Written Statement of

Dr. David Mooney

Director

Electricity, Resource and Building Systems Integration Center

National Renewable Energy Laboratory

Presented to the U.S. House of Representatives

Committee on Science and Technology

Subcommittee on Energy and Environment

June 16, 2010

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].

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.

---

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

[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 <file:///G:\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 <file:///G:\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

Impact of Wind Forecasts on Grid Operating Costs

	Peak Load	Wind Generation	Annual Operating Cost Savings: SOA Forecast vs. No Forecast	Annual Operating Cost Savings: 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.

<u>How can solar and wind forecasts be improved?</u>

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 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 US 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.

<u>What are Potential Roles of the Private and Public Sectors?</u>

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.