U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

The Parker Ranch installation in Hawaii

High Penetration Solar Deployment II Workshop

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Sacramento, CA

June 13, 2011

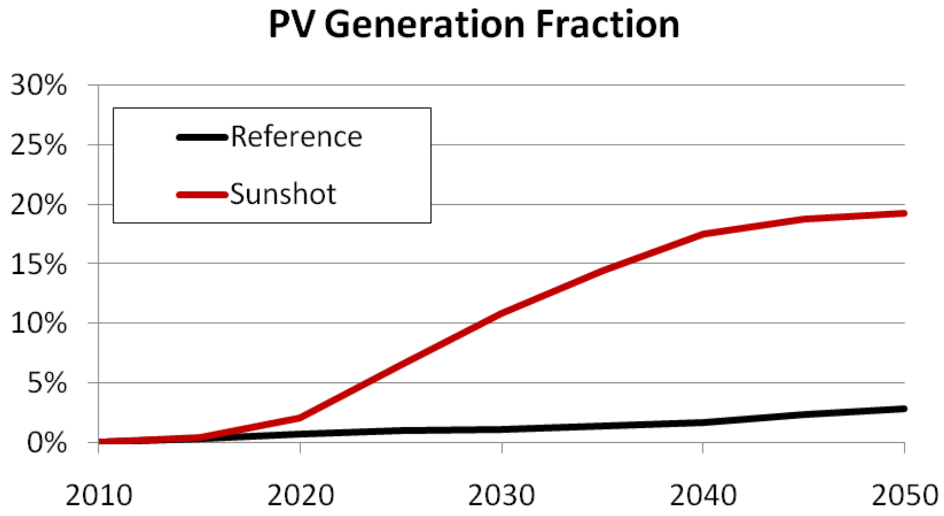
Table of Contents

The SunShot Initiative

- **Price and date targets**
  - 5-6c/kWh installed at the MW scale by end of decade
  - Unsubsidized grid parity in residential and commercial markets by end of decade

- **Transformational technologies**
  - PV Modules
  - BOS
  - Power Electronics

- ***Problem***: Lowering the cost of solar technologies does not necessarily allow greater U.S. market penetration. To reach 4% energy from distributed PV nationwide by 2030, we need to overcome the barriers to high penetrations of solar on the distribution system.



11% PV in 2030
19% PV in 2050

Split between distributed and utility is roughly 35% DG, 65% utility

High Pen I vs II

- High Pen I Three Topics
  - Improved Modeling Tools Development - better model the effects of high penetration solar electricity generation on the electric distribution system.
  - Field Verification of High-Penetration Levels of PV into the Distribution Grid - model, field test, and validate high-penetration levels of PV on prototypical distribution circuits.
  - Demonstration of PV and Energy Storage for Smart Grids - integrate PV and energy storage into Advanced Metering Infrastructure pilot programs.
- Purpose for High Pen II
  - ***High Penetration***: There were very few (if any) feeders with high penetrations of PV on the grid. Now some exist. We need to investigate them and develop lessons learned.
  - ***Holistic Approach***: Very few of the awards are looking at how to utilize all of the tools together into address the issues as a whole.
  - ***Distribution and Transmission***: None of the current awards look at the intersection of distribution feeders feeding power back to the transmission system.
  - ***Storage***: Only one award uses energy storage, and the focus is not necessarily allowing the integration of more solar onto the grid.
  - ***Distribution Feeders***: We need to continually look at more distribution feeders that are representative across the grid and typically used for solar projects.

High Penetration Solar Deployment II

- Very high penetrations of solar on a feeder (50-100%)
- Utilize a complete set of approaches
  - Modeling
  - Forecasting
  - Technology Development
  - Look specifically at the use of storage
- Look at a variety of representative distribution feeders
  - Long feeders with high penetration solar generators located at the end of the circuit
  - Circuits with high penetration solar generators and back-feeding capability
  - Secondary networks
  - Circuits with high penetration solar generators located close to the distribution substation
  - Circuits with highly distributed solar vs. centrally located solar on the circuit.

High Penetration Workshop II

SMUD Sacramento, California

June 13, 2011

Summary of Comments

Workshop Comment Summaries: Definition of High Penetration Level

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- **Definition of High Penetration Level?**

  - Penetration level alone does NOT tell you whether there is an issue.
  - Penetration levels is useful for broad policy/program goals, but NOT for electrical performance of feeders
    - The question is what penetration is low enough to not cause concerns (procedural/rules)
    - Penetration may be better defined by impact (e.g., impact/no impact; low impact/high impact).
    - Defining penetration by voltage-related impact is a possible short-term approach
  - Consensus is that a single percent value (e.g. 15%) is not an adequate metric. There seems to be movement toward using minimum daytime load as a more appropriate metric. However, historical minimum load data may be difficult to obtain and maybe unreliable. Voltage could be used as a performance index.
  - Hosting capacity depends on more than just the penetration level. A comprehensive set of metric should be used including peak/minimum load, feeder topology, location of PV, and regulation schemes, etc.
  - Need to determine the dependence for how distributed the PV and/or loads as opposed to a single large PV systems and large spot loads.
  - The tool/process should be straightforward and not require lengthy studies in most cases; the tool/process/database should be constantly maintained as a part of the daily work flow
  - Include a definition of penetration level in the DOE FOA.

  - **How aggressive should DOE be when defining high penetration as part of a potential funding opportunity?**
    - Hawaii is a good case—they are pushing the limits, solving problems as they go
    - Should look at challenging situations (but these may not be representative of common situation)
    - Should take into account where PV is being deployed now and in the near future
    - Can we target demonstrations to inform procedural thresholds to simplify alternate study process.

Workshop Comment Summaries: Modeling

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- **Modeling**

  - **Key Gaps**
    - Tools that model inverter characteristics at a high fidelity level can be expensive. Need method to convert those models to the simulation packages and T&D operation tools used by utilities.
    - Limited access to detailed inverter models is an issue. Inverter companies (especially DOE funded) should be required to publish models of their inverters that can be used in distribution simulation packages.
    - There are needs for detailed generic inverter models that are representative of the commercial product, however, there is concern about IP from the vendors.
    - More discussion on how highly distributed generation and load control will be integrated into distribution system operations.
    - Utilities may have issues with transferring existing 3 phase distribution model information into unbalanced models.
    - PV High Penetration Case studies need to be published in a timely fashion
    - Identification of the mitigation strategies. Include not just the systems that did not require any mitigation.

  - **Possible metrics to measure success in the modeling and operational tools include:**
    - Improved screening method to simplify interconnection process
    - Raising the penetration limit on triggering a supplemental study (from 15%)
    - How the commercial software vendors utilize a consensus based generic model for distributed PV?
    - Reductions in cost and time to do supplemental studies
    - Accuracy of the inverter models.

Workshop Comment Summaries: Feeder Identification

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- **Feeder Identification**

  - **Key gaps**
    - Uncertain which “feeders types” are likely to account for the majority of high penetration solar deployment in the future
    - Uncertain whether the broad range of distribution feeders can be classified into broad “feeder types” for the purposes of understanding high penetration solar impacts
    - Unclear how high penetration solar impacts and solutions vary based on the type of feeders, and whether broad conclusions can be reached
    - Feeders and distances are not all created equal.

  - **Impacts of high penetration PV that external stakeholders consider most critical**
    - Voltage regulation is the main issue. Challenging for substations with multiple feeders, different load and PV penetration levels
    - Var-sourcing PV inverters could be a solution? Yes, but technically complicated.
      - Standards compliance issue
      - Var sourcing from PV could reduce switching duty, but who controls PV inverters?
      - Utilities feel they need to remain in control of voltage regulation
      - Local control at inverters could mimic utility voltage regulating equipment
    - Potential islanding and reverse power flow problems. Harmonics and flicker are not critical issues., Fault duty is not an issue due to low PV fault current.

  - **Metrics to measure success in the feeder identification tools**
    - Instead of focusing on feeder topology, focus more on limiting factors of feeder such as voltage regulation schemes, reserve power flow, CVR (how is the system operated), bands that exist (5% versus 2%), stiffness on the system and load serving (residential versus commercial).

Workshop Comment Summaries Feeder Identification

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- **Feeder Identification (continued)**

  - **Possible utilization of the Hosting Capacity (European Model):**
    - Choose a phenomenon and a performance index
    - Determine a suitable limit for the performance index
    - Calculate the value of the performance index as a function of the amount of DG
    - Obtain a hosting capacity value

  - **Distribution feeder designs that should be considered higher priorities for demonstrations:**
    - Large commercial rooftops are easier (shorter, beefier circuits, loaded), but could be most common case for many utilities
    - Rural circuits are challenging (longer distance, smaller substations, multiple VRs, load shape/factor)
    - Incentive structures drives PV build out
    - Residential PV seems to be “easy”, but could have issues with secondaries if PV is large (10 kW). Also, new interesting case scenario is residential PV with Evs (electric vehicles).
    - PV may not drive feeder design as much as EV integration.

Workshop Comment Summaries: PV Forecasting

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- **PV Forecasting**
  - There is no near-term need to forecast PV resources at the distribution grid level, i.e. minute-by-minute forecasting with finer spatial resolutions
  - Day-ahead PV forecast has been and will still be very important for transmission grid
  - It may be beneficial to treat forecasting as a separate topic
  - With regards to FOA and siloed analysis, metrics for uncertainty have to be clear to measure uncertainty and value of forecast for application; clear definitions of “near term”, “long term”, etc.; must be applicable to all technologies available for forecasting
  - Counting PV as a capacity resource would be a useful metric for success in solar forecasting
  - Penetration level does not need to be tied to PV forecasting
  - Value of forecast must be tied with other mitigation strategies – what are the most cost effective strategies and how would they be deployed? What kind of operational scheme will be in place as opposed to predicting specific clouds?

Workshop Comment Summaries: Energy Storage

- **Energy Storage**
  - **How does the integration of energy storage enhance the value of distributed PV resources to customers and utilities?**
    - Energy Storage (ES) is used to defer upgrades to utility infrastructure or reduce spinning reserve requirements because of variability
    - ES could help system reliability by providing generating capacity during abnormal conditions
    - Value proposition – it is difficult to measure the reliability value
    - At the utility level, less storage is needed for smoothing variability if there are more distributed and large amount of PV installed
    - Community Energy Storage / Substation Storage – where does it make most sense for economics?
    - Do we need to focus on load variability instead of the PV variability?
    - There are other types of less expensive energy storage that can be used aside from the battery type (load type – i.e. thermal storage, water heater storage)
    - Research topic: What is the most functional size (ratio) in relationship to the PV size?
    - Storage for individual PV should be avoided – it should be storage for the grid
    - Energy storage to support PV alone does not provide the highest value versus cost. Energy storage should be installed for other smart grid applications in order to maximize its value
    - Customers may invest in storage for reliability (i.e. backup power) and economics (i.e. avoiding peak price)
    - Better use of demand response may make more economic sense that ES
    - There should be as little energy storage required with PV due to cost

Workshop Comment Summaries: Energy Storage

- **Energy Storage (continued)**
  - **What are the possible metrics to measure success in the energy storage area?**
    - Customers finding value (reliability and economics) for adding energy storage to PV systems
    - Creating regulatory requirements to move towards motinizing the value of storage
    - Considering ES as part of the integrated resource planning
    - Counting ES as one of the primary tools or options you can use to mitigate system problems

Appendix A

Original RFI Questions

Request for Information (RFI)-

Solar High Penetration

Request for Information

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Request for Information: SunShot Initiative Solar High Penetration

Open Date: 05/17/2011

Close Date: 06/06/2011

Funding Organization: Solar Energy Technologies Program

Funding Number: DE-FOA-0000526

Summary:

Reducing the total installed cost for utility-scale solar electricity to roughly 6 cents per kilowatt-hour (kWhr) without subsidies will result in rapid, large-scale adoption of solar electricity across the United States. Achieving the SunShot goal could enable PV penetration levels as high as 8% by energy production by 2020, 14% by 2030, and 18% by 2050.

The U.S. Department of Energy (DOE) is requesting information to develop a technology roadmap (i.e., multi-year planning) in this area. In the future, DOE may issue a Funding Opportunity Announcement (FOA) for research to define, evaluate, and test the effects of high concentrations of solar-generated power on electric power systems. Potential projects may include modeling, forecasting, technology innovations, new inverter technologies, energy storage, etc. DOE is specifically interested in determining the level of penetration at which technical problems are demonstrated to occur and how these impacts may vary based on distribution feeder topologies.

Respondents are asked to comment on questions in a Request for Information (RFI) to help shape DOE's multi-year planning and possible future FOAs. Respondents are also encouraged to comment on the value of a possible SunShot High Penetration Solar Deployment FOA, as well as your organization's anticipated interest in participating in such an opportunity.

For more information, see the full solicitation.

Last updated: 05/17/2011

Funding amounts and schedules are subject to change.

About the RFI responses

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- RFI issued 5/17/2011, response period closed on 6/6/2011
- 25 respondents, spanning the entire solar grid integration industry, including:
  - Manufacturing Industry
  - Utilities and Power Sector Consultants
  - Software Developers
  - Industry Nonprofit Organizations & Consortia
  - DOE National Laboratories
  - University-affiliated Organizations and Research Institutions
- The full questions and names of respondents are listed in Appendix A & B of this slide deck
- For each question, a tally of total # of responses, a tally of responses to each part of the question, and key comments are provided

Note: Not all respondents answered a given question, and in many cases, only a part of the question was answered. This document is intended to provide a general picture of the RFI responses for the purposes of the High Penetration Solar Deployment II Workshop.

Question 1 – Part 1

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In this RFI, DOE has identified tools such as new inverter technologies, energy storage, forecasting, feeder modeling, etc. as a comprehensive set of tools to address high penetration issues.

- **Is this a comprehensive list? What other tools would you recommend? Why?**

# of responses: 24/25	Responses
Comprehensive	13
Not Comprehensive	11

Additional Tools:

- Inverter functionality: Advanced communications and control tools.
- Advanced Protection and Distribution Automation (DA) schemes
- Scale: A clear distinction between the deployment of solar technologies as large-scale (centralized or decentralized) and small-scale (distributed) installations.
  - The two classes of deployment require a different set of integration tools.
- Microgrid specific tools and applications.
- Tool integration, particularly in the area of forecasting and feeder modeling.
- Tool to generate high temporal frequency simulations of PV system output, include enhanced solar irradiance and power output simulation.
- Tool to correlate solar forecast errors on a range of time and space scale for a given geographical area.

Question 1 – Part 2

Is there a recommended emphasis on particular tools? Why or why not?

- **Not Just Tools** "Understanding how high penetrations of PV will impact the grid is broader than development of tools alone. Utilities will need to understand how large amounts of distributed generation connected to their distribution systems will impact how the plan and operate their systems, how the intermittency of PV interacts with the intermittency of load, and how different PV technologies interact with one another."
- **Solar Forecasting** "The German grid authority has disallowed the allocation of additional spinning reserve due to renewable energy resources, because it deems it unnecessary given the high accuracy to which solar generation can be forecasted now in Germany…without indirect costs for system operator."
- **Advanced Energy Storage "**Energy storage is essential to the success of the program due to energy storage's multifunctional capacity, and therefore should be emphasized in any high penetration solar application."
- **Electric Vehicles** Incorporation of electric vehicles and advanced energy storage as a system solution rather than discrete components.
- **Microgrid-Specific Issues and Applications**

Question 2

Individual high-penetration PV projects involving grid stability, voltage regulation, power quality, protection coordination, advance modeling and simulation, advanced inverter technology, communication control systems and storage have been performed independently in the past.

- **Should there be a focus on a more consolidated approach? What other projects similar to this unified approach would you specifically recommend and why?**

# of responses: 20/25

Yes	16

Comments:

- **Staged approach** should be used to add capability in incremental steps. A development roadmap should be prepared and implemented.
- The solar energy industry is today quite fragmented with various technology solutions addressing separately the numerous challenges. We believe that this **fragmentation has significantly limited the potential of solar energy**.
- Integrate potentially disruptive technologies such as **distributed micro grids** and **electric vehicles**.

Question 3

Are the goals and timeline in Figure 1 appropriate to enable the market to demonstrate the SunShot goals of 8% solar energy as a percent of the total annual energy needs for the US by the end of the decade? Why or why not?

13/15 Respondents said that the SunShot goals are appropriate

Comments:

- **Regional Penetration:** The DOE could consider a **more aggressive goal than 8%** for the South West region, given that the South West will lead the nation in deployments, and volume based cost reduction—benefits which should trickle down to other regions of the country that do not have superior solar insolation.
- No. The $1.00/watt SunShot goal will be difficult to achieve as balance of system components are increased (communications, data logging, storage etc.), albeit the value of the distributed resource will increase proportionately to the cost as these devices become grid interactive and supportive. **The SunShot goal must include grid optimization and consumer participation value as well as cost per generated watt.**
- **Achieving 8% penetration is a rather moderate goal**. Uniform input at 20% is above the threshold for stability and would push the need for the improvements outlined for storage, inverters, and feeders.
- We think it would be easier to meet SunShot's goals with **utility-scale PV**.

Question 4

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

How do you define high penetration? Should penetration levels be defined with respect to the peak load on the feeder, or the minimum load on the feeder? Why?

- **Based on your definition of high penetration, how aggressive should DOE be when defining high penetration as part of this potential funding opportunity?**

# of responses: 15 /15	Peak Load	Other
Yes	9	
No	6	

Comments:

- Future research needs to focus on grid impacts and mitigations of high penetrations of PV where PV production exceeds either 100% of minimum daytime load on a given circuit or 30% of that circuit's peak load.
- We believe that the DOE should be more aggressive in its definition of high penetration to allow for advanced studies and breakthrough technologies to participate rather than raising the bar too low.

Question 5

What problems related to high penetration solar integration are the highest priority to you and your stakeholders? (19/25 responses)

Comments:

- DOE/EPRI/PNNL need to decide/standardize on 5 or more **representative distribution circuit** topographies so all researchers are dealing with the same base lines.
- The **intermittency** of the solar resource, and instability—in both energy and voltage—that accompany rapidly changing energy supply on a distribution system are the key challenges in achieving high penetration of solar integration.
- It is becoming apparent that **local voltage issues** are likely to precede protection, load, fault, harmonic, and stability issues as penetration increases.
- **Reverse power flow**, and impact on operation of voltage control and regulation equipment (voltage-controlled capacitor banks, line voltage regulators and LTCs) due to moderate to high penetration levels are a high priority, particularly on long and lightly-loaded distribution feeders.

Question 6

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If DOE were to utilize a similar program structure to the 2009 High Penetration Solar Deployment FOA, would this structure be appropriate?

- **How else could we structure it? Should additional areas be included?**

Comments:

- **Move away from distribution system only** applications to include solar deployment at the bulk transmission level.
- Market adoption modeling in order to assess policy decisions and technology advancements, including improved levelized cost of energy (LCOE) metrics.
- Real-world component performance characterization for the validation of models.
- Modeling of interactions between solar and other types of renewables or technologies. (Storage, electric vehicles, etc.)
- Incentivize utilities to participate in more than one project.
- There should be a down select of projects.

Question 7

How would you recommend DOE elevate the lessons learned from these activities so that outcomes or findings can be more universally applied?

Should DOE continue to include modeling and simulation in efforts funded under this potential funding opportunity?

21/22 Respondents said that Modeling & Simulation are essential

Comments:

- **Require participation in a Modeling Tools working group** to share best practices. This working group would also supervise selection of feeders and simulations for these feeders.
- Required use of published, standard variability models rather than developing custom approaches.
- Develop the previous modeling efforts to include the ISO/RTO and LSE stakeholders to develop cross boundary Locational Marginal Pricing structure modeling at the distribution feeder level.
- Emphasis should be placed on modeling and simulating distributed energy resources leveraging PV and energy storage when coupled together.
- DOE should make sure that it allows **private industry** to retain rights to this software. We view the approach that CSI has taken to this topic to be excellent.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

What funding level in total or per award is required to meet the DOE goals, taking into account investment from federal, state, and private entities?

- **Would it be more productive to fund several awards at $800,000 to $1miilon per year for 2 to 3 years, or fewer awards at greater than $1 million per year for 2 or 3 years? Why?**

# of responses: 21/25	More/Smaller (~<$1M)	Fewer/Larger (~>$5M)
Support	15	6

Comments:

- More awards, between $800,000 to $1 million range per year for 2 to 3 years.
- Fewer awards, greater than $5 million, with more industry and non-federal cost sharing.
- There should be a mix of the two funding levels noted above. Several large projects, and a host of smaller manageable projects.
- The role of the national labs to provide federal in kind services can unduly hamper utility, industry and academic bidders.
- Most respondents were comfortable with 2 to 3 years.

Question 9

What would be meaningful objectives for a FOA and multi-year planning? Can the objectives under some topics be developed in shorter periods?

Comments:

- Market-driven Objectives (cost, reliability, meeting demands for energy, etc.)
- Tool Specific Objectives (Forecasts should reduce mean absolute percentage error
- Demonstration Objectives involving energy storage
  1. Evaluate **islanding a feeder** of a distribution system to enable PV plant production to continue while alleviating a heavily loaded feeder or substation.
  2. Evaluate the use of energy storage to store and shift energy delivery to match the load profile and the capacity value of renewable resources.
  3. Evaluate using energy storage for regulation during high solar-production time-of-day to **mitigate short-term intermittency** issues associated with solar PV plant operation.
  4. Demonstrate the ability of a PV plant to continue **operating through a real-power output curtailment** event by utilizing local and/or distributed energy storage assets.
  5. Demonstrate that the combination of intermittent, renewable-based, distributed generation and storage can mitigate voltage level fluctuations, as well as enable peak shifting
  6. Quantify and refine performance requirements, operating practices and cost and benefit levels associated with the use of advanced storage technologies to **turn distributed renewable generation into a firm, dispatchable resource**

Question 10 – Part 1

As new technical benchmarks are reached within the U.S. related to high penetration solar scenarios, the development or modification of codes and standards will be required and in some instances will be running in parallel (i.e. 1547.8, Rule 21, etc.).

Which codes and standards are affecting, or either will preclude or may potentially preclude, high penetrations of solar?

- IEEE 1547.7 and 1547.8
- IEEE P2030 and P2030.2
- Reexamining the 15% standard or “Rule 21” in CA
- Several of the IEEE C37 standards
- Communications and security standards
  - Including IEC 61850, IEC 61970, IEC 61968, IEC 60870-6, IEC 62351, NISTIR 7628, NEC, UL, and state and local building codes.
- Tariffs associated with the value of mitigating storage

Question 10 – Part 2

Would support to accelerate the codes and standards process be helpful? How could DOE play a role?

- DOE should support the **acceleration and harmonization** of codes and standards process to orchestrate the various agency in a highly coordinated manner.
- Support an industry standards working group to provide the long-term perspective in developing standards.
- DOE should support participation of parties that are not currently engaged.
- With respect to IEEE 1547.7 support development of modeling/simulation guidelines.
- Specific issues related to DC microgrid deployment
- DOE partnership with OSHA to evaluate product testing ‘bandwidth’ on a regional basis would show that there are significant areas in the US that would benefit from additional testing capabilities and that this would decrease both price and time to test for new products, allowing for higher penetration of PV systems.

Question 11

DOE anticipates that if a FOA is released, it would be open for 60 days.

- **Is this a sufficient amount of time to respond adequately?**
- **If not, how much time will be required to prepare an adequate application?**

# of responses: 18/25 **Categorized response count not mutually exclusive*

Shorter period sufficient	N/A
60-day period sufficient	12
Longer period necessary	6 @ 90 Days

Comments:

- An R&D project can take less time and effort to plan than developing a multi-party demonstration. Considering the emphasis on partnerships 60 days is a short time.
- Advanced notice should be considered, even if the open period stays at 60 days.

Question 12

What type of partnerships would be required or need to be involved to demonstrate high penetration scenarios?

Partnerships should include some or all of the following:

- **Utilities or Electricity Provider -** Forward-thinking utilities that are eager to deploy PV panels and long-duration energy storage systems to support the changing panorama of the distribution grid are integral partners.
  - *Note: Utilities as a contractual participant should not be a requirement.*
- **Microgrid Operators & Independent System Operators**
- **Manufacturers, Developers and other PV Suppliers**
- **Universities & Research Institutions**
- **National laboratory, State and Local Governments**
- **Consulting/Technology Specific Firms**
- **Data acquisition and reporting firm -** An independent third party data acquisition and reporting firm is suggested in order to provide unbiased results

# of responses: 19/25

**Categorized response count not mutually exclusive*

Question 13

What evaluation criteria should be included in a FOA to help measure the potential of a proposal? What evaluation criteria should DOE use to evaluate applicants' qualifications to ensure they meet the needs of the industry?

Criteria to Consider:

- **Project Approach & Potential Impact:** Potential for results to advance the science of high penetration solar, reduce costs associated with deployment and operation of solar facilities and the distribution of generated power on the grid. Does the final product has the potential to change or benefit the market?
- **Project Team:** Strength based upon qualifications, experience, track record. Organization and management of the team, and ability to cope with unforeseen events.
- **Technical Knowledge:** Strength of the scientific/technical approach, IP management.
- **Access to Resources:** Access to feeders, feeder data with high PV penetration, availability of accurate solar forecasts. Capacity to implement mitigation measures to increase PV penetration. Cost share commitment.
- **Project Schedule:** LAB TO MARKET! The speed by which a team can move innovation into commercial markets is essential. Reasonableness of the proposed work schedule.
- **Creativity:** Creativity of the approach.
- **Outreach:** Plan for dissemination of the results to stakeholders and other interested parties.

# of responses: 19/25

**Categorized response count not mutually exclusive*

Appendix A: Original RFI Questions

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1. In this RFI, DOE has identified tools such as new inverter technologies, energy storage, forecasting, feeder modeling, etc. as a comprehensive set of tools to address high penetration issues.
   - Is this a comprehensive list? What other tools would you recommend? Why? Is there a recommended emphasis on particular tools? Why or why not?
2. Individual high-penetration PV projects involving grid stability, voltage regulation, power quality, protection coordination, advance modeling and simulation, advanced inverter technology, communication control systems and storage have been performed independently in the past.
   - Should there be a focus on a more consolidated approach? An example might be more than one distribution feeder that includes back-feed capabilities, combined with PV systems incorporating advanced inverters capable of utility control via communications for reactive power and frequency control, and utilizing advanced distribution modeling and analysis software to evaluate any technical issues surrounding grid planning, operations, and reliability.
   - What other projects similar to this unified approach would you specifically recommend and why?
3. Are the goals and timeline in Figure 1 appropriate to enable the market to demonstrate the SunShot goals of 8% solar energy as a percent of the total annual energy needs for the US by the end of the decade? Why or why not?

Appendix A: Original RFI Questions

4. **How do you define high penetration? Should penetration levels be defined with respect to the peak load on the feeder, or the minimum load on the feeder? Why?**
   - **Based on your definition of high penetration, how aggressive should DOE be when defining high penetration as part of this potential funding opportunity?**
5. **What problems related to high penetration solar integration are the highest priority to you and your stakeholders?**
   - **Are there particular distribution situations or circuit designs that would be higher priorities?**
6. **If DOE were to utilize a similar program structure to the 2009 High Penetration Solar Deployment FOA, would this structure be appropriate?**
   - **How else could we structure it? Should additional areas be included?**

7. **Modeling and simulation are essential in understanding how solar interacts with the grid, and there was a strong focus on modeling and simulation activities during the 2009 awards.**
   - **How would you recommend DOE elevate the lessons learned from these activities so that outcomes or findings can be more universally applied?**
   - **Should DOE continue to include modeling and simulation in efforts funded under this potential funding opportunity?**
8. **What funding level in total or per award is required to meet the DOE goals, taking into account investment from federal, state, and private entities?**
   - **Would it be more productive to fund several awards at $800,000 to $1miilon per year for 2 to 3 years, or fewer awards at greater than $1 million per year for 2 or 3 years? Why?**
9. **What would be meaningful objectives for a FOA and multi-year planning? Can the objectives under some topics be developed in shorter periods?**

Appendix A: Original RFI Questions

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

10. As new technical benchmarks are reached within the U.S. related to high penetration solar scenarios, the development or modification of codes and standards will be required and in some instances will be running in parallel (i.e. 1547.8, Rule 21, etc.).
    - Which codes and standards are affecting, or either will preclude or may potentially preclude, high penetrations of solar?
    - Would support to accelerate the codes and standards process be helpful?
    - How could DOE play a role?
11. DOE anticipates that if a FOA is released, it would be open for 60 days.
    - Is this a sufficient amount of time to respond adequately?
    - If not, how much time will be required to prepare an adequate application?
12. What type of partnerships would be required to demonstrate high penetration scenarios? What types of entities need to be involved in the project to ensure that goals can be achieved?
13. What evaluation criteria should be included in a FOA to help measure the potential of a proposal? What evaluation criteria should DOE use to evaluate applicants’ qualifications to ensure they meet the needs of the industry?

Appendix B

RFI Respondents

Appendix B: RFI Respondents

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- **A+A Enterprises**
- **Aerisun LLC**
- **Amonix, Inc. / EMB Energy Inc.**
- **Argonne National Laboratory**
- **Arkema, Inc**
- **AWS Truepower, LLC**
- **Clean Power Research, LLC**
- **CleanTECH San Diego**
- **Enegis, LLC / Jet Propulsion Laboratory**
- **Florida State University**
- **IBM TJ Watson Research Center / State University of New York – Albany**
- **Nextek Power Systems Inc. / University of Toledo**
- **NREL Integrated Applications Center**
- **Power Analytics**
- **Premium Power Corporation**
- **Qado Energy, Inc**
- **Quanta Technology, LLC**

Appendix B: RFI Respondents

- Regents of the University of California, San Diego
- The Sacramento Municipal Utility District (SMUD)
- SEMATECH, Inc. on behalf of the soon to be incorporated SEMATECH Photovoltaic Manufacturing Consortium (PVMC)
- SRI International
- Sunverge Energy, LLC
- University of California, San Diego
- University of Colorado
- Wichita State University

Appendix C

Modeling

Breakout Sessions with Comments

High Penetration Workshop
- Modeling Breakout Questions Combined

- Sacramento, CA| June 13, 2011
- **Facilitators: Ben Kroposki, NREL / Barry Mather, NREL**
- Note Takera: Alvin Razon, DOE / Guohui Yuan, DOE

Appendix C: Modeling Breakout Sessions – General Questions 1

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

10 mins

- **Penetration Levels -** How do you define high penetration? Should penetration levels be defined with respect to the peak load on the feeder, or the minimum load on the feeder? Why? Based on your definition of high penetration, how aggressive should DOE be when defining high penetration as part of this potential funding opportunity?
- **High Penetration Issues** - What problems related to high penetration solar integration are the highest priority to you and your stakeholders? Are there particular distribution situations or circuit designs that would be higher priorities?

- No consensus on defining high penetration. There seems to be movement toward using minimum daytime load. Include a definition of penetration level in the FOA.
- Should not require a very high (50-100%) penetration for demos, but require modeling of those levels validated with the real system.
- High pen issues: Voltage regulation, backfeeding substations, flicker
- Need to define issues and mitigations with timelines and costs

Distribution Models

- **Steady-State model** – used in power flow and voltage regulation studies
- **Short Circuit model** – used in protection coordination studies
- **Transient model** – used in power quality, harmonics, and switching transient studies
- **Dynamic model** – typically not used in distribution studies
- **Aggregation model** – not developed for distribution system analysis

Appendix C: Modeling Breakout Sessions – Modeling Questions 1

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

10 Mins

- **Lessons Learned -** Modeling and simulation are essential in understanding how solar interacts with the grid, and there was a strong focus on modeling and simulation activities during the 2009 awards.
- How would you recommend DOE elevate the lessons learned from these activities so that outcomes or findings can be more universally applied?

- Publish case studies of existing high pen examples in an expedited manner.
- Identify the mitigation strategies and include not just the systems that did not require any mitigation.

Appendix C: Modeling Breakout Sessions – Modeling Questions 2

15 Mins

- **Modeling Gaps -** Two of the modeling and simulation gaps are the lack of validated PV inverter and system models, and validated method to model aggregated PV systems for distribution planning studies.
- What are the iterative strategies would you recommend to address these gaps?

- Tools that model inverter characteristics at a high fidelity level can be expensive. Need method to convert those models to the simulation packages used by utilities.
- Limited access to detailed inverter models. Inverter companies (especially DOE funded) should be required to publish models of their inverters that can be used in distribution simulation packages.
- Need generic models that are representative of the commercial product.
- Utilities may have issues with transferring existing 3 phase distribution model information into unbalanced models.

Appendix C: Modeling Breakout Sessions – Modeling Questions 3

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

15 Mins

- **Operations -** Another two recognized modeling and simulation gaps are the lack of operational tools to allow utility operators understand the impacts of distributed solar in the system and standard method to evaluate voltage regulation, protection and power quality of high penetration PV in utility distribution system planning and operations.
- What are the iterative strategies would you recommend to address these gaps?

- Need more discussion on how highly distributed generation and load control will be integrated into distribution system operations.

Appendix C: Modeling Breakout Sessions – Modeling Metrics 1

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

10 Mins

- What are possible metrics to measure success in the modeling and operational tools?

- Improved screening method to simplify interconnection process
- Raising the penetration limit on triggering a supplemental study (from 15%)
- How many commercial software vendors utilize a research or generic model for distributed PV.
- Reductions in cost and time to do supplemental studies
- Accuracy of the inverter models

Appendix D

Energy Storage

Breakout Sessions with Comments

High Penetration Workshop
Energy Storage Breakout Questions

- Sacramento, CA| June 13, 2011
- **Facilitator: Ben Kroposki, NREL / Mark Rawson, SMUD**
- Note Taker: Guohui Yuan/Alvin Razon

Appendix D: Energy Storage Breakout Sessions Combined - Questions 1

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Strategic Objective 1	**Understand how the integration of energy storage could enhance the value of distributed PV resources to customers and utilities**
Key Research Questions	• Does the location of energy storage significantly change the utility's ability to "firm" customer load and distributed PV capacity? • How much storage is necessary to accomplish the desired PV and load firming effects? • Can an integrated PV/energy storage system provide service reliability benefits for customers? • Can new PV inverter topologies be developed that utilize storage and better enable grid optimization and integration?

- There is a need for reliably testing the ability to transition to a stand-alone mode for reliability
- Community Energy Storage / Substation Storage – where does it make them most sense for economics
- At the utility level, the more distributed and large the amount of PV is, less storage is needed for smoothing variability.
- Energy Storage could be of value if you are hitting high voltage limits because of installed PV

- Additional storage functions aside from smoothing advantage.
- Load variability – do we need to focus on this instead of the PV variability?
- There are other types of energy storage that are not battery type (load type – i.e. thermal storage, water heater storage)
- Will the ramp rate shorten the life of the power system equipment (LTC etc.)?
- Different types of storage – avoid to create a new peak problem
- Storage technologies - leave the door open for all type of technologies
- Permitting issues – environmental concern (lead acid)

Appendix D: Energy Storage Breakout Sessions Combined - Questions 2

Strategic Objective 2	Determine if the addition of energy storage could add value for the utility
Key Research Questions	• Can energy storage in a high penetration solar deployment help support a utility's peak, particularly when PV output drops off after 5PM? • Does the location of energy storage significantly affect the ability of the utility to manage the resource? • What is the right amount of storage needed to mitigate PV intermittency as a function of PV plant capacity? • How do storage control/dispatch strategies change depending on location of storage relative to PV plant and other loads on feeders? • How variable is PV output within a community or distribution feeder, and what is the potential operating impact for the utility? • Does storage allow the utility to plan less ancillary services for intermittent PV production, thus saving grid operation costs?

- Could use ES to defer upgrades to utility or reduce spinning reserve requirements because of variability
- ES (and PV) can mask load that may reappear over time or if the units trip off line
- If utility can get load and generation at a feeder aggregate level, it would be useful to understand distribution system operations
- ES could help system reliability by removing load during abnormal conditions
- Value proposition – it's difficult to measure the reliability value
- There should be as little energy storage required with PV due to cost
- Research topic: What is the most functional size (ratio) in relationship to the PV size?
- Cost of storage will dictate the location
- Energy storage ancillary services – more categories need to be included (distribution and transmission systems have different requirements)
- Individual/granular storage ancillary service is more difficult to control than an aggregated storage
- Storage for PV should be avoided – it should be storage for the grid
- Customer behavior

10 Mins

Strategic Objective 4	**Determine if capacity firming and advanced pricing signals will influence the energy usage behaviors of customers**
Key Research Questions	• Do the customers who have capacity firming capability (energy storage) behave differently than those who do not? • How does energy storage impact the customer's ability/desire to respond to pricing signals?

- Better use of demand response may make more economic sense that ES
- Virtual power plant, dynamic price signals, forecasting technique and smart metering need to work together

10 Mins

Strategic Objective 3	Determine how to leverage utility's AMI or Smart Grid investment to manage a distributed PV/energy storage resource
Key Research Questions	• Can a smart meter be used to monitor and control a PV and/or storage system, and to what extent? • What are the practical challenges associated with using AMI or Smart Grid for managing PV and storage? • How best should storage be controlled – via direct utility control (for grid reliability) or via price signals (for customer energy cost reduction) or both? What control architectures will enable both? • What are the technical requirements for integrating PV and/or storage inverters and smart meters, and what codes, standards and reference designs must be developed?

- AMI will be able to give voltage readings from meters. This may be useful to understand system conditions, but not integrated with operations.

- AMI has its own value but it's not clear that it will have major contribution on the control of PV storage
- Utility would want to have bandwidth to control the meter for revenue reason (not for other means)
- Seasonal ability to change the set points remotely

10 Mins

- What are possible metrics to measure success in the energy storage area?

- Start at customers to find value (reliability and economics) for adding energy storage to PV systems
- - overproduction of PV energy during day
- - provides backup power

- Find demonstration where storage is the most economic option to allowing higher penetrations of PV

- Reliability
- Regulatory needs to move towards motinizing the value of storage (grid point of view)
- Location effective
- Where it should go and how big it should be. Profile of responsiveness.
- Energy storage is considered in Integrated Resource planning
- One of the many tools or options you can use to mitigate system problems
- Capacity credit

- .

Appendix E

Feeder Identification

Breakout Sessions with Comments

High Penetration Workshop
Feeder Identification Breakout Questions

- Sacramento, CA| June 13, 2011
- **Facilitators: Jeff Smith, EPRI**
- Note Takers: Kristen Nicole, DOE

Appendix E: Feeder Identification Breakout Combined - Questions 2

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Feeder Topology and Identification

Themes:

“Feeders are not all created equal”

and now

“Distances are not all created equal”

Same feeder, same conductor, same loads, but how the utility operates that feeder another factor because operations of feeder can add in another level of uncertainty.

Appendix E: Feeder Identification Breakout Combined - Metrics 1

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- What are possible metrics to measure success in the feeder identification tools?

More metric based versus feeder topology and focus on limiting factors of feeders

- **Feeder regulation schemes**
- **Reverse power flow**
- **CVR – how the system is operated**
- **What bands exist (5% versus 2%)**
- **Stiffness on the system**
- **Load serving (residential versus commercial)**
- **Keep EVs separate (more of a controllable load)**

Hosting Capacity (European Model)

1. Choose a phenomenon and a performance index
2. Determine a suitable limit for the performance index
3. Calculate the value of the performance index as a function of the amount of DG
4. Obtain a hosting capacity value

– Hosting Capacity exercise

- Where in the system there is headroom to accommodate PV?
  - Improved capacity studies. Mapped and published available capacity to accommodate interconnection. Has to be continually maintained, not a stagnant process.
  - Created buckets of what they could handle. Going to want a big safety margin.
  - Look **at system impact versus cheap interconnection** to look at stiffness. Utility needs to look at feeders to develop that map. Address the need to look at feeders and approach to develop a map.

- Effort at state level to do a similar activity. Can we do this at the national level?

Penetration Levels and Issues

- Substation rating
- Minimum load (not always night, could be during middle of the day) . 15% of peak is meant to simulate minimum load.
- Not all utilities have good minimum load data on their feeders.
- Definitions have to be flexible to fit operations data to quantify system impact.
- Is that PV going to reverse the power flow? If yes, then we need to take a further look at it. If no, not a big deal, just do it.

- Minimum load is what we really want to know. How do we measure that?
    - Distribution SCADA
    - More AMI, etc.
    - More and more we are able to measure minimum load.

- Need visibility

High Penetration Workshop

Feeder Identification Breakout Questions

- Sacramento, CA | June 13, 2011
- **Facilitators: Abe Ellis, Sandia**
- Note Takers: Kirsten Orwig, NREL

Overall Goals and Gaps – **1 min**

- DOE is specifically interested in demonstrations high solar penetration in distribution circuits, where significant technical challenges occur and are successfully addressed by application of tools (inverter technology, energy storage, forecasting, modeling, and other)
- There is a wide variety of feeders based on customer class, location, loading, voltage, topology, electrical characteristics, system strength, etc.
- Key gaps
  - It is not well know which “feeders types” are likely to account for the majority of high penetration solar deployment in the future
  - It is not known whether the broad range of distribution feeders can be classified into broad “feeder types” for the purposes of understanding high penetration solar impacts
  - It is unclear how high penetration solar impacts and solutions vary based on the type of feeders, and whether broad conclusions can be reached

Feeders Topology – 15 mins

- Can feeders be “classified” into several categories?
- Possible deployment scenarios of interest
  - **Commercial warehouse or bigbox store districts** – Urban circuits that range in length from 1-5 miles and have a large concentration of commercial or retail space with large area roofs. Typically these are fairly strong circuits in terms of system impedance. Individual PV systems can range from 200kW – 5MW, with possibly several systems connected to the same feeder.
  - **Utility-scale PV connected into distribution.** 1-20MW PV systems connected along the feeder or directly to the station, located on suburban/rural areas with available land and solar resources.
  - **Residential neighborhoods.** This classification applies mostly to new residential construction, but could include a significant amount of retrofits. Individual system sizes would be small (1-5kW) scattered along the length of a feeder (1-5 miles). The aggregated PV capacity would be in the MW range. Single phase.
  - Combination of the above

Definition of Penetration levels - 15 min

- Hosting capacity depends on more than penetration level
  - Larger penetration is possible if PV systems are located adjacent to a substation
  - Problems may occur at lower penetration as the distance to the substation increases
  - Penetration with respect to minimum load seems to be a more appropriate metric, but historical minimum load data may be difficult to obtain, or may not be relied upon
  - Would it make sense to state how much PV could be installed in increments of 1, 2, 3, …. Miles from substation?
  - May need to determine the dependence for how distributed the PV and/or loads are as opposed to a single large PV systems and large spot loads.

Identification of Feeders - 15 min

- Should we identify a group of typical feeders and analyze each?
- Alternatively, can we identify a consolidated approach/PROCESS to quantify feeder hosting capacity?

Notes

- Approach/process to determine hosting capacity could be very useful for identifying how much PV can be integrated easily in a circuit.
  - Greatly simplify interconnection study process
  - More technically appropriate than 15% screen, for example
- The question is what is the appropriate metric
  - Load (minimum?) is a primary indicator of hosting capacity
  - Voltage could be a performance index

Appendix E: Feeder Identification Breakout Combined - RFI Questions

Targets and Priorities – 5 min

- **RFI 5a:** What are the impacts of high penetration PV that utilities and other

Notes

- Voltage raise/regulation is the main issue, flicker not so much.
  - Challenging for stations with multiple feeders and different load/DG penetration levels
  - Pole mounted VRs are too small to completely solve this problem
  - Var-sourcing PV inverters could be a solution? Technically, yes, but it is complicated
    - Standards compliance, issue
    - Utilities feel they need to remain in control of voltage regulation
    - But note that local control at inverters could mimic utility voltage regulating equipment
    - Switching duty Var sourcing from PV could reduce switching duty, but who controls PV inverters?
  - Need to accommodate as much PV as cost-effectively as possible, overall
- Harmonics is not an issue. Fault current is low—fault duty is not an issue
- Potential islanding when PV and other DG (small hydro, anaerobic digestors) on the same circuit; however engine generators may actually help inverters trip faster (e.g., San Ramon case)
- Backfeeding... There are LTC control options that would work with reverse flow, but none of them completely solve the problem. Germany study dealt with service transformers, but not really station transformers?
- Protection coordination (proper term) is a non-issue because low sc capacity.

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Targets and Priorities – 5 min

- **RFI 5b:** Are there particular distribution situations or circuit designs that should be considered higher priorities for demonstrations?

Notes

- Demonstrations on systems where PV is “showing up”
  - Large commercial rooftops are easier (shorter, beefier circuits, loaded), but could be most common case for many utilities
  - Rural circuits are challenging (electrically longer, smaller substations, multiple VRs, load shape/factor)
  - Incentive structures drives PV build out
  - Residential PV seems to be “easy”, but could have issues with secondaries if PV is large (10 kW). Also, new interesting case would be scenario with residential PV with Evs.
  - PV may not drive feeder design as much as EV integration.

Penetration Levels and Issues – 5 min

- **RFI 4a:** How do you define high penetration? Should penetration levels be defined with respect to feeder peak load, or feeder minimum load? Why?

Notes

- Penetration level alone does NOT tell you whether there is an issue.
- Penetration levels is useful for broad policy/program goals, but not for electrical performance of feeders
  - The question is what penetration is low enough to not cause concerns (procedural, rules)
  - It is recognized that 15% (and the like) thresholds are a compromise, low common denominator.
- Penetration may be better defined by impact (e.g., impact/no impact; low impact/high impact). Defining penetration by voltage-related impact is a possible short-term approach

Penetration Levels and Issues – 5 min

- **RFI 4b:** Based on your definition of high penetration, how aggressive should DOE be when defining high penetration as part of a potential funding opportunity?

Notes

- Hawaii is a good case—they are pushing the limits, solving problems as they go
- Should look at challenging situations (but these may not be representative of common situation)
- Should take into account where PV is being deployed now and in the near future
- Can we target demonstrations to inform procedural thresholds to simplify alternate study process.

Appendix F

Solar Forecasting

Breakout Sessions with Comments

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High Penetration Workshop

Solar Forecasting Breakout Questions

- Sacramento, CA | June 13, 2011
- **Facilitators: Jan Kleissl, UCSD**
- Note Taker: Kristen N., DOE

Appendix F: Solar Forecasting Breakout Session – Jan/Kristen

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- **Q1: Extent of use in operations**
- Being used, but at what state; utility level – older → state of the art starting to be utilized in areas with higher penetrations
- Needed for day-ahead commitments for utilities
- Utility obligation of IPP forecasts for day-ahead (7 day rolling) scheduling
- PV forecast will integrated into load forecasting (net load forecasting) – has to be power forecast (not energy) to be useful
- Value of forecast must be tied with other mitigation strategies – what are the most cost effective strategies and how would they be deployed? What kind of operational scheme will be in place as opposed to predicting specific clouds?
- Who is going to be responsible to do the forecast? The utility for balancing load? The generator? Utility has to provide a forecast for generation commitments. Depends on tariff structure. Italy for example has an incentive for IPP to provide forecast.
- Difference between grid side and consumer side – distributed will be handled differently

Appendix F: Solar Forecasting Breakout Session – Jan/Kristen

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- **Q2: metric for forecasting uncertainty**
- Would not be interested in rsme over a month long period (like some references in literature), or even on a daily basis; within some time frame (ex: 15min) what is max rsme over a specific region; there is a max that operators would like to be below, but what is a critical timeframe and region operationally? It's not useful to lump together uniform (clear) days with highly variable days to calculate errors;
- Ramp events are of interest and how those are characterized
- How does the forecast benefit the utility in a day ahead for commitments (rsme describes how well you follow that curve—extreme intermittency; mae is more useful) – critical: how is it calculated and where is it calculated?
- Different metrics for real-time operations than for day-ahead operations – different needs; how should DG be aggregated for forecast

Appendix F: Solar Forecasting Breakout Session – Jan/Kristen

- **Q3: need for accuracy of forecast**
- Many measures: confidence intervals; ERCOT uses quantiles; depends on risk attitude and flexibility of operator; mixture of forecasting tools is useful (NYISO)—ensemble
- **Q4: various methodologies**
- Challenge is geographic availability; ensemble NWPs are useful; timescale of NWP models; power forecast is needed for sub-hourly timeframe
- Sensor networks deployed; AMI and smart grid deployed; don’t have to assume a continues network of monitoring; don’t write off ground based measurements
- With regards to FOA and siloed analysis: Metrics for uncertainty have to be clear to measure uncertainty and value of forecast for application; clear definitions of “near term”, “long term”, etc.; must be applicable to all technologies available for forecasting;
- Forecasting intermittency versus variability (i.e. extent of ramping versus amount of variance over time)
- Nightmare for operator is no inertia with no control to maintain reliability; need to consider load control (ex: bi-directional PEV) and storage

Appendix F: Solar Forecasting Breakout Session – Jan/Kristen

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- **Q5: Forecast timeframes and priority**
- All of the horizons are useful; system expansion (annual and multiannual); day ahead is highest priority for high pen scenarios for scheduling
- ISO and utility perspective (day ahead, followed by 6hr); ISO interested in sub-hourly
- Planning entities (seasonal and annual)
- Solar forecasting is that big of a problem considering the load forecasting and associated variability with load
- **Q6: metrics for success in solar forecast**
- Counting PV as a capacity resource would be a useful metric (interesting link with NERC regarding reserve requirements)
- Utility side of meter – resource adequacy used in CA
- True ROI analysis

Appendix F: Solar Forecasting Breakout Session – Jan/Kristen

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- **Q7: high penetration**
- Penetration level doesn't need to be tied to forecasting, and isn't very relevant
- Foreknowledge of variability has more context in some situations than others; for forecasting it's not just time and space, but also control area; however DG is a completely different mindset (you plan for your system to operate with no generation)
- **Q8: problems relate to high penetration solar integration are highest priority**
- Variability and ramp rates are highest priority; ability of generation resources to ramp and how it relates to load variability; in DG once interconnected you have no control over how it affects operation
- All comes back to mitigation strategies and the forecast to enable the implementation of those strategies

Thank You

DOE Solar Energy Technologies Program
Systems Integration Subprogram

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