Summary and Recommendations from the Staff Workshop on Research Needs for Renewable Energy Forecasting

On January 17, 2017, California Energy Commission staff held a workshop entitled “Research Needs for Renewable Energy Forecasting”. The objective of the workshop was to obtain feedback from different experts, utilities, operators, stakeholders, and the public on the opportunities to improve forecast quality, cost, and usefulness in California. Feedback and suggestions gathered from stakeholders during this workshop will be used to inform the implementation of renewable energy forecasting projects, and to prepare and refine funding initiatives to be included in the Electric Program Investment Charge (EPIC) 2018-2020 Triennial Investment Plan.

The workshop was organized into two parts:

- Panel I: *Renewable Energy Forecasting Research Opportunities and Solutions to Support Modern Grid*
- Panel II: *Forecasting Gaps, Building a Sensor Network, and Managing Costs*.

Panel I: **Renewable Energy Forecasting Research Opportunities and Solutions to Support Modern Grid**
Panel I was comprised of two parts, presentations and a moderated discussion with expert panelists from different research institutions. This panel brought together renewable energy forecasting researchers and developers to discuss forecasting quality and future forecasting solutions in the pipeline, including identification of research opportunities on data sets, and forecasting instruments and models for attaining an efficient power system operation in California.

Facilitator: Melinda Marquis, National Oceanic and Atmospheric Administration - Earth System Research Laboratory
Panelists: Case van Dam, University of California Davis
Carlos Coimbra, University of California San Diego
Frank Monforte, Itron, Inc.
Ben Norris, Clean Power Research
John Zack, AWS Truepower
Aidan Tuohy, Electric Power Research Institute
Rob Farber, Independent Consultant

<u>Main comments to Panel 1 questions</u>:

1. Is there a particular forecast horizon relevant for the California energy market that is not addressed by forecasting models you have developed?
    - There is a need to understand the benefits of improving forecasting in certain horizons. Those benefits change depending on the time horizon, for example, when improving forecast day ahead we deal with economic efficiency because we can make informed decisions of what operators can use; this is due to the nature of electricity markets. Improving forecast hour(s) ahead or real time, resolves reliability issues, reduces area control error, and reduces cost caused by ramps and shortage of capacity. Preliminary results conclude that probabilistic forecasting can be better for day ahead and short term horizons can be better for ramp forecasting.

- There is a need for five minute level ramp forecasts on the load side. In order to make it possible, there is a need for a five minute ramp forecasting model for solar generation, storage, etc.
- Need for a statistical framework that combines the solar, wind and load forecast uncertainty with respect to a common set of weather concepts and stations.

2. What are the biggest challenges in increasing the accuracy of renewable energy and load forecasting at utility and distribution level?
    - Ramps are seen as the biggest challenges because they are driven by small scale atmospheric features – which currently need much more data.
    - Need for better intra-day short time scale improvement. It is a combination of better modeling, measurement, and a focus on small scale features to get five or fifteen-minute ramp rates that in larger ramps can cause difficult problems for system operations and other users of the forecasts.
    - Solar has tools, such as satellite or sky imagers, that gives a good view of the phenomenon that causes the variability of the path and that you are able to track, but models that anticipate change is still needed.
    - Persistence is good at the short term, but as it pertains to ramps, persistence is not a good forecasting tool because per definition, ramps deviate significantly from Persistence. In short term, we need to identify what tools can be used to get more data.
    - There is currently no tool for mapping out small scale wind features.
    - Ramps are often not weather related and there is a need for more information to predict them.
    - There is an issue of communication between plants and grid operators.
    - Another challenge with load forecasting is the need to understand what is occurring in behind-the-meter (BTM) generation and pairing with the current demand for power.
    - There is a lack of real-time metering of demand, BTM solar generation, BTM storage, storage etc., as well as a lack of understanding of customer behavior and how it is affected by the adoption of behind the meter generation and storage.
    - There is the challenge of understanding distributed solar and the link between solar generation, electric vehicles, etc. and what factors are linked with weather or consumer behavior.

3. What are the research opportunities to increase the accuracy of forecasts at higher temporal resolution, including at longer time horizons?
    - Improve BTM solar generation forecasts at the five minute level of temporal resolution for forecast horizons of up to two to four hours ahead, develop a statistically integrated framework for producing a net load uncertainty, have a band forecast at the five minute level of temporal resolution for forecast horizons up to 48 hours, and move towards ramp rates. The new way of thinking is to move away from worry about annual energy consumption and peaks, and start thinking about ramp rates and how we operate the energy system.
    - Build operations around what forecasting is trying to accomplish.
    - Understand how to move operations to deal with issues that are trying to be solved.
    - More research can be done in solving seasonal or sub-seasonal challenges for longer time horizons.

- Assemble probabilistic forecasts and real time grid forecasting where real-time grid forecasting is to fine tune forecast as the goal, with better telemetry. It can also help to address seasonal variation. Since the weather and climate is changing; the model needs to follow the temporal changes in shorter periods and keep up with changing weather and climate.
- Define accuracy so the research has a clear goal to achieve. It is important to identify the most important attribute of the forecast to drive the research and help to identify the correct type of data and model to achieve the goal.

4. Two important factors that contribute to the quality of forecasting are higher-density and high-quality measurements collected from instruments that are rigorously calibrated and well-maintained. Can you share your ideas on research opportunities for these two areas?
    - Need to know how best to combine advantages of satellite and ground measurements. This shows the importance of input selection and the benefit of using a statistical model because it is constantly evaluated.
    - Using satellite imagery with low cost sensors and meshing them is the best way to get information.
    - There is still a need to develop smart sensors that communicate on a network and work independent of the power plant.

5. Next generation satellite Geostationary Operational Environmental Satellite-R Series (GOES-R) will probably lead to more incremental improvements in forecasting throughout California. The improvements of GOES-R are related to the repeat time and the number of bands. This will improve the ability for short-term forecasting especially for fast-developing convective cloud systems in eastern California. Can you mention the specific improvements in your forecasting model with the utilization of GOES-R products? In general, what will be the GOES-R products' role in improving forecast capabilities in California and how will it be integrated in the current forecasting efforts?
    - There will be improvements in shorter-time periods with the GOES-R updates, as well as small scale features.
    - There is an opportunity to pair that data in the High Resolution Rapid Refresh (HRRR) model to potentially improve forecasting.
    - New information from the GOES-R allows operators to monitor and anticipate what drives short term ramp events. GOES-R will increase temporal resolution from 30 minutes to five minutes which will improve real time market forecasts, spatial resolution will be four times that of GOES-West which will improve small cloud and cloud edge detection, as well as improved navigation and directional stability for more accurate cloud placement, more spectral channels for improved cloud phase retrievals, and improved Aerosol Optical Depth (AOD) for greater local accuracy.

Panel I Public Questions & Answers – What are the research needs for varying density measurements or new improvements in measurements?

- UCSD is currently working on a project researching the benefits of a high density network of sensors and finding how much resolution is lost when one of the sensors is turned off in the network.

- 5 minute variability etc., high density is more important. With a one km^2 sensor, it is more accurate for what is happening in that area but will not provide any information as you move across the solar field. There is lost correlation between that sensor and points farther from it.
- There is a need for new and smart instruments to communicate and reduce bias. Wind variability suffers from a lot less measurement density.

Panel II: **Forecasting Gaps, Building a Sensor Network, and Managing Costs**
Panel II was also composed of two parts: individual presentations followed by a moderated discussion with utilities, operators, and users. This panel focused on the forecasting needs of grid operators, deployment of sensors to improve grid monitoring, adjustments to operational practices to manage uncertainty, and potential costs and values of improved forecasting and sensor deployment. Discussion included key anticipated trends that will impact forecasting capabilities and other areas not earlier considered or addressed.

Facilitator: William Shaw, Pacific Northwest National Laboratory – Department of Energy

Panelists: Kevin Clifford, Pacific Gas & Electric
Rick Aslin, Pacific Gas & Electric
Amber Motley, California Independent System Operator
Benjamin Lee, Southern California Edison
TJ Vargas, Sacramento Municipal Utility District
Pjoy Chua, Los Angeles Department of Water and Power
Scott Winner, Bonneville Power Administration
Clinton MacDonald, Sonoma Technology Inc.

Main comments to Panel 2 questions:

1. What forecasting tools do you currently use? Are these tools meeting your current needs, and will they meet your anticipated needs?

    - LADWP: Metrologica Web, the primary tool used for renewable energy forecasting and weather station data, is a secure web based portal that provides forecasting information on wind, solar, and geothermal projects. The data is used as an operation and planning tool that is sufficient in meeting conservative operational changes, but may not address needs in the future.
    - PG&E: For short term forecasting, we use a combination of different weather models with a consolidated approach to determine the accuracy of each model in order to schedule the distributed resources.
        - There is an advantage to having different operational groups use the same weather plan. North American Mesoscale Forecast System (NAM), The Weather & Forecasting Model (WRF), Clean Power Solar Anywhere, the European Model, the Global Forecast System (GFS), and machine learning with data that is available from statistical analysis of the observations of short lead time forecasts are all usable tools.

    - There is a need for field observations with sensors. Going forward, there are opportunities for forecasting the marine stratus and radiation fog because of their accuracy issues in localized management.
- PG&E: Currently using distribution operation forecasting tools in the very short term, using rudimentary tools that rely on local judgment from engineers that look at what load is going to be on a particular circuit for the next day.
    - Tools are used for maintenance planning and don't include specificity over distributed generation.
    - Needs are currently being met with identified use cases, but in the future, other use cases need to be considered. 3-10 year out forecasting would be useful on the operation side.
    - Currently using LoadSEER, a geospatial forecasting model from Integral Analytics, for load forecasting and individual customer adoption models for distributed generation.
- SCE: For energy procurement, tools have been built internally on R or Statistical Analysis Software (SAS). They use a system level forecast from energy procurement groups and aggregate it down to the customer level.
    - There is a mix between internally built tools and the key is aligning those tools and the forecasts. It is difficult to align from system level forecast to granular customer level forecast.
    - The system level is fairly accurate but there is a need for improvements going forward.
    - There is a need for a long term forecasting tool for different levels and types of generation, distributed energy resources (DER), and load – looking for a tool to connect assumptions between forecasting models to make a central forecast hub.
- BPA: They are using EMS and weather and energy prognosis vendors in Germany. From those two forecasts, they create a Super Forecast Methodology to decide which forecast to use.
    - The Super Forecast Methodology is an algorithm that evaluates each hour of the two forecasts for quality over the last seven days, and the best one is published. This allows the vendors to specialize.
- CAISO: Forecasts are used to get the energy schedule. Renewable forecasts are used by market participants as a real time update and forecasts are used for operational awareness and reliability.
    - Currently using large scale forecasts for wind and solar, aggregating data up from behind the meter generation, and numerical weather prediction models and looking at the differences over time.
    - This is meeting current needs but new tools are always good – especially ones using irradiance forecasting values. HERR has different irradiance forecasting methodology in the short term.
    - Irradiance data straight out of the NWP model can be helpful to integrate into other models such as temperature forecasting.
    - There is a need to see actual solar values for rooftop generation.
    - Their anticipated needs emphasize the importance of holistic forecasts for renewables because they are dispatching economically down and it's important

to research the best way to get an accurate forecast without an actual telemetry value. When persistence isn't available, accuracy takes a hit. There is a need to develop a tool that provides a full view without telemetry in certain situations.

2. Forecasting has progressed greatly in the last 5 years, and one of the advancements is that probabilistic forecasting has begun to replace deterministic forecasts. Does your organization use or plan to use probabilistic forecasting models? If yes, is there any special application for the decision?

   - CAISO: Probabilistic forecasting can't be a replacement, but it is a nice tool for markets that are dependent on forecasting accuracy.
   - SMUD: Can't use probabilistic forecasting for real-time; it's more useful for planning. They are currently using probabilistic forecasting to plan to a certain confidence level and building out from that.
   - PG&E: Probabilistic forecasts typically get averaged and turned into a deterministic forecast, but they can be useful for areas in which there isn't a lot of data, like EVs and storage.

3. How does the increase in distributed energy resources change California's forecasting requirements?

   - SCE: There is a need to understand behind-the-meter generation and its impact on the system, how to split the load from generation, demand response programs to understand how customer behavior is changing load profiles, tracking the differences between forecasts and tracing it back to understand assumptions.
   - CAISO: There are big net load drops on sunny days due to an increase in behind-the-meter solar, but low-temperature, cloudy days also have big drops in net load even with less production from behind-the-meter solar. It's difficult to forecast when there are competing forces on the net load that we don't have enough data or visibility to separate.
     - It is important to know how much generation is on the system at any time. Basic interconnection information could be very useful.

4. What is the current scale of sensor deployment on the transmission and distribution grid? What would be the benefits of increasing the number of sensors, and what types of sensors would be the most beneficial?

   - Sonoma Technology: There is a multiyear research study on research grade networks that have sensors assimilating data into models to improve forecasting, and determining the "bang-for-your-buck" sensor network.
     - There is a difficult step in translating improvements in forecasting accuracy to economic benefits, and this is important to know to justify investments in the long term.
     - Looking forward, meteorological data for energy has many applications outside of energy, so having multiple users to support beneficial sensor networks is an important step to ensure long term viability of networks. For example, air quality groups and grid operators can collaborate on installing meteorological sensors and sharing the data.

- SCE: Sensors that are currently being utilized are Advanced Meter Infrastructure (AMI) data, weather information, and Supervisory control and data acquisition (SCADA) to monitor load at different points.
    - There is a plan to put out more sensors on the distribution grid to get more SCADA data to better understand load flow.
    - Have a full roll-out of AMI, but need sensors on behind-the-meter generation.
    - Also looking at advanced analytics with AMI meter data to improve forecasting and advanced analytics for behind-the-meter information to achieve granular data.
    - Need more and better weather sensors to tailor forecasts to micro-climates.
- PG&E: There are already a lot of sensors deployed with a full roll out of AMI meter data. SCADA system is deployed widespread in their network, covering over 70% of line circuits.
    - The question is how to efficiently, and with greater effect, utilize current data before employing more sensors.
    - Sensors like radiometers, sonar, and Lidar can be used with data simulation to understand boundary layer dynamics and can be better integrated into modeling.
- CAISO: There is value in the information from demand response and AMI. CAISO doesn't currently get AMI data. There is not a need for sensors on every house, but there is a need to have a good enough distribution of sensors on houses to aggregate up.
    - There is a need to understand the behavioral changes of the use in the house, and you can't get that granularity to train a model with the data that is currently available.
    - Data is not needed on every house but it does need to be in real time to be effective.
- SMUD: Use cases are important. Can use a sample of high-metered sites to approximate what's happening on the grid.

5. Will the value of better forecasting and additional sensors offset the cost of these measures?

    - SCE: They are planning on putting out more SCADA sensors, but forecasting is an external benefit. The original intent was for reliability issues. Need to think about multiple uses for the technologies and tools to maximize value.
    - SMUD: Looking at how to use solar forecasting to get rid of secondary metering, but operations, energy contracts, etc., have competing requirements that make this difficult. Putting a dollar amount on the value of more sensors and better forecasting is really tricky, but they will be necessary going forward.

6. Are there particular forecast horizons for which you would like to see a significant improvement in forecast accuracy?

    - LADWP: As they prepare for higher renewable penetration, there is an anticipated need for a sub-hourly forecasting tool or something that is capable of 15 minute interval forecasting. They have found that long term weather forecasting isn't very reliable.

    - There is also need for a planning tool to analyze operational requirements and to increase variable energy resources, real time system parameters like variable energy resource forecasts for energy and variability.
    - They would like for the software to improve day ahead generation schedules and include system hedge room and leg room, ramping capability, transmission constraints, unit availability, demand response, on an hour ahead or better resolution.
- SCE: They would like to see the long term forecast horizons to see significant improvements in order to look at the potential of deferring capital upgrades by using DER.
    - Accurate long term forecasting is critical for this. Historically for system planning, forecasted at peak day and what that is going to look like in the future.
    - Load profiles change day to day so it is more important to forecast and plan for all 8,760 hours of the year than for the annual peak.
- PG&E: 5 minute interval in the next one or two hours is important for determining variability for optimization. 15 minute over next 6-8 hours specifically available at the beginning of the work day.
    - For distribution operations, need more situational intelligence with 1-3 day out forecasting horizons.
    - The biggest concern is what is happening tomorrow, especially with DER.
    - There is a need for 3 days ahead forecast horizons to plan for switching of loads or mitigating operating procedures.
    - They are trying to get more reliable forecasts for 3, or 5, or 10 years out but having an hourly resolution for that is a stretch.
    - Better hour granularity on longer term forecast is needed to identify infrastructure investment needs. Spatial granularity is the biggest concern now due to ramping, and how to get a system in place to handle the ramping and how to integrate DER.
- CAISO: Day ahead horizon forecasts are important from a financial perspective for the day ahead market run. When talking about reliability, real time updates are going to become more important. For the market operator, it is important that they get real time updates to ensure market optimization.

7. Can you share any additional insights that would be useful in developing the next generation forecast products?

- LADWP: Given that renewable generation is dependent on weather patterns, more accurate weather forecasting would be helpful for planning. Ideally they are looking for sub-hourly forecasting with a 95% confidence level.
    - This will help energy reconciliation groups to establish economic trends.
- BPA: An important question to ask if why forecasting quality is important and what are the costs associated with forecast error. Create a “forecast error forecast” to identify forecast error.
    - Sandia National Laboratory and UC Davis are producing confidence intervals that are linked to forecast error instead of confidence interval and traces that went into the forecast.
- PG&E: There is a need for 3-5 day horizon for situational awareness.

    - Analog method is helpful with that right now. Self-organizing maps use analog matching of expected patterns to be used in forecasting guidance.
    - Regional and local efforts, like SIPS, for larger scale analogs can be useful for West Coast. There can be more development around WRF solar to operationalize current solar markets.
- CAISO: West Coast WRF solar would be beneficial. Load forecasting accuracy is at an interesting spot on the West Coast because of the higher penetration of behind-the-meter solar, electric vehicles and demand response integration.
    - The question is if the typical load forecasting model supports this type of technology on the distribution system, and what kind of load forecasting model is needed to handle all those different types of data.
    - There needs to be a common effort to identify what a load model needs to look like.
- SMUD: There's good work coming out of IBM and UCSD with solar imaging cameras.
    - There's a lot of growth in customer-side resources like behind-the-meter, demand response and smart thermostats. It's important for utilities to work with customers to install equipment that will be beneficial to both the customer and the grid operator.

8. What are operational changes that would be helpful to make in concert with improved forecasting to manage uncertainty on the grid?

    - LADWP: There is recognition that forecasting is an essential tool, especially with the introduction of renewables into the system. It would be helpful to manage huge swings on the grid if there was a better forecasting tool and to pair up a good forecasting tool with battery storage, and a minimum requirement for flexible and contingent reserves. Quick start as needed.
    - SCE: Improving situational awareness, from a week out to real time, would be helpful. Perform power flow and knowing what is going on, automated decision making to help cope with issues, leverage DER, Distributed Energy Resources Management Systems (DERMS), etc. Operational planning is helpful, but when that fails you need situational intelligence to make the right decisions at the right time.

Panel II Public Questions and Answers

Dr. Rob Farber, Atmospheric Clarity: Do we know enough to identify an end goal? We know where we need to make improvements but how much improvement do we need to make?

- CAISO: In terms of load forecasting, they would like to see accuracy not degrade. Improvement in the forecasting will continue to be important as you have more of a mix in generation, but you need to know uncertainty around that forecast and you need to use probabilistic forecasting to depict that uncertainty. No exact sure number, but accuracy is the end goal.

Key Recommendations for Research and Follow-up Activities:

The following list is a summary of key recommendations from the workshop as selected by staff based upon EPIC program requirements.

1. Identify the uncertainty of the forecast and how that can be used by grid operators to make informed decisions. Grid operators need accurate energy forecasts across ranges of time and spatial scales.
2. Identify and quantify the costs associated with load forecast error.
3. Develop a statistically integrated framework for producing a net load uncertainty and include explicit treatment of behind-the-meter (BTM) solar generation to adequately capture weather-driven load swings for load forecasting that accounts for the impact of BTM storage, time-of-use (TOU) rates, electric vehicle (EV) charging, and demand response activities.
4. Understand the relationship between BTM generation and demand for power with changes in consumer behavior due to BTM adoption.
5. Increase reliability of long-term weather forecasting, develop a long-term forecasting tool with any type of generation (distributed energy resources and load) and coordinate enhanced use of forecasting models to make a central forecast hub.
6. Accurate long term forecasting is critical for understanding the potential of deferring capital upgrades and system planning by using distributed energy resources (DERs) and to understand the effects of DERs to the grid.
7. Develop more accurate prediction of ramps (timing, amplitude, duration). Understand the relationship between ramp rates and how we operate the energy system.
8. Increase data resolution in ground telemetry, and find the ideal combination of satellite and ground measurements to get the best information. More and better data, telemetry, and better utilizing existing sensors, reduce errors and improve forecasting skill.
9. Develop smart sensors that communicate on a network and that can work independent of the power plant.
10. Research on distributed sensor networks that are relevant to improve forecasting skills of the models and enable telemetry intensive forecasting models.
11. Research the best way to get an accurate forecast without a telemetry value and develop tools to do so.
12. Assemble probabilistic forecasts and real-time grid forecasting with better telemetry to increase the accuracy of forecasts at higher temporal resolution. Real-time forecasting is very important for reliability and reduces costs caused by ramps and shortage of capacity.
13. Research high performance computing resources and improved data management, and address the lack of real-time metering of demand, BTM solar generation, BTM storage, storage, etc.
14. Provide means for utility and stakeholder engagement. (e.g., input into research planning and operation use).