the utilities and wind data modelers to discuss needs and applications for wind datasets as inputs for integration studies. Feedback from the utility, forecasting, and research community at these forums has been tremendously positive, with participants learning a great deal about the needs and capabilities and limitations of the other sectors.

The figure below illustrates the roles of the parties and the overlapping nature of their interests. DOE/NREL and UWIG foster open discussions on the data needs, differing forecast product needs, and the value of forecast improvement . This facilitation role and DOE funding of related collaboration as described in the answer to Question #1 are critical for continued wind power deployment and economic integration into the nations electric system.

As wind/solar penetrations increase, operational integration challenges become greater. Continued forecasting improvement through public and private collaborative efforts along with DOE/NREL's role in identifying and addressing cross sector issues will remain important.



Q3. Dr. Michaels noted in his testimony that, in Texas and Colorado, it has been found that large increases in wind power production resulted in increases in pollutant emissions, and unchanged CO_2 emissions, because the baseload electricity required to support the wind power operations forced coal generators to make unusually quick adjustments that increased pollution.

Please provide NREL's reaction to this concern. Has the issue been studied in sufficient depth to provide an understanding of its significance and impact? If not, given NREL's expertise and the Obama Administration's emphasis on reducing CO_2 emissions and other pollutants, will NREL examining be this issue in further detail?

A3. DOE/NREL sponsored, and other wind integration studies examine in detail the needed electric system reserves and part-load operations of conventional generators in response to the variability and uncertainty of wind and solar power resources. The BENTEK study referenced was (to our knowledge) not publicly reviewed, and we believe it comes to erroneous conclusions regarding overall emissions rates. Xcel, the primary utility provider in Colorado, agrees that the report is in error. Reference Denver Post Letter to the Editor, May 28, 2010, reprinted below.

DOE/NREL are committed to fully evaluating the impact of wind on utility system operations, including impacts on emissions. Ongoing and future work will continue to address emissions, system wear and tear, and generator cycling issues.

Denver Post Letter to the Editor, May 28, 2010

Re: "Did wind mandate worsen pollution?," May 16 John Andrews column.

Earlier this year, the Independent Petroleum Association of Mountain States (IPAMS) commissioned BENTEK Energy to prepare a study of the impact of renewable energy generation on Colorado air quality IPAMS's study claims that increasing wind generation is harming Colorado's air quality, a claim that has been reinforced in recent columns in The Denver Post, including John Andrews'.

It's time to set the record straight regarding wind energy in Colorado.

Xcel Energy currently has almost 1,300 megawatts of wind capacity on our system and plans to add an additional 700 megawatts by 2015. Wind is an important part of Xcel Energy's balanced electricity portfolio.

Wind is not perfect, and the study focuses on its primary problem: Wind turbines generate electricity only when wind blows. We must balance our system to match generation with demand. As a result, we must "ramp" up and down other power plants as the wind changes. Generally, we prefer to ramp gas-fired plants because they respond quickly to sudden system changes. If we ramp coal-fired units, the plant's efficiency may decline, causing its emission rate to increase for short periods.

The IPAMS study correctly points to this fact, but then carries its conclusions too far. The study implies that small, short-term emission increases associated with ramping result in significant increases in the total emissions. This is simply wrong. Since 2007, we have added hundreds of megawatts of wind generation, and our overall emissions have declined. In 2009, wind produced 10 percent of the energy delivered to our customers. Without wind, that electricity would have been generated by gas or coal, creating greater total emissions.

While our emissions have declined overall, emissions from individual units may vary, in part to accommodate wind integration. Nevertheless, we haven't seen increases in emissions at any plant that approach the levels implied by the IPAMS study. We find no evidence that our wind portfolio is affecting coal plant operations enough to degrade air quality.

We agree with IPAMS that wind integration is a challenge, and we should not understate it. We are working with experts to improve our ability to forecast and integrate wind on our system, as well as evaluating generation technology additions to aid in the effort. That's something on which IPAMS, Xcel Energy and all Coloradans can agree.

Frank Prager is vice president of environmental policy with Xcel Energy.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Pascal Storck, Vice President, 3TIER

Question submitted by Representative Ralph M. Hall

Q1. You appended to your testimony a joint statement by 3Tier and two of its competitors that expresses "concerns over the emergence of "new" government wind forecasting research and product development that replicates what commercial providers have been doing operationally for years."

Please elaborate on this concern. What potentially duplicative product or service is the Federal Government providing, and through what agency or entity? Has 3Tier communicated this concern to the agency or agencies in question, and if so where does the issue stand? Please provide any specific recommendations you have regarding how best to address this concern.

A1. The U.S. Government, through its agencies, such as NOAA, and its national laboratories, such as NREL, has become increasingly active in the area of information services in support of renewable energies. Over the past several years, as the renewable energy market has developed, the importance of information to characterize wind and solar fluctuations has become clear. Since weather is the driving fuel of a wind or solar project, understanding how it varies in time (i.e. from day to day) and how it varies over space (i.e. where is it windiest in a particular county), is key to building the most productive projects and then operating them efficiently. To fill this requirement for information, small and medium sized businesses, such as 3TIER, AWS Truewind and Windlogics (all signatories to our joint statement) have provided these services over the past several years. Our fear, which is beginning to be realized, is that the U.S. government now sees the opportunity to provide these information services in support of those that are producing tangible products in the renewable energy space. Put most simply, when the government talks of accelerating renewable energy for domestic and export use—it very often means supporting those that are producing the wind turbines and the solar panels at the expense of those providing information or data services.

A perfect example of this in action is NREL (the National Renewable Energy Lab) creating a solar dataset to accelerate renewable energy in India. 3TIER already offers this product, but the U.S. government, in its interest to accelerate the development of renewables in India and the market for U.S. products (solar panels) there, wants to make this information freely available. While this may accelerate development in India, it hurts companies like 3TIER that provide these information based products. Most recently our CEO was on a trade mission to China, hosted by the Department of Commerce, and one of the active areas of discussion was the potential creation of renewable energy (wind and solar) datasets by our government (most likely NREL) to accelerate efforts. To be fair to NREL, it subcontracts out the creation of this data to the private sector (companies like 3TIER), but our point is that this simply puts industry into a role of supporting government efforts. The better model is one in which the users of the information come to companies like 3TIER directly to purchase that information, thereby putting the burden of payment on those that benefit, while creating an actual industry to serve this growing market.

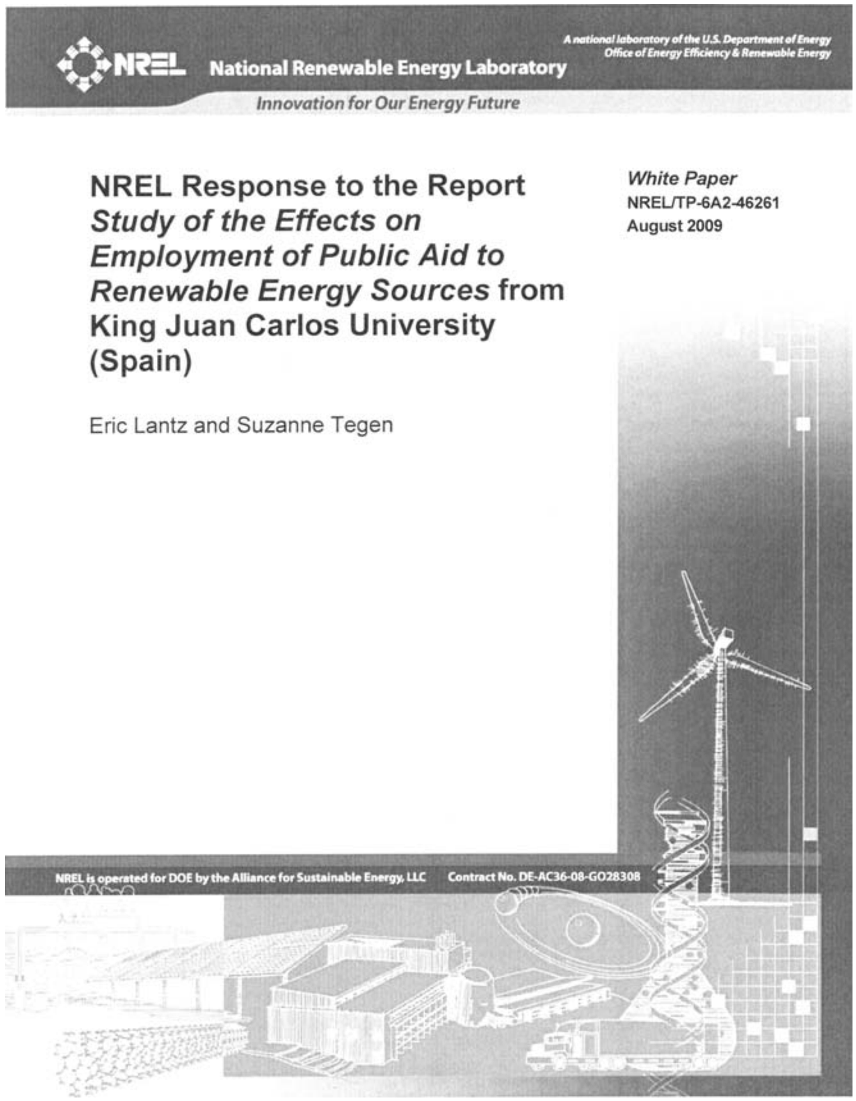
Another example of this work is in wind energy forecasting, where NREL, together with a division of NOAA, the Research Applications Lab (RAL) have teamed together to create a wind energy forecasting system for a utility (Xcel Energy). As was discussed in our letter, the private sector is well positioned to provide these services, but the government (or certain individuals in these agencies) see an opportunity to provide a very valuable product to the renewable energy industry. What they often forget is that in doing so, they are displacing the efforts of the private sector.

We have communicated our concerns to NOAA and NREL. While the agencies say all the right things about public/private partnerships, I don't see them changing their behavior. Renewable energies are being actively promoted by the current administration, and the labs and agencies, especially with the funding of the Department of Energy, see the current interest as an opportunity to provide relevant products and services (such as solar maps for India and forecasting systems for Xcel). As was stated in my testimony, these agencies should be encouraged to focus on the big challenges, like providing better weather forecasts for the entire country, and then leave the private sector to provide specific services for specific clients in specific industries.

Appendix 2:

Additional Material for the Record

NREL RESPONSE TO THE REPORT *Study of the Effects on Employment of Public Aid to Renewable Energy Sources* FROM KING JUAN CARLOS UNIVERSITY (SPAIN)



National Renewable Energy Laboratory

Innovation for Our Energy Future

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

NREL Response to the Report *Study of the Effects on Employment of Public Aid to Renewable Energy Sources* from King Juan Carlos University (Spain)

White Paper
NREL/TP-6A2-46261
August 2009

Eric Lantz and Suzanne Tegen

NREL is operated for DOE by the Alliance for Sustainable Energy, LLC   Contract No. DE-AC36-08-GO28308

NOTICE

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

Background

Job generation has been a part of the national dialogue surrounding energy policy and renewable energy (RE) for many years. RE advocates tout the ability of renewable energy to support new job opportunities in rural locations and the manufacturing sector. Others argue that spending on renewable energy is an inefficient allocation of resources and can result in job losses in the broader economy.

The report *Study of the Effects on Employment of Public Aid to Renewable Energy Sources,* from King Juan Carlos University in Spain, is one recent addition to this debate. The report asserts that, on average, every renewable energy job in Spain "destroyed" 2.2 jobs in the broader Spanish economy. The authors also apply this ratio in the U.S. context to estimate expected job loss from renewable energy development and policy in the United States (Alvarez et al. 2009).

The analysis by the authors from King Juan Carlos University represents a significant divergence from traditional methodologies used to estimate employment impacts from renewable energy. In fact, the methodology does not reflect an employment impact analysis. Accordingly, the primary conclusion made by the authors – policy support of renewable energy results in net jobs losses – is not supported by their work.

This white paper discusses fundamental and technical limitations of the analysis conducted by King Juan Carlos University and notes critical shortcomings in assumptions implicit in the conclusions. The white paper also includes a review of traditional employment impact analyses that rely on accepted, peer-reviewed methodologies, and it highlights specific variables that can significantly influence the results of employment impact analysis.

Summary of King Juan Carlos University Methodology

The authors of the King Juan Carlos study intend to relate the economic efficiency of renewable energy jobs to those of the broader economy. To do this, they compare the government expenditure per estimated RE job with the average private-sector resources expended per worker and the average productivity per worker. Their quantitative approach is shown below.

Calculation A: $$\frac{\textit{Subsidy to renewables per worker}}{\textit{Average capital per worker}}$$

Calculation B: $$\frac{\textit{Annual subsidy to renewables per worker}}{\textit{Average productivity per worker}}$$

The Spanish report asserts that the results derived from the ratios above represent job loss as a result of public investment in renewable energy. This is based on the assumed principle that every dollar spent subsidizing renewables represents a reduction of one dollar in private-sector investment *and* that every dollar spent in the private sector will generate jobs equally.

In contrast, traditional jobs analyses evaluate how changes in demand for specific goods and services will affect economic activity and jobs within specific industries, their supply chain, and the broader economy. The input-output tables applied in traditional analyses are derived from real inter-industry transactions at a specific time. The most sophisticated analyses account for a reduction in demand where substitutions occur (e.g., reduced demand for conventional electricity generation due to new renewable generation), as well as the effects of government expenditures and changes in commodity prices (e.g., electricity).

Fundamental Limitations

- **The metrics used in the Spanish study are not jobs impact estimates.** The primary conclusion of the report is that the Spanish economy has experienced job loss as a result of its RE installations. However, comparing the RE subsidy per job with the Spanish economy's average capital per job and average productivity per job is not a measure of job loss. Traditional methods for estimating jobs and economic impacts are discussed below.

- **The comparison of RE jobs with average economy-wide metrics fails to recognize the variability within the modern economy.** The cost of job creation varies significantly among economic sectors. For example, creating employment for legal or medical professionals costs more than creating employment for clerical or administrative professionals. Applying a methodology that compares renewable energy employment with an economy-wide average explains very little about how RE job creation compares with comparable industries. A more informative analysis would compare metrics relating to RE workers with metrics for workers in other electricity generating industries. It would also show the range of metrics that exist across industries rather than economy-wide averages.[1]

- **The report fails to account for technology export potential.** Robust RE technology exports can greatly affect economic impacts of renewable energy (Lehr et. al. 2008).With its proactive RE policies, Spain is already a major exporter of renewable energy equipment (David 2009).[2] If global demand for RE technology increases, Spain's early investment could allow it to capitalize on a global market for RE technology, which would contribute further to the Spanish economy.

- **The study ignores the role of government in facilitating growth of valued new industries.** Governments invest in renewable energy technologies to promote the growth of the industry as a whole. Emerging RE technologies have not achieved levels of maturity and economies of scale that traditional technologies have; nor have they benefited from years of public and private investment. As a result, there may be a role for government to play in leveling the playing field between new and old technologies and in supporting emerging technologies. In the United States, all conventional energy technologies received government support in their early stages, and still benefit from government investment today (EIA 2008).

Technical Limitations

- **The calculation of average capital and average productivity per worker is based on jobs resulting from economic activity at all levels (i.e., it includes direct, indirect, and induced jobs).**

[1] These results could simply suggest that RE jobs require more highly trained – and, therefore, more costly – workers than the Spanish economy, in general. Moreover, the deviation from the economy-wide average capital and productivity per worker observed for renewables may be well within the statistical norms of a diverse and robust modern economy.

[2] Spain was the second-largest supplier of U.S. wind turbine generator imports in 2007 and 2008, and its overall exports of wind-powered generator sets reached $469.7 million in 2008 (David 2009).

However, the RE jobs estimate used to calculate the RE subsidy per job is based on a quantification of direct and indirect impacts only. The RE employment data used in this analysis is based on analysis of the direct and indirect job impacts from investment in renewable energy (MITRE 2003). Yet the average capital per worker and average productivity per worker are based on employment estimates that include jobs resulting from direct, indirect, and induced economic activity. A more complete comparison would include induced jobs impacts in the total RE jobs estimate that is used to estimate the average RE subsidy per worker.[3]

- **The report relies on jobs estimates that were developed in 2003 and do not reflect Spain's RE industries in 2009.** The total RE job creation estimate used by the authors was derived from two hypothetical Spanish deployment scenarios conducted in 2003 (MITRE 2003). However, neither of these projections reflects the actual deployment of renewable energy capacity in Spain. The authors imply that these results are a valid approximation. This approach ignores the discrepancies between assumptions that were reasonable in 2003 and the empirical reality that exists today.

- **The report lacks transparency and supporting statistics.** It is striking that the authors' calculations with two very different economic metrics generate the same result. The authors claim this increases their confidence in their result. However, because there is no statistical analysis, it does not seem reasonable to draw conclusions regarding confidence in either result. The authors also fail to justify their chosen methodology or cite others who have applied a similar methodology.

Shortcomings in Assumptions

- **The authors assume that a dollar spent by the government is less efficient than a dollar spent by private industry and that it crowds out private investment.** Government spending may be more or less efficient than private investment. To the extent that government spending is a correction for market failures (e.g., existing fossil fuel subsidies, environmental externalities), it is less likely to represent an inefficient allocation of resources. Furthermore, there is no justification given for the assumption that government spending (e.g., tax credits or subsidies) would force out private investment. This assumption is fundamental to the conclusion that Spain's renewable energy policy has resulted in job loss.[4]

  Even if every public dollar spent on renewables does result in fewer jobs than the average dollar spent in the Spanish economy, public investment in renewables will only result in overall job loss when: there is full employment, all private-sector funds are spent on job-generating activity (i.e., not on shareholder dividends or paying down debt), and there is no positive benefit for the society from renewable energy in general. Without each of these conditions holding true, one cannot claim that public investment has resulted in job loss, regardless of the efficiency of the public investment.

- **The authors assume that results from Spain are reflective of the impact of RE technologies in other countries.** Countries have different regulations, policies, and incentives for renewable energy.

[3] Direct and indirect impacts include the impacts from expenditures in the industry of focus, as well as the various industries that supply the industry that is the subject of the analysis. Induced economic activity results from spending income generated through the original investments at the direct and indirect levels. A full social accounting matrix of economic activity includes all three levels of economic activity.
[4] Government spending may result in reallocation of resources.

Minor policy differences can have great impacts on outcomes. Applying a single result derived from a specific set of market and policy conditions to renewable energy, in general, is a distortion of real differences in global market and policy conditions. For example, Spanish feed-in tariff (FIT) policies require utilities to purchase all electricity generated by RE resources at a price that is often much greater than the wholesale prices paid to conventional generators. This policy differs greatly from U.S. incentives such as the production tax credit (PTC).

- **The report relies on jobs as the sole metric to assess the value of renewable energy.** The number of jobs resulting from an impact analysis is an important metric. However, it is not the only value of interest. An analysis of relative costs per job within a specific industry or economy fails to account for the array of costs and benefits that are associated with any investment alternative. For example, Spain relies on natural gas and coal for roughly 52% of its electricity production (IEA 2006). Decreasing that dependence has a number of important energy and economic security implications (NREL et. al. 2008).

In summary, the analysis performed in this recent study is not a jobs impact estimate and, therefore, provides little insight into job creation or job loss from Spanish RE policy. Additionally, this analysis has oversimplifications and assumptions that lead to questions regarding its quantitative results. Finally, the authors fail to justify their implication that because of the jobs comparison, subsidies for renewables are not worthwhile. This ignores an array of benefits besides employment creation that flow from government investment in renewable energy technologies.

Nevertheless, the authors' basic question regarding whether investment in RE provides a positive or negative employment impact is a fair one. The following portion of this white paper briefly reviews additional literature that considers this question.

Traditional Employment Impacts Analysis

Traditional methods applied in jobs and economic impacts analyses rely on input-output models to estimate job creation or loss. These models measure how changes in demand for specific goods and services affect economic activity and jobs within the specific area of study. At the most basic level, jobs analyses rely on a straightforward estimate of gross economic impacts from new investments in specific energy technologies under different scenarios. Such efforts in the United States suggest that, in some cases, the project-level job creation impacts of wind power are greater than that of conventional energy generation resources, including coal and natural gas (Tegen 2006, Lantz and Tegen 2008).

More sophisticated models allow for estimates of net jobs impacts. These models account for a reduction in demand for conventional generation, the effects of government expenditures on RE in the economy, and electricity price impacts.[5] The results of analyses applying these more sophisticated models are mixed; however, with today's cost projections, RE technology jobs and impacts generally have been shown to be greater than business-as-usual scenarios. Some examples follow.

The Monitoring and Modeling Initiative on the Targets of Renewable Energy (MITRE) determined that across Europe, as well as in Spain, renewable energy development would have a net positive impact on

[5] Such models typically use a combination of input-output and macroeconomic modeling capabilities.

employment (MITRE 2003).[6] Work focused on Germany, conducted in 2005, found that feed-in tariff (FIT) policies in their country would result in a surge in employment between 2004 and 2008 as deployment proceeded rapidly; but net employment would turn negative in 2010 as construction of new facilities declined and the higher costs of renewable energy impacted the broader economy (Hillebrand et al. 2006). More recent work finds that, in Germany, net employment remains positive for all renewables deployment scenarios across a variety of sensitivities, and growing export markets greatly increase the net employment impact (Lehr et al. 2008).[7] Finally, an April 2009 study conducted on behalf of the European Commission's Directorate-General Energy and Transport shows "[p]olicies that support renewable energy sources (RES) give a significant boost to the economy and the number of jobs in the EU. Improving current policies so that the target of 20% RES in final energy consumption in 2020 can be achieved will provide a net effect of about 410,000 additional jobs and 0.24% additional gross domestic product (GDP)" (Ragwitz et al. 2009).

In general, comprehensive analyses show that net employment impacts are sensitive to assumptions regarding future energy prices, strategies for addressing greenhouse gas (GHG) emissions reductions, and the capacity to export technology. With increased awareness of potential energy price scenarios, recent research has found that it is only when conventional energy prices are forecast to be very low that net employment impacts from RE investments are negative.[8]

Conclusions

The recent report from King Juan Carlos University deviates from the traditional research methodologies used to estimate jobs impacts. In addition, it lacks transparency and supporting statistics, and fails to compare RE technologies with comparable energy industry metrics. It also fails to account for important issues such as the role of government in emerging markets, the success of RE exports in Spain, and the fact that induced economic impacts can be attributed to RE deployment. Finally, differences in policy are significant enough that the results of analysis conducted in the Spanish context are not likely to be indicative of workforce impacts in the United States or other countries.

Energy policy has always been a politically charged subject. And in today's economy, where job creation is at a premium, questions pertaining to the impact of energy policy on employment magnify the sensitive nature of this debate. Measuring long-term economic and employment impacts is a complex task, sensitive to an array of unknowns, including future prices for both conventional fuel and renewable energy. Because this work is highly sensitive to assumptions and the quality of research, it is critical that policy makers seriously evaluate the work presented to them; and even after careful scrutiny, place jobs estimates within the broader context of energy, the economy, the environment, and the future.

---

[6] Remarkably, this is the same resource that the King Juan Carlos University authors use to argue that the Spanish economy is losing jobs as a result of its policies promoting renewable energy.
[7] Even with conservative assumptions relative to today's prices – where renewable energy is not expected to be wholly cost-competitive until 2020 (at oil prices of $60 per barrel in 2020 and CO_2 at €15 per ton) – there is a net positive impact that is further boosted by technology exports. It is only in the most extreme scenarios with very low energy prices ($30 per barrel oil in 2020) and no exports of RE equipment, that the net employment impact of Germany's feed-in tariff policies is negative (Lehr et al. 2008).
[8] In most recent analysis, electricity-price increases from renewable energy deployment are minimal. The U.S. Energy Information Administration's analysis of two scenarios with a national 25% renewable energy standard (RES) showed that national electricity prices are impacted by less than 1% by 2030 (EIA 2009). A similar NREL report showed that of the RES proposals analyzed, no state experiences electricity price increases of more than 5%, and most states actually experience electricity price decreases rather than increases (Sullivan et al. 2009).

References

Alvarez, G.C.; Merion Jara, R.; Rallo Julian, J.R. (2009). *Study of the Effects on Employment of Public Aid to Renewable Energy Sources.* King Juan Carlos University. March 2009.

David, A.S. (2009). *Wind Turbines Industry & Trade Summary.* Published for the U.S. International Trade Commission. June 2009.
http://www.usitc.gov/ind_econ_ana/research_ana/ind_trade_summ/documents/ITS-2_Summary.pdf

Energy Information Administration (U.S.) (EIA). (2009). *Impacts of a 25-Percent Renewable Electricity Standard as Proposed in the American Clean Energy and Security Act Discussion Draft.* April 2009. SR-OIAF/2009-04.

EIA. (2008). *Federal Financial Interventions and Subsidies in Energy Markets.* April 2008. SR/CNEAF/2008-01.

Hillebrand, B.; Buttermann, H.G.; Behringer, J.M.; Bleuel, M. (2006). "The Expansion of Renewable Energies and Employment Effects in Germany." *Energy Policy* 34 (2006) 3484-3494.

International Energy Agency (IEA). (2006). *Energy Statistic by Country: Spain 2006.*
http://www.iea.org/textbase/stats/countryresults.asp?COUNTRY_CODE=ES

Lantz, E.; Tegen, S. (2008). *Variables Affecting Economic Development from Wind Energy.* July 2008. NREL/CP-500-43506.

Lehr, U.; Nitsch, J.; Kratzat, M.; Lutz, C.; Dietmar, E. (2008). "Renewable Energy and Employment in Germany." *Energy Policy* 36 (2008) 108-117.

Monitoring and Modeling Initiative on the Targets for Renewable Energy (MITRE) (2003). *Meeting the Targets and Putting Renewables to Work: Country Report Spain.* Produced for the European Commission, 2003.

National Renewable Energy Laboratory (NREL), and World Resources Institute, in cooperation with the Center for Strategic and International Studies. (2008). "Opportunities for High Impact U.S. Government International Renewable Energy and Energy Efficiency Initiatives."

Ragwitz, M.; Schade, W.; Breitschpf, B.; Walz, R.; Helfrich, N.; Rathman, M.; Resch, G; Faber, T.; Panzer, C.; Haas, R.; Nathani, C.; Holzhey, M.; Zagame, P.; Fougeyrollas, A.; Konstantinaviciute, I. (2009). Published for the European Commission DG Energy and Transport. *The impact of renewable energy policy on economic growth and employment in the European Union.* April 2009.

Sullivan, P.; Logan, J.; Bird, L.; Short, W. (2009). *Comparative Analysis of Three Proposed Federal Renewable Electricity Standards*. May 2009. NREL/TP-6A2-45877.

Tegen, S. (2006). *Comparing Statewide Economic Impacts of New Generation from Wind, Coal, and Natural Gas in Arizona, Colorado, and Michigan.* May 2006. NREL/TP-500-37720.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Executive Services and Communications Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE *(DD-MM-YYYY)*
August 2009

2. REPORT TYPE
White Paper

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
NREL Response to the Report *Study of the Effects on Employment of Public Aid to Renewable Energy Sources* from King Juan Carlos University (Spain)

5a. CONTRACT NUMBER
DE-AC36-08-GO28308

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
E. Lantz and S. Tegen

5d. PROJECT NUMBER
NREL/TP-6A2-46261

5e. TASK NUMBER
SAO9.2011

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

8. PERFORMING ORGANIZATION REPORT NUMBER
NREL/TP-6A2-46261

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*
Job generation has been a part of the national dialogue surrounding energy policy and renewable energy (RE) for many years. RE advocates tout the ability of renewable energy to support new job opportunities in rural locations and the manufacturing sector. Others argue that spending on renewable energy is an inefficient allocation of resources and can result in job losses in the broader economy. The report *Study of the Effects on Employment of Public Aid to Renewable Energy Sources*, from King Juan Carlos University in Spain, is one recent addition to this debate. The report asserts that, on average, every renewable energy job in Spain "destroyed" 2.2 jobs in the broader Spanish economy. The authors also apply this ratio in the U.S. context to estimate expected job loss from renewable energy development and policy in the United States. This white paper discusses fundamental and technical limitations of the analysis conducted by King Juan Carlos University and notes critical shortcomings in assumptions implicit in the conclusions. The white paper also includes a review of traditional employment impact analyses that rely on accepted, peer-reviewed methodologies, and it highlights specific variables that can significantly influence the results of employment impact analysis.

15. SUBJECT TERMS
NREL; renewable energy; job generation; RE; King Juan Carlos University of Spain; U.S. jobs; employment; analysis; job impacts; job development; energy sources; manufacturing; Eric Lantz; Suzanne Tegen

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
Unclassified	Unclassified	Unclassified	UL		19b. TELEPHONE NUMBER *(Include area code)*

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

F1147-E(10/2008)

SUPPLEMENTAL TESTIMONY OF DR. ROBERT MICHAELS, SENIOR FELLOW, INSTITUTE FOR ENERGY RESEARCH, DATED JUNE 28, 2010

I. Introduction

My name is Robert J. Michaels. I am Professor of Economics at California State University, Fullerton and Senior Fellow at the Institute for Energy Research. Other biographical data appear in the direct testimony I presented at the Committee's June 16th hearing. Near the conclusion of that hearing, Dr. David Mooney of the National Renewable Energy Laboratory (NREL) responded to a question on job creation by investments in renewable power. He stated that NREL staff had produced research purporting to show that investment in renewables indeed created employment opportunities.[1] I responded that I was aware of other studies, in particular one from Spain, purporting to show that renewables were responsible for the destruction of jobs, because building them entailed very high capital costs per worker. Dr. Mooney responded that NREL researchers had refuted that report. I responded that NREL's computer model of job creation was at best an inappropriate research tool. Regardless of the data used to run it, the model's mathematical structure guaranteed that the only possible outcome was job creation. It was then agreed that Dr. Mooney would give the committee a copy of NREL's response to the Spanish study, and that I would provide support for my assertions about the inappropriateness of NREL's model. This testimony responds to that request.

This testimony makes and documents three basic points:

1. No matter what numerical data is input into NREL's model, the only result it can possibly produce is that renewables result in job creation. With job creation its only possible finding, the model is valueless for evaluating any claims about either job creation or job destruction. NREL is well aware of this weakness, but continues using this model despite the availability of less-flawed alternatives.
2. NREL's claim that its method is "traditional" is insupportable, and its model is in no sense a typical tool for analyzing job creation. Its primary author was not an economist, and the model has no foundation in the peer-reviewed economics literature. Its structure and findings have also not been presented in refereed economics journals, despite abundant opportunities for NREL staff to present them to the economics profession.
3. Despite its use in analyzing numerous renewable projects, NREL has produced no publicly available studies that compare its predictions of job creation with the actual outcomes of those projects. There are good reasons to expect that the model's predictions will in fact be far off the mark.

This testimony does not address the study brought up at the hearing whose authors found job destruction resulting from renewable investments in Spain.[2] The Committee specifically requested backing for my claim that NREL's method of calculating job creation is fundamentally flawed, and these flaws exist independently of whatever other research might exist. NREL's critique of the Spanish study is primarily devoted to comparisons between its research methods and NREL's, and in particular it provides no figures that might usefully be compared with the Spanish study's numerical estimates of job destruction.[3] To my knowledge, neither of the two studies has been subjected to the type of peer review process normally required for publication in professional economics journals.[4]

II. The structure of NREL's model guarantees that its only possible finding will be job creation.

NREL's "JEDI" (Job and Economic Development Impact) model is an "input-output" system. At a conceptual level, it can illustrate interdependencies of production in various sectors of the economy and their possible effects on employment and incomes. As implemented in JEDI, consider a planned renewable project. The builders

[1] The discussion can be found at approximately 1 hour, 25 minutes into the session video.

[2] Gabriel Calzada Alvarez et al, *Study of the Effects on Employment of Public Aid to Renewable Energy Sources*, Universidad Rey Juan Carlos, March 2009. *http://www.juandemariana.org/pdf/090327-employment-public-aid-renewable.pdf* The Committee did not ask me for any evaluation of that study.

[3] Eric Lantz and Suzanne Tegen, "NREL Response to the Report *Study of the Effects on Employment of Public Aid to Renewable Energy Sources* from King Juan Carlos University (Spain)," White Paper TP-6A2-46261 (Aug. 2009), 4. (subsequently cited as Lantz and Tegen)

[4] I am familiar with this process, both as author of peer-reviewed articles and as Co-Editor of *Contemporary Economic Policy*, a peer-reviewed official publication of Western Economic Association International.

must purchase construction materials and services. The funds flow to workers on the project (a "direct" effect) and ultimately to those employed by suppliers of materials (an "indirect" effect). The increased demand for building materials may require that suppliers expand and hire more workers, and quite possibly those who supply the suppliers may also need to do so. The various workers spend their new incomes on consumer goods and services, which may also expand those industries. The cumulative effect is that of a "multiplier" in which spending to build the renewable leads to expansions of output and employment in numerous other industries. Summing all of the induced changes yields a figure for job creation.

The only possible outcome of this model is job creation. Both the initial expenditure on the renewable and all subsequent rounds of respending can only increase demand for construction materials, consumer goods, and workers in all of these industries. There is nothing in the model that could conceivably decrease employment or output in other sectors of the economy. Any project considered by JEDI, no matter how efficient or inefficient as a source of electricity, will show a positive effect on employment. That increase may be large or small, but we can be certain that it will not be negative.[5]

JEDI's plausibility depends heavily on unrealistic assumptions. If these assumptions are untrue, the picture becomes far more complex and ambiguous. Begin by asking where the workers come from. Unless there is a large pool of long-term unemployed people with just the right skills and experience, the new workers (in both construction and in supplier industries) must largely be attracted from other jobs. The net effect on employment may still be positive, but only in exceptional circumstances (not yet shown to hold for renewables) will a large percentage of the employees be taken out of long-term unemployment and jobs truly be "created." Again, NREL has admitted so much, saying that JEDI "does not account for potential constraints on labor and money [i.e. capital] supplies." Further, it "assumes there are adequate local resources and production and service capabilities to meet the level of local demand identified in the modeling assumptions."[6] It is not enough to have the right numbers and types of workers in the area—to actually create jobs on a net basis they must also be long-term unemployed.

Authors of studies using JEDI acknowledge that it "offers a gross analysis rather than a net analysis; that is, the model does not account for the net impacts associated with alternate spending of project funds."[7] A "gross analysis" is one that disregards the fundamental economic concept of opportunity cost. JEDI treats the renewable like a proverbial "free lunch," a gain to the economy for which nothing need be sacrificed.[8] Many other effects might reduce job creation or possibly turn it into destruction. JEDI's creators have noted that "the JEDI model does not factor in costs to consumers," which can be important because higher energy bills mean fewer employment slots in other industries where consumers do not spend. They also note that "[f]luctuations in different technologies (e.g., natural gas prices) may make construction of a new power plant price prohibitive," i.e. that the cost of increasing employment (assuming that it happens) may be too high to warrant construction of the renewable.[9]

JEDI's creators recognize that the net effect of increased renewable investments on employment is ambiguous. On occasion they have cited the works of others who

---

[5] Note that the effects on employment will be largely transitory. After they are finished the construction workers (and workers in supplier industries) will receive no more income from it and will be unable to budget for higher spending. There will, of course, be some workers who obtain long-term employment operating and maintaining the plant.

[6] NREL, The Jobs and Economic Development Model (JEDI), About JEDI and Frequently Asked Questions (FAQ), July 2008, unpaginated. *http://www.nrel.gov/analvsis/jedi/pdfs/jedi_manual_0708.pdf*

[7] Sandra Reategui et al, "Generating Economic Development from a Wind Power Project in Spanish Fork Canyon, Utah: A Case Study and Analysis of State-Level Economic Impacts," Utah State University, DOE/GO-102009-2760, App. B. *http://www.windpoweringamerica.gov/pdfs/economic_development/2009/ut_spanish_fork.pdf*

[8] There are variants of JEDI used for (e.g.) comparisons between investments in coal-burning generators and wind turbines. Reports based on them often turn opportunity cost reasoning on its head. Thus we see claims that a wind unit is to be preferred because it requires more workers to build and operate than a similarly sized coal unit. By that reasoning, some other technology that required still more workers than the wind unit would be even better. In reality, the extra workers are an increased cost and not a benefit—employing them here means sacrificing more of the economy's alternative outputs than necessary. Eric Lantz and Suzanne Tegen, *Variables Affecting Economic Development from Wind Energy*, NREL Conference Paper, NREL/CP-500-43506 (June 2008).

[9] Both statements are from Suzanne Tegen *et al*, *Jedi II: Jobs And Economic Development Impacts from Coal, Natural Gas, And Wind Power*, Poster Presentation at 2006 Windpower Conference, Pittsburgh. *http://www.windpoweringamerica.gov/pdfs/wpa/poster_2006_jedi.pdf*

use more complex models capable of forecasting both job creation and job destruction. Such models can incorporate factors that include responsiveness to higher power prices, reductions in employment in conventional power, and the "crowding out" of other capital spending by increased investment in renewables. Sometimes such models produce negative effects on employment in the long run.[10] NREL's researchers are thus aware that other models that capture important complexities are available (or they could surely create their own). For unknown reasons, they instead persist in using a model that can produce only the single result of job creation from renewables.

III. NREL's model is neither "traditional" nor mainstream, and claims of its professional credibility are without foundation.

Despite JEDI's unrealistic structure, Lantz and Tegen have claimed that it uses "traditional methods." Specifically, those methods applied in jobs and economic impacts analyses "rely on input-output models to estimate job creation or loss."[11] By this standard, JEDI is hardly a traditional model—instead of estimating "job creation or loss" it can only produce estimates of creation. Perhaps the most convincing evidence that JEDI is far from the mainstream is its near-total absence from the peer-reviewed economics literature. One would expect researchers who believe JEDI is scientifically useful to publish its results in academic journals, where its structure and findings could be evaluated by a wider readership than is enjoyed by NREL reports.

JEDI itself was not created by a professional economist, but by an independent consultant who holds a Master's degree in Community and Regional Planning and whose biography includes no peer-reviewed articles in economics journals.[12] I have found no other NREL employee associated with JEDI who has published applied research based on that model in peer-reviewed economics journals.[13] Further, renewables are not economically unique. If JEDI's structure is indeed useful, one would expect to see variants of it used to analyze other governmental policies and private investment projects. Models structured like JEDI might be particularly valuable for evaluating the consequences of the numerous stimulus programs that have been enacted during the current recession, but I am not aware of any such studies that have used them.

IV. There are no publicly available reports comparing JEDI's predictions with actual project performance.

NREL is right in saying that models like JEDI can at best be approximations that are far from comprehensive. One JEDI-based report puts readers on notice that JEDI "is not intended to be a precise forecasting tool. Rather it provides a reasonable profile of how investment in a wind project may affect a given economy."[14] Unfortunately, that statement gives no guidance regarding reasonableness. How could one possibly determine which profiles are "reasonable" without making comparisons between JEDI's predictions and post-project reality? More subtly, what is a "given" economy? A substantial number of JEDI-based studies appear to have been performed for localities to forecast local tax revenues and employment.[15] This is an odd allocation of effort by a Federal laboratory—the fact that a project generates local

---

[10] Lantz and Tegen (at 4–5) in fact cite such studies and results from Europe, but do not discuss the importance of their consequences for their own JEDI findings.

[11] Lantz and Tegen, 4. They supply no references or citations.

[12] NREL contracted with Marshall Goldberg of MRG Associates to construct the model. See Goldberg *et al*, "Job and Economic Development Impact (JEDI) Model: A User-Friendly Tool to Calculate Economic Impacts from Wind Projects," (Preprint, 2004), 2. Goldberg's 2005 biography is at *http://puc.sd.gov/commission/dockets/electric/2005/el05-022/goldbergexhibita.pdf*. Of NREL people associated with the model that I have been able to check, none has any published works in peer-reviewed economics journals. These checks were made using the standard databases JSTOR and Econ Lit. I have not been able to check citations in the more specialized energy literature.

[13] I acknowledge in advance that this search may not have been complete. It was made using the standard databases JSTOR and Econ Lit. A new version of JEDI, known as JEDI !!, retains the same basic structure as the original. See Suzanne Tegen, Marshall Goldberg and Michael Milligan, "JEDI II" at *http://www.nrel.gov/docs/fy06osti/39908.pdf*

[14] Rategui et al, *Op. Cit*. 25.

[15] This has other interesting consequences. In some cases the authors of such studies treat it as a virtue that the immediate area of the project gains most of the benefits. An economist should immediately note the consequences—if the area in which I can trade is small, I will not be able to trade on terms as advantageous as if it is large. Among those who will suffer are distant suppliers who are foreclosed from competing for my business, and ratepayers in the area who will pay more for their plant than they had to.

employment and tax revenue carries no implications that such benefits will expand to a wider region or to the entire nation.

The issue of localized benefits becomes particularly important if a substantial fraction of project-related jobs will in fact be filled by persons who are already otherwise employed. NREL could perform a genuine service and possibly increase public confidence in its activities by looking at the actual origins of people who fill new job slots associated with renewables projects. Such a question requires no complex modeling at all. Just identify the newly created positions, interview the people filling them, and find out whether they came from other employments, and where those employments may have been. The more of them came from employment elsewhere, the fewer the jobs the project actually created.[16] Funding such studies would be a minor fiscal burden, and they could easily be integrated with other NREL research programs. Other governmental modeling efforts are under continuous scrutiny for the accuracy of their predictions. For example, elsewhere in the Department of Energy those responsible for the National Energy Modeling System (NEMS) produce the Energy Information Administration's *Annual Energy Outlook* forecast. With that forecast come annual retrospective reviews of its predictions that will be used to help improve the future predictive powers of NEMS.[17] Surely one can envision such retrospective studies that might sharpen the logic and improve the forecasting abilities of JEDI.

V. Conclusions

NREL's models of job creation by renewables are inadequate in virtually every dimension. As a bare minimum, any such model should be able to forecast both increases and decreases in employment depending on the data input to it. JEDI, however, can only generate increases in employment. For unclear reasons its authors chose not to acknowledge the fact that the only truly new jobs created by renewables will be held by those who were not employed elsewhere prior to starting them. Implicitly, for truly new jobs to match JEDI's "gross" figures, there must be massive numbers of long-term unemployed persons with just the right types of skills. This picture hardly corresponds with the realities of unemployment, even in today's recessionary economy. JEDI is a singular model that is far from the mainstream of economics, whose authors have for unknown reasons apparently chosen not to present it in peer-reviewed economics journals. It remains open to potential improvements that could make it both more trustworthy and applicable to analysis of projects other than renewable powerplants. Doing so, however, would require that its predictions be tested against reality and its structure modified as necessary to minimize the variance between them. In its current form, however, JEDI can only mislead and produce a far-too-optimistic picture of the real consequences of investment in renewables.

[16] There can be further problems for researchers, but they are probably of second-order importance relative to the basic calculation. For example, It is possible that the jobs formerly held by newly-hired renewables workers would have vanished soon after they quit, leaving them long-term unemployed were it not for the renewables. Estimating the numerical importance of phenomena like these will be an additional task for those making the comparisons.

[17] See, for example, EIA, *Annual Energy Outlook Retrospective Review: Evaluation of Projections in Past Editions* (1982–2009) DOE-EIA-0640 (2009), Mar. 2010. *http://www.eia.doe.gov/oiaf/analysispaper/retrospective/retrospective_review.html*

THE INSTITUTE FOR ENERGY RESEARCH: THE NREL'S FLAWED WHITE PAPER ON THE SPANISH GREEN JOBS STUDY

The NREL's Flawed White Paper on the Spanish Green Jobs Study

By: The Institute for Energy Research (IER)

September 3, 2009·

In the debate over "green jobs," one of the most damning pieces of evidence was a blockbuster March 2009 study [.pdf] by researchers at King Juan Carlos University in Madrid. The study—whose lead author, Gabriel Calzada Álvarez, has a Ph.D. in economics and teaches Environmental Economics—agreed with President Obama and others who single out Spain as the leader in aggressive government funding of renewable energy. However, the study parted ways with President Obama when it revealed that Spain's experience has been a disaster, where 2.2 private sector jobs were destroyed for every "green" job created by government subsidies.

Not surprisingly, proponents of spreading the wealth around from taxpayers to the producers of renewable power did not care for the Spanish study. When Dr. Calzada visited the United States to publicize his team's findings and warn Americans not to repeat Spain's mistakes, the usual ad hominem attacks came forth. Now, the National Renewable Energy Laboratory (the "renewables" part of the Department of Energy) has recently issued its own critique [.pdf] of the Spanish study.

To its credit, the NREL critique focuses on the Spanish study itself, rather than casting aspersions on the economists who wrote it. But here too the critics fall flat on their faces, making arguments that are at times contradictory and often downright silly. Because of space constraints we can't discuss *every* (unfounded) objection, so we'll just focus on three of the "Fundamental Limitations" as alleged by the NREL, and we'll conclude by mentioning the first of the alleged "Shortcomings in Assumptions" just because it's too funny to ignore.

The first bulleted "Fundamental Limitation" concerns the measurement of job losses:

The metrics used in the Spanish study are not jobs impact estimates. *The primary conclusion of the report is that the Spanish economy has experienced job loss as a result of its RE [renewable energy] installations. However, comparing the RE subsidy per job with the Spanish economy's average capital per job and average productivity per job is not a measure of job loss. Traditional methods for estimating jobs and economic impacts are discussed below.*

The Spanish study gauged the cost of government subsidies through different techniques, both of which yielded the result that every "green" job created by the government came at the expense of 2.2 jobs in the private sector. In the first calculation, the Spanish study took the subsidies per worker in the renewables sector, and compared it to the (much lower figure) of the capital invested per worker in the Spanish economy. The comparison showed how many jobs were created in the subsidized renewables sector, versus how many jobs the same amount of resources could support in the private sector. In the second technique, the Spanish study compared the annuity value per worker of the expected stream of government subsidies, and compared it with the average productivity of workers in the private sector. In both techniques, the answer was the same: a given amount of resources supported 2.2 times as many jobs in the private sector, as in the government-supported renewables sector.

This result should not be surprising, since the political process is hardly an efficient way to ration resources. In some cases, the subsidies were outrageous—since 2000, the Spanish government spent more than one million euros per job created in the wind industry. On average, the government spent some 571,000 euros per "green" job. This is clearly an example of economic inefficiency, as the actual workers were certainly not taking home such lucrative paychecks.

Incidentally, the "traditional methods" cited by the NREL for estimating the impact of subsidies often completely ignore the *downside* of government involvement. As IER documented in its own study, "Green Jobs: Fact or Fiction?", some of the leading studies promoting green job investment commit this basic fallacy. They use apparently sophisticated "input-output models" to count up all the jobs fostered in various sectors by big government spending, but they completely *ignore* the impacts of the taxes and deficits needed to *fund* these grandiose projects. That money comes from *somewhere*, and the source is taxpayers' incomes, now or later. The economic concept of "opportunity cost"…what one could have done with the money if the government had not snatched it…appears lost on the authors.

In reality, no one can know exactly how many jobs Spain would now have, had its politicians not squandered so much money on green boondoggles. No model can show us with certainty what the Spanish economy looks like in that alternative universe. But the virtue of the Spanish study—in contrast to the ones put out by "progressive" US think tanks—is that it acknowledged that government money has to come from somewhere, and so it necessarily carries a cost in terms of reduced capital available for the private sector.

Another alleged "Fundamental Limitation" involves export potential:

The report fails to account for technology export potential. *Robust RE technology exports can greatly affect economic impacts of renewable energy…With its proactive RE policies, Spain is already a major exporter of renewable energy equipment…If global demand for RE technology increases, Spain's early investment could allow it to capitalize on a global market for RE technology, which would contribute further to the Spanish economy.*

We really have to wonder if the NREL team considered the implications of what they're saying here. It sure *seems* as if they are saying: "Yes, the Spanish government's spending didn't create many jobs in Spain. But if governments *all over the world* subsidized Spain's renewables sector, then we would we see strong job growth." In any event, we point out that this justification only applies to the pioneers in the field—namely, Spain. It can't be true that *all* countries "capitalize on a global market for RE technology" by early investment. If anything, this NREL bullet point shows that the United States should expect a *worse* return (measured in job creation) from its own subsidies to renewables, since—as NREL explains in the quotation above—the Spaniards already have such a head start and will export their renewables abroad as global demand increases.

Another of the Spanish study's alleged "Fundamental Limitations" concerns the apparently wonderful innovation spurred by Big Government:

The study ignores the role of government in facilitating growth of valued new industries. *Governments invest in renewable energy technologies to promote the growth of the industry as a whole. Emerging RE technologies have not achieved levels of maturity and economies of scale that traditional technologies have; nor have they benefited from years of public and private investment.*

First, plenty of renewable energy technologies have received massive government support, for decades. Tax incentives for solar generation originated with the Energy Tax Act of 1978 (Public Law 95-618), which established a business energy tax credit of 10 percent of investment in solar technologies. It became permanent with the passage of the Energy Policy Act of 1992. That legislation also introduced the production tax credit (PTC) for wind, which has expired and been reinstated several times since its origination. Most recently, the Emergency Economic Stabilization Act of 2008 (Public Law 110-343) extended the PTC through 2012, and President Obama has directed that $83 billion of the $787 billion economic stimulus plan go to prop up green technologies which otherwise fail consumer market tests. The Energy Information Administration in a report cited by NREL has shown that in fiscal 2007, total Federal subsidies for electric production from either solar or wind power are almost 100 times more than the subsidies for electric production from natural gas and petroleum liquids on a watt-for-watt basis.[1] The reason they have not achieved "levels of maturity and economies of scale that traditional technologies have" is that *they are grossly inefficient and costly*. The market has thus far relied on traditional energy sources such as coal, oil, and natural gas because they are the most efficient means of delivering power to consumers in convenient forms and at low prices.

Yes, government can artificially create entire new industries if it's willing to throw enough taxpayer money into the boondoggles, but politicians are hardly the people who should be picking winners and losers in the energy sector. Relatively unregulated sectors, such as the computer and cell phone industries, show the rapid-fire innovation and cost-cutting of free market capitalism. It is the most heavily regulated and politicized sectors, such as education and health care, that suffer from stagnation and wasted resources.

Finally, we turn to one of the alleged "Shortcomings in Assumptions" brought up in the NREL critique:

The authors assume that a dollar spent by the government is less efficient than a dollar spent by private industry and that it crowds out private investment. *Government spending may be more or less efficient than private investment. To the extent that government spending is a correction for market failures (e.g., existing fossil fuel subsidies, environmental externalities), it is less likely to represent an inefficient allocation of resources. Furthermore, there is no justification given for the assumption that government spending (e.g., tax credits or subsidies) would force out private investment. This assumption is fundamental to the conclusion that Spain's renewable energy policy has resulted in job loss.*

In the first place, we are discussing tangible job creation. Even if it were true that greenhouse gas emissions represented a "negative externality" because of manmade global warming, government policies to combat this outcome would register as job destroyers. The "efficiency" would kick in because of the theoretically milder climate inherited by future generations.

The Spanish study was not factoring in all the pros and cons of environmental benefits versus economic losses, because *the proponents of a "green recovery" argue that we can have our cake and eat it too*. When President Obama and others point to Spain as a "success story" for government funding of renewables, his message was *not* that the Spanish economy shed jobs, but gained the comfort of knowing their grandchildren would live in a cooler world. No, the message has been that the Spanish subsidies to renewables were *good for the economy*. And as the Spanish study and its worst-in-the-EU economic performance has shown, this is simply not the case. The Spanish government itself is bowing to the economic realities of its mistake.

As for the NREL's complaint that "there is no justification for the assumption that government spending…would force out private investment," we have to ask: Where does NREL think the government's money comes from, the Tooth Fairy? The assumption that money itself is renewable is a common governmental misconception, aided no doubt by annualized budget awards which simply appear from the thin air of Washington. The awards get larger if one can justify an agency's existence.

Yes, yes, Paul Krugman and other leading Keynesian theorists can come up with fancy mathematical models purporting to show that there really is a free lunch during a severe economic recession, so that government deficits actually promote job growth on net. Whether or not one agrees with Krugman is irrelevant. The Spanish study looked at the evidence from the year 2000 onward, well before the current crisis hit. Furthermore, the proponents of massive "green" spending programs don't intend for the funding to dry up once the global economy has returned to normal. So when the NREL asks for a justification for assuming that government spending reduces private investment, we simply remind them, "Money doesn't grow on trees." It's ironic that we have to point this out to people with impeccable environmental awareness.

In conclusion, we can do no better than to update Professor Calzada's pointed question he posed in testimony to US Congress: With Spain's July unemployment running at 18.5% versus the US rate of 9.4%, why in the *world* would we want our policymakers looking to Spain for tips on job creation?

○