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House Science and Technology Committee
Energy and Environment Subcommittee
Hearing on Real-Time Forecasting for Renewable Energy Development

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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:

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1 Regulation is generating capacity under automatic generation control that is dispatched on a 4-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

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

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of energy in the real-time market to address longer-term imbalances that are not addressed by regulation.

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:

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

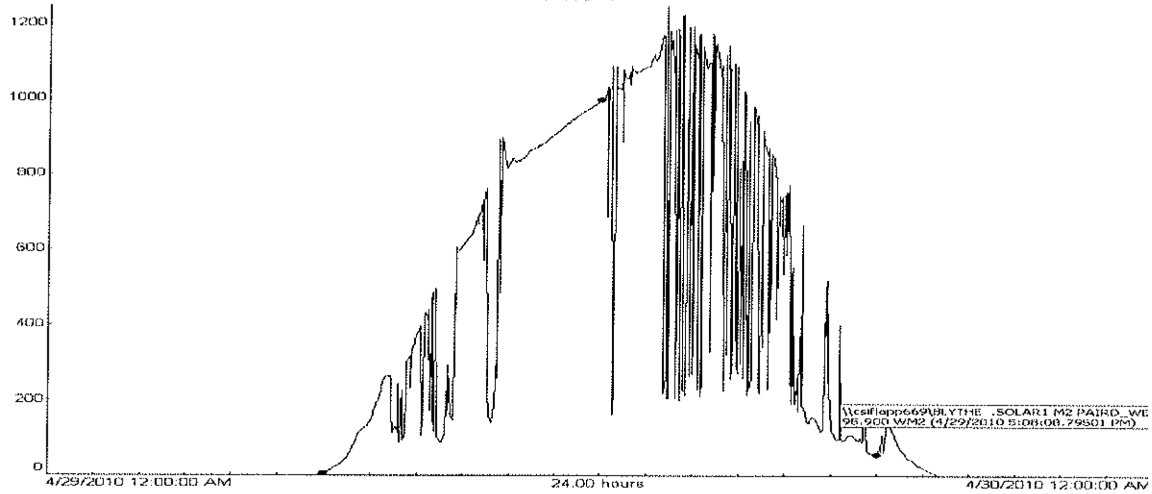
2 "Western Wind and Solar Integration Study" (May 2010) at http://www.uwig.org/wwsis_final_report.pdf.

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.

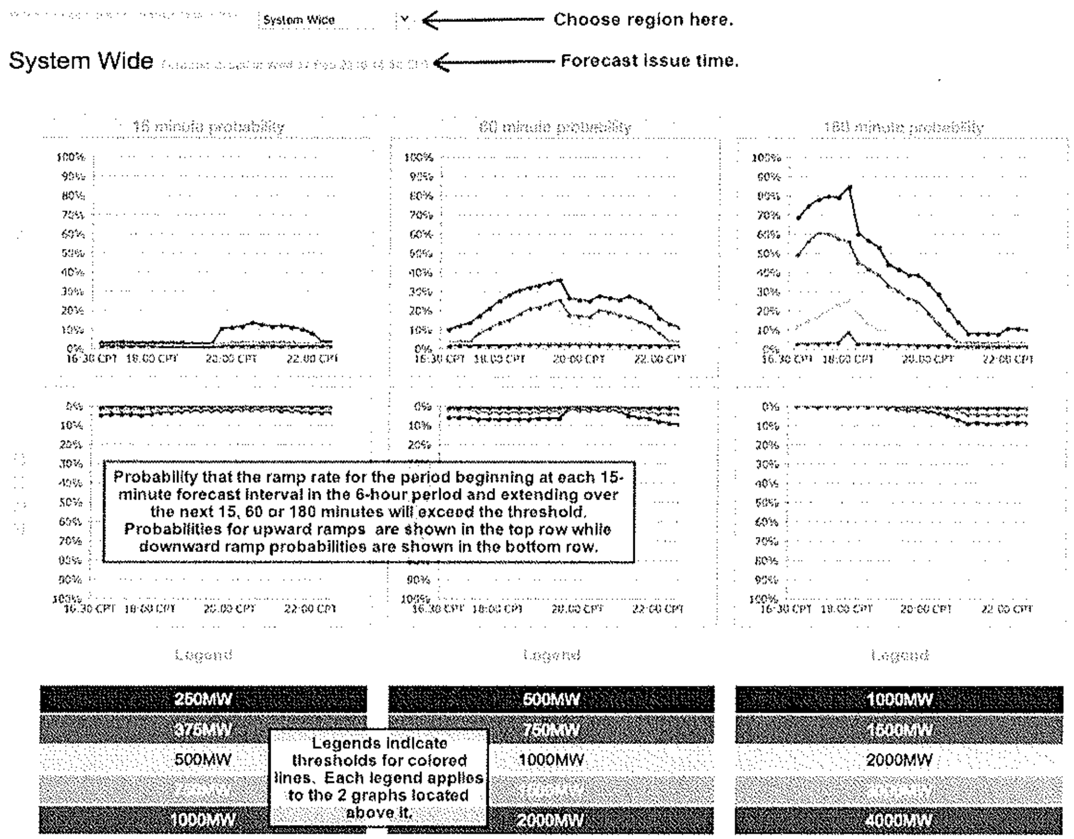
The severity of renewable resource ramping events is highly dependent on both the weather causing the ramp and geographic diversity of renewable resources within the ISO. For example, wind generators shut down when wind speeds exceed safe operating limits. As a result, a big storm front with high wind 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 ERCOT, 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.

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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.