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

SOLAR ENERGY TECHNOLOGIES PROGRAM

PV Validation and Bankability Workshop

San Jose, California

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Contents

1. Executive Summary ... 1
2. Background ... 2
3. Workshop Presentations ... 2
    3.1. The Need for Validation from Concept to a Terawatt, David Williams, CleanPath Ventures ... 3
    3.2. DOE's Efforts to Address the Communities' Needs for Validation, Kevin Lynn, DOE 3
    3.3. Validation Information for PV Power System Project Review, Jeff Newmiller, BEW Engineering ... 4
    3.4. Overcoming the Barriers to Achieving Large-Scale Production—A Case Study, Scott Burroughs, Semprius ... 4
4. Workshop Registration Survey Results ... 5
5. Breakout Session I: Identifying the Opportunity ... 6
6. Breakout Session II: What Does Validation Look Like? ... 7
7. Workshop Summary and Next Steps ... 9
Appendix A: Workshop Attendees ... 10
Appendix B: Workshop Agenda ... 12
Appendix C: Breakout Session I Highlights by Team ... 13
Appendix D: Breakout Session II Highlights by Team ... 16
Appendix E: Draft Validation Plan ... 20

1. Executive Summary

On August 31, 2011, Sandia National Laboratories, The National Renewable Energy Laboratory (NREL), and Florida Solar Energy Center (FSEC) hosted the Photovoltaic (PV) Validation and Bankability Workshop in San Jose, California on behalf of the U.S. Department of Energy (DOE) Solar Energy Technologies Program (SETP). The workshop brought together over 60 PV industry leaders to discuss the current state of PV in the United States and to consider a planned regional test center (RTC) program that is a part of the DOE's SunShot Initiative. During the workshop, attendees provided substantive input on ways the DOE can best support the needs of the stakeholder community and provide a necessary level of confidence to encourage private financing to fund U.S. PV industry growth.

During the workshop's two discussion sessions, participants offered a broad range of opinions on the roles and functions of the RTCs. Participants suggested that the RTCs should define and publish evaluation standards and protocols rather than endorse PV technologies. Standards and protocols would aid regional test locations and third-party independent reviewers. The RTCs should establish a certification and audit process for established and future independent systems testing locations. Attendees proposed that the RTCs should develop a ratings structure for PV systems that would serve a broad range of reviewers. Finally, RTCs should define a strong business plan. Consistent throughout both discussion sessions was the participants' desire that the RTCs should develop a standard set of technical requirements and the technical data sets for demonstrating bankability. This could also lead to the development of a standardized bankability report.

Participants also concentrated on ways to improve current validation and bankability practices. Of primary concern was a need for development of standards and guidelines that would define the range of data collected and procedures for collecting and filtering data, operations and maintenance processes, and modeling parameters. These procedures could inform the development of a comprehensive rating system. Participants were unanimous in their expectation that the RTCs should quickly establish data ownership and transparency guidelines that would encourage the greatest amount of participation among manufacturers.

Organizers intend to use attendee feedback to begin defining the roles and functions of the RTCs as well as a system of industry standards and practices. Ongoing discussions and work will focus on determining the validation needs and requirements, defining the needed standards, and agreeing on standard monitoring and baseline equipment.

2. Background

The U.S. Department of Energy (DOE) has established a goal for solar-generated power to account for 15 to 18 percent of the United States' electricity generation by 2030. To accomplish this goal, DOE established the SunShot Initiative (SunShot) to support efforts by commercial organizations, academia, and the national laboratories to explore photovoltaic (PV) technologies and best practices that could contribute to helping DOE accomplish its $0.06 per kilowatt-hour target for solar electricity production. Achievement of this target could encourage higher penetration of large-scale solar energy systems that would be cost-competitive with fossil fuel-based forms of energy production.

DOE is currently investigating development of a regional test center (RTC) concept that is intended to supplement SunShot programs to help advance the DOE's production goals and foster stakeholder confidence in new and existing PV technologies and projects. The RTCs are part of DOE's plans to accelerate the maturation of the U.S. PV industry into a reliable and robust energy production sector that will encourage greater private investment.

With support from the DOE's Solar Energy Technologies Program (SETP), Sandia National Laboratories (Sandia), The National Renewable Energy Laboratory (NREL), and Florida Solar Energy Center (FSEC) organized and conducted the PV Validation and Bankability Workshop on August 31, 2011 in San Jose, California. The workshop brought together over 60 industry leaders representing manufacturing, financial, engineering, and scientific organizations for one full day of presentations and dialogue to consider the development, objective, and role of the RTCs and their potential influence on the U.S. PV industry. The workshop had the following objectives:

- Ensure output provided by RTCs meets the needs of the stakeholder community
- Elicit information and requirements necessary to provide stakeholders with confidence to finance the scale-up of U.S. module manufacturers and to finance PV projects with quantified technical risk

The workshop was divided into two functional components—a series of four presentations to establish the workshop's mission followed by two breakout sessions. In the breakout sessions, attendees spent several hours identifying validation needs and potential gaps and brainstorming functional characteristics that the RTCs would have to deliver to satisfy financial organizations' requirements to fund new PV developments.

3. Workshop Presentations

Invited presentations offered a broad view of issues affecting PV project development. A link to each presentation is provided at the end of each summary for separate download.

3.1. The Need for Validation from Concept to a Terawatt, David Williams, CleanPath Ventures

Mr. Williams presented an approach to establishing the viability of proposed PV projects from the perspective of a solar project investment firm. Williams opened his remarks with the simple statement, "…money drives the process." Investors want certain guarantees that their investments will produce profits. Williams suggested that a one-percent increase in a project's yield results in a ten-percent increase in profit. Further, reducing uncertainty in degradation rates and reductions in operations and maintenance (O&M) costs can be worth millions to an investor. Quality is monetized at each step in a quality control chain, as illustrated in Figure 2.1.1, taken from Williams' presentation.

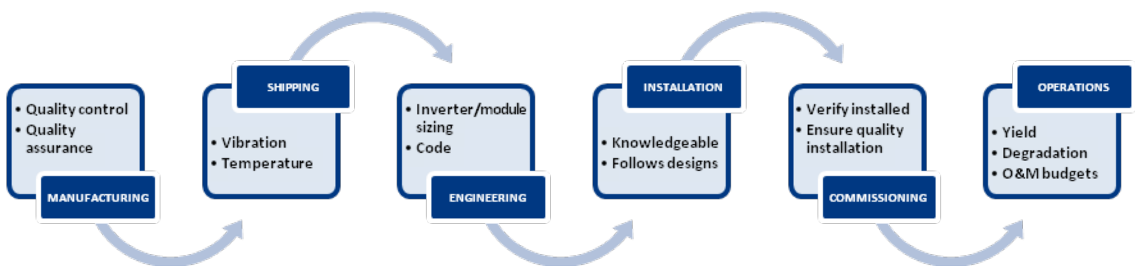

Figure 2.1.1 A Quality Control Chain (Williams)

Investors demand quality tests to have faith in a project's viability. Quality tests are essential but can be difficult to conduct. Manufacturers, engineers, and technologists need to start dialogues with financiers earlier in the project development process to satisfy investors' criteria to determine project profitability including but not limited to better methods to prove residual value probability, certainty of yield, certainty of O&M requirements, and certainty of degradation.

The Need for Validation from Concept to a Terawatt

3.2. DOE's Efforts to Address the Communities' Needs for Validation, Kevin Lynn, DOE

Mr. Lynn began his presentation with a comprehensive view of SunShot describing the impetus behind the program and how DOE is working to make solar energy cost competitive without subsidies. One goal of SunShot is to strengthen U.S. market shares in PV manufacturing and application that have been in decline since the mid-1990s. Lynn introduced a need for the RTCs by offering the following problem statement:

There is uncertainty in the performance, reliability, and safety in components and systems. In more mature industries, these uncertainties are better understood leading to the appropriate assessment of risk and cost. In less mature industries like solar, these uncertainties are (or can be perceived) not as well understood. This greater uncertainty can lead to an unnecessarily high assessment of risk and cost.

Figure 2.2.1 Understanding Uncertainty (Lynn)

Developers of new PV and concentrating PV (CPV) technologies or manufacturing methods are having difficulty achieving bankability, including companies that have established commercial-level manufacturing facilities. The RTCs will serve to validate technologies by quantifying performance of defined system scales in different U.S. regions.

To begin the discussion on RTCs, Mr. Lynn encouraged attendees to address the following considerations during the workshop's breakout sessions:

- What are the gaps in current system validation?
- What are the essential components of a validation program?
- What data should be collected and how should it be shared?
- What metrics will constitute a solution to this problem of uncertainty?

DOE's Efforts to Address the Communities' Needs for Validation

3.3. Validation Information for PV Power System Project Review, Jeff Newmiller, BEW Engineering

Mr. Newmiller presented an approach to validation from the perspective of an independent engineering review firm. Financial organizations rely on impartial reviews to get clear indications of a project's potential profitability, operations and maintenance (O&M) costs, risks, and long-term performance characteristics. Root causes or failures that can affect any or all of these indicators include production performance, weather, and materials reliability.

Newmiller suggested that validation evidence is a critical determinant of a project's bankability and should include qualification testing, installation and O&M, laboratory performance, field performance, safety testing, and manufacturer process.

Validation Information for PV Power System Project Review

3.4. Overcoming the Barriers to Achieving Large-Scale Production—A Case Study, Scott Burroughs, Semprius

Mr. Burroughs presented a case study showing how his company, a global CPV module manufacturer, progresses large-scale projects from concept to full production—the commercialization process—with limited funding. Burroughs suggested that customers such as utilities usually progress toward commercialization at a conservative pace. It is important to have a well-established project development process that includes:

- Ideas that incorporate low cost into the design and document this using levelized cost of electricity (LCOE) data;
- Improvement on the idea by maximizing early learning from customers and industry leaders;
- A thorough R&D process that could include multiple design iterations drawing continuous reliability feedback;
- Acquisition of early and frequent third party cell, module, and system performance certifications; and
- Communication with investors to ensure continued funding

Mr. Burroughs suggested the RTCs would serve as the bridge between the project development steps listed above and a customer's pilot project.

Overcoming the Barriers to Achieving Large-Scale Production—A Case Study

4. Workshop Registration Survey Results

Workshop invitees completed a registration survey to help organizers better understand participants' preferences for industry standards related to validation. Results from the 68 responses were presented to the attendees prior to the start of the second workshop breakout session.

Survey questions focused on PV system validation needs, validation data collection standards, and validation analysis techniques. The most common areas of interest included:

- Validation priorities that included demonstration of kWh/kW performance, demonstration of system robustness in different climates, and verification of performance models accuracy;
- Typical system scales between 50 kW and >1 MW with owners/operators and utility representatives favoring a minimum >1 MW scale for test systems;
- String-level data collection at 15-minute intervals; and
- A broad range of interests in performance and reliability analyses.

The results of the survey are coupled with the outcome of the breakout sessions. Both will be used by the organizers to inform decisions on the implementation of the RTCs.

PV Validation and Bankability Workshop Registration Survey Results

5. Breakout Session I: Identifying the Opportunity

The first breakout session focused on identifying needs and opportunities for validation and bankability. Organizers presented the following topics for discussion:

- What are current baselines for validation and bankability and are they still relevant?
- What are potential validation and bankability gaps? Is it appropriate for DOE to address these gaps?
- What is the role for DOE funding?
- Does the proposed RTC structure appropriately address stakeholder needs?
    - What functions are high priorities for the RTC? Medium priorities? Out of scope?
    - Is support information available or missing?

During the session, participants focused on the first two topics and identified gaps in the validation process, gaps in assuring reliability, and gaps in the current bankability process. In addition, a primary role for the RTCs was identified as working with independent engineers and financiers to identify the range of data needed to support a project (i.e., the technical case for bankability).

Teams suggested that the RTCs should not function strictly as validation facilities. Rather, they should publish validation assessment standards and guidelines for use by independent review organizations. The guidelines would define data collection, interpretation and reporting procedures; O&M processes; modeling conventions; input requirements for bankability assessments; and validation periods. Because of their scope in the program, teams proposed that the RTCs should focus on systems-based validation and manufacturers should focus on component-scale testing (e.g., modules, inverters). The manufacturers would follow the established validation standards.

Teams also spent a considerable amount of time in the first breakout session discussing reliability. Discussions centered on ways to show potential project financiers a technology's dependability and therefore provide quantification of long-term risk. Participants suggested that the RTCs should establish parameters for technology benchmarking, develop long-term performance predictions using accelerated lifecycle testing (ALT), employ performance and reliability models to accurately predict yield over the lifetime of the system, and utilize field data to measure power quality and system reliability.[1]

Additional discussion points identified by each team are included in Appendix C.

6. Breakout Session II: What Does Validation Look Like?

The second breakout session started with an overview of a draft validation plan that would establish the objectives and roles of the RTCs. See Appendix E. The validation plan proposed standardization of the following datasets to sufficiently quantify risk and satisfy investors' investment requirements:

- Commissioning (e.g., Simulator IV-flat plate, Simulator IV-CPV, Field IV-flat plate, IR-flat plate, EL-flat plate)
- Performance (e.g., energy, energy yield, performance ratio (PR), AC efficiency, commercial manufacturer's or integrator's performance model compared to PVSyst, SAM, and PVWatts, manufacturer model, Sandia model, degradation rate, P90)
- Reliability (e.g., visual inspection, field IV, IV as a function of irradiance, temperature, and angle of incidence (AOI) according to IEC 61853, simulator IV, IR)

Teams discussed the most important components in a successful validation plan and how the RTCs would serve to establish a system that serves the stakeholder community. Following on from the first breakout session, teams reiterated that the RTCs should function as a source for defining standards and protocols for equipment testing and commissioning; the government should not certify or endorse specific technologies. The RTCs should develop validation standards that can be transferred to industry. This system could potentially increase validation coverage to all geographic and economic locations. Participants proposed that the RTCs should test set size parameters (e.g., number of modules, kW produced) with a capacity to tailor the scale to meet the needs of a particular market[2]. Although the RTC concept was originally directed at US-based module manufacturers, participants expressed an interest in developing validation standards at the system level that could be applied to testing modules, inverters, and other emerging balance-of-systems designs.

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[1] Editor's note: The interplay between performance testing, ALT, modeling and large systems validation could provide supplementary benefits. DOE's SETP programs at NREL and Sandia as well as the internal reliability programs at many component manufacturers currently perform component-scale performance and reliability testing such as ALT. DOE SETP also supports ongoing development of performance and reliability predictive modeling. The addition of the large system validation into the RTC program could provide the data sets required to corroborate component-level test results with systems-level predictions thus informing improvements to component-level test protocols.

[2] Editor's note: Participants did not reach consensus on a standard system size for testing. It was noted that different system sizes would produce different levels of confidence, and participants discussed various requirements in this area.

Teams expressed concerns about data collection and sharing. A primary concern was a need for the RTCs to quickly define data ownership. Some participants suggested that identification and distribution of performance data might necessitate incentives to guarantee manufacturer participation. Teams suggested that the RTCs should establish a protocol for publishing data that could take the form of aggregation of multiple manufacturers' data to ensure a level of anonymity, a time-delayed distribution system to mitigate data sensitivity, and/or a data holding period of a pre-determined number of years. The RTCs would also need to create a standardized reporting method that may include varying information densities to facilitate easier comprehension by specific users (e.g., researchers, financiers).

The RTC concept as presented proposed testing systems of 125 kW – 250 kW in size in three locations. Participants offered a broad range of responses to this proposal. In general, participants agreed that more test locations would be desirable. This reinforced the need for the RTCs to develop standard validation processes for use by other test entities. There was disagreement on the best system size to test. Participants suggested systems as small as 50 kW and as large as 1 MW per site. It was clear that the value obtained in testing different system sizes depended on the data recipient (e.g., module manufacturer vs. integrator vs. independent engineering firm).

Results from both breakout sessions will serve as the basis for future, more-detailed planning sessions to define validation and bankability standards for the industry. Additional discussion points identified by each team are included in Appendix D.

7. Workshop Summary and Next Steps

Workshop organizers met the day after the event to discuss participants' feedback and plan next steps to ensure that the RTCs respond to the expectations of the stakeholder community helping the DOE achieve its SunShot goals. One primary concern of the workshop participants was a need for the RTCs to develop standardized technical requirements and the technical data sets to support bankability reports that demonstrate bankability.

Additional priorities are shown below and delineate immediate RTC objectives with those targets that could occur later in the RTC program.

Immediate Goals	Long-term Goals
1. Develop validation standards built around industry and federal consensus engaging independent engineers and financial groups early in the process 2. Develop guidelines (e.g., field testing, documenting field performance, data filtering) to supplement the standards and foster industry consistency 3. Develop data collection standards with a determination on whether to rely solely on remote monitoring or allow on-site monitoring that could include executing corrective actions 4. Determine the minimum density of data that will satisfy stakeholders 5. Develop O&M processes 6. Establish modeling standards including which models to use 7. Determine minimum test block size 8. Establish the potential impacts of validating various block sizes 9. Establish procedures to certify other test sites/locations to act as validation centers 10. Define partnering requirements for manufacturers/users 11. Establish data ownership and transparency with a possibility to leverage cost sharing, tariffs, or a power purchase agreement (PPA) 12. Develop a strong RTC business plan	1. Accommodate additional RTC functions that could address grid integration, ramp rate control, interacting energy storage, new advanced inverter controls and smart grid, forecasting and sky imaging, inverter sizing and clipping, CPV models, and irradiance network 2. Contract out some RTC functions to collaborating third-party test labs 3. Develop rating classifications for systems 4. Develop the translation between the test results and the financial implications (improve the uncertainty quantification)

Appendix A: Workshop Attendees

Name	Organization
Jason Hevelone	Abound Solar
Ben Lenail	Alta Devices
Erhong Li	Alta Devices
Jeff Newmiller	BEW Engineering, Inc.
Ralph Romero	Black & Veatch Corporation
Jasbir Bath	Christopher Associates/SEMA
David Williams	CleanPath
Gary Banta	ClearSpot Energy, Inc.
Simmie Graves	Computer Design Solutions
Tony Chen	Cool Earth Solar, Inc.
Paul Dentinger	Cool Earth Solar, Inc.
Eelco Bergman	Cyrium
Narayan Ramesh	Dow Chemical
James Foresi	EMCORE
Travis Coleman	Electric Power Research Institute (EPRI)
Stephen Barkaszi	Florida Solar Energy Center (FSEC)
Dave Click	Florida Solar Energy Center (FSEC)
Bob Reedy	Florida Solar Energy Center (FSEC)
Joe Walters	Florida Solar Energy Center (FSEC)
Stephen Barkaszi	Florida Solar Energy Center (FSEC)
Noah Goldstein	Lawrence Livermore National Laboratory (LLNL)
Jin Wu	MEMC Corporation
Ken Johnston	MEMC/SunEdison
Michael Brassington	Nanosolar, Inc.
Dirk Jordan	National Renewable Energy Laboratory (NREL)
Sarah Kurtz	National Renewable Energy Laboratory (NREL)
John Wohlgemuth	National Renewable Energy Laboratory (NREL)
Brian Hill	New Energy Risk
Dustin Keele	Photon Energy Services, Inc.
Mark Weiss	PPA Partners, LLC

Name	Organization
Martin Waters	Recurrent Energy
Alan Beale	RefuSol
James Mokri	San Jose State University
Jennifer Granata	Sandia National Laboratories
Vipin Gupta	Sandia National Laboratories
Cliff Hansen	Sandia National Laboratories
Dan Riley	Sandia National Laboratories
Joshua S. Stein	Sandia National Laboratories
Scott Burroughs	Semprius, Inc.
Richard Realmuto	Sigma Energy Solutions
Scott Burroughs	Semprius, Inc.
Robert MacDonald	Skyline Solar Inc.
Clark Crawford	Soitec Solar, Inc.
Christine Covington	Solar Energy Industries Association
Ravi Menon	Solar Frontier Americas, Inc.
Tomoya Shitara	Solar Frontier Americas, Inc.
Kent Whitfield	Solaria Corporation
Shuying Yang	Solaria Corporation
David McFeely	SolarTech
Doug Payne	SolarTech
Eric Lee	SoloPower
Deepak Nayak	SoloPower
Justin Howard	SRA International, Inc.
Joseph McCabe	SRA International, Inc.
Andrew Truitt	SRA International, Inc.
Joshua Moore	Stion Corporation
David Kavulak	SunPower
Denis de Ceuster	TetraSun, Inc.
Oliver Schultz-Wittmann	TetraSun, Inc.
Eric Ma	Trina Solar Limited
Kevin Lynn	U.S. Department of Energy Solar Energy Technologies Program
Devarajan Srinivasan	ViaSol Energy Solutions, LLC
Puon Penn	Wells Fargo

Appendix B: Workshop Agenda

Wednesday, August 31, 2011		
08:25	Welcome	Jennifer Granata, Sandia National Laboratories
08:30	The Need for Validation from Concept to a Terawatt	David Williams, CleanPath Ventures
09:00	DOE's Efforts to Address the Communities' Needs for Validation	Kevin Lynn, DOE SETP
09:30	Validation Information that is Difficult to Obtain when Reviewing Projects	Jeff Newmiller, BEW Engineering, Inc.
09:50	Overcoming the Barriers to Achieving Large-Scale Production	Scott Burroughs, Semprius
10:10	Break	
10:30	Breakout Session I: Identifying the Opportunity	Introduction by Jennifer Granata, Sandia National Laboratories, prior to teams' dialogue
12:00	Lunch	
13:00	Results of Breakout Session I	Team leads
13:30	Workshop survey results	Jennifer Granata, Sandia National Laboratories
13:45	Breakout Session II: What Does Validation Look Like?	Introduction to the draft RTC validation plan by Sarah Kurtz, National Renewable Energy Laboratory, prior to teams' dialogue
15:45	Break	
16:15	Results of Breakout Session II	Team leads
16:45	Closing remarks	Jennifer Granata and Sarah Kurtz
17:00	Adjourn	

Appendix C: Breakout Session I Highlights by Team

Items listed below present an overview of gaps and opportunities that were identified by each breakout session team.

<u>Team One: Jennifer Granata, moderator</u>

Validation Gaps

- Specific input requirements for bankability assessments
- Standards of measurement [e.g., mean time between failure (MTBF), mean time to failure (MTTF), mean time to repair (MTTR)] on a system scale
- Predictions of early life failures; monitoring system that captures failures or poor performance prior to an event
- Specific, well-defined and accurate system models that include actual performance tracking models
- Set validation periods
    - Short term to allow a first-level qualification of confidence; existing testing and modeling to support this step
    - Long term that requires sufficient testing and modeling to accurately predict performance in the out years
- Standardization for systems analysis so independent engineering firms use the same techniques
- A possible need to validate inverters as well as module designs

Reliability Gaps

- Established parameters for prediction
- Benchmarking—definition of quality metrics
- Better understanding of fire hazards

<u>Team Two: Sarah Kurtz, moderator</u>

Validation Gaps

- Modeling standards that include training and education on model application use
- Increased dialogue between technical and financial communities
- System design
- Standard measurements that include small-scale installations near manufacturers
- Long-term performance data
- Third-party reviews

- O&M costs that include a standard framework for reporting costs; cost reports should cover installation costs, down time; and climate-related O&M variations

Reliability Gaps

- Long-term predictions from accelerated life testing (ALT) that correlate with performance data from various climates
- Better understanding of fire risks, materials, and recyclability

<u>Team Three: Joshua S. Stein, moderator</u>

Validation Gaps

- Verification standards that include validation of a concept, performance, reliability, and O&M metrics
- Performance models that could build on PVSyst, SAM, and manufacturer's estimates to accurately predict real results; use of existing fielded systems' data (e.g., GSA)
- Performance indicators that include durability and reliability, quality and consistency, O&M data, and power quality
- Development of highly accelerated lifecycle testing (HALT) protocols linked to field performance and reliability
- Determination whether to focus on new or existing technologies
- Determination of the most valuable use of resources (e.g., ten 100 kW sites, one 1 MW site?)
- Different potential roles for RTCs
    - Create standards and protocols for manufactures who develop products and expand manufacturing capabilities and developers who design and build projects
    - Verify of manufacturers' performance and reliability claims
    - Act as an incubator to develop validation protocols for transfer to private industry avoiding specific technology selection or certification

<u>Team Four: John Wohlgemuth, moderator</u>

Validation Gaps

- Removal of "culture of secrecy" to foster greater collaboration in all sectors that requires increased transparency of quality, reliability, and failure data to encourage greater developer participation
- Verification of standards to satisfy business community that include design with respect to location, quality certification of manufacturers' production facilities
- Established measurement protocols
- Expansion of already-drafted validation plan

Bankability Gaps

- Higher risk will influence financiers to pursue proven technologies like single crystal or polycrystalline silicon
- Risk to investors depends upon the financing mechanism; one might be more receptive to new technology
- Multiple financing structures that account for new technologies versus old technologies; risk to investors depends upon the financing mechanism; one might be more receptive to new technology
- Need to better understand bankability hurdles including tax leases not carried by banks by lease holders; tax leases with for profit are best for new technologies
- Banks don’t care about 20% of the performance, because they are investing in 80% of the system, for which these PV systems have high probability of producing 80% of rated performance
- Non-profits are going away after 1603 expires
- Tax lease risk is not on the bank shoulders but on the lease holder shoulders

Appendix D: Breakout Session II Highlights by Team

Items listed below present key validation plan elements that were identified in each breakout session team.

Team One: Jennifer Granata, moderator

Validation Opportunities

- Development of validation standard that can be propagated to the industry
- Development of testing standards including but not limited to time under test, infant mortality, degradation, failure rates, root cause analysis
- A DOE five-year program commitment
- Development of industry-wide protocols
    - Agreement that would define regulations like data ownership, sharing, and access, siting an installation, and decommissioning
    - Systems and commercial validation services based on market demands

Testing Opportunities

- Development of testing standards using a decision matrix to determine appropriate next test steps
- Definition of accuracy requirements that include a cost vs. accuracy relationship to present potential tradeoffs
    - Benchmarks for monitoring equipment to guarantee collection of reliable data
    - Confidence interval for kWh/kW
- Definition of accuracy requirements that include a cost vs. accuracy relationship to present potential tradeoffs

RTC Design

- Size requirements—a large number of small systems versus a small number of large systems
- Preparation for future including ability to field 1000 VDC systems

Funding and support

- Placing RTCs in established markets; affected by incentives, regulation, economic conditions
- Determination of criteria for manufacturer participation

Database

- Searchable and downloadable

- Quarterly data verification reports that would include root cause analysis, events and failures, and power ratios

Team Two: Sarah Kurtz, moderator

Data

- Definition of data standards that include performance and reliability measurements
- Determination of who owns data and how information is distributed to all stakeholders
- Determination of data scope and how to filter information based on stakeholder market sector
- Public distribution of data in a package format to validate models while keeping performance data private; possible data sharing options include:
    - Anonymous data in aggregate form
    - Private for x number of years after which sharing allowed
    - Gradual or timed-delayed distribution of data

RTCs

- Provisions for locating test sites based on economics (e.g., market needs) or specific data desired (e.g., local environmental stressors); possibility to certify new sites making all locations viable
- Determination of size by either number of modules or kW produced with a potential to vary based on scaled need (e.g., residential, commercial, utility); smaller options to accommodate companies that aren't ready to test greater than 125 kW systems
- Setting system-level testing limits by encouraging manufacturers to manage component-level tests
- Setting a role to validate (e.g., demonstrate) rather than feed marketing (e.g., comparative analysis)
- Defining maintenance and repair protocols

Team Three: Joshua S. Stein, moderator

Commissioning

- Performance testing that would include:
    - Derates from cell to module to array to inverter to field
    - AC output vs. insolation, temperature, etc.
    - Full spectrum including GHI, GNI, and DNI
- Reliability (annual) testing that would include:
    - Field wet resistance test (i.e., wet megger test)
    - IR and EL
    - String-level IV curves

    - Install "monitoring modules" that are not connected to the system that can be tested without disrupting the system architecture (won't be valuable for all tests)
- Failure predictions
    - Minimizing design and manufacturing issues using well-developed ALT
    - Mitigating installation complications with improved workmanship thus reducing costs
    - Forensic activities to determine what level of change would make failure detectable; a review of failure mechanisms to establish root cause and design-appropriate accelerated aging tests
- Detailed commissioning procedures to ensure similarly installed systems among sites

RTCs

- Definition of roles including how test sites will interact with manufacturers and installers
- Protection of data with possibility to require a non-disclosure agreement (NDA)
- Monetizing system production as an incentive for manufacturers

Team Four: John Wohlgemuth, moderator

O&M

- Include periodic inspection of systems; protocol already defined in NREL's Inspection Guide
- Flash test when soiled; clean then repeat flash test
- Soiling losses. Geographical data for soiling
- Baseline a system with clean modules on a clear day

Data

- Standardized report from operational test results that includes:
    - Light induced degradation, short term degradation, long term degradation and wear out degradation;
    - MTBF, MTTF, and MTTR;
    - Tracker accuracy;
    - Failure analysis with an attempt to duplicate using ALT;
    - Mechanical and environmental factors; and
    - Spectral variations
- Net metering similar to City of Davis, California

RTCs

- Number of systems to test
- Identical installations that measure different uses (e.g., residential, commercial, industrial, utility, military)

- Centers of expertise where manufacturers install and test their own technologies following established RTC methodologies that would guide validation
- Scalable test sites

Validation

- DOE policies to drive the industry
- Three-months to three-year degradation rates
- Manufacturer benchmarking
- System-level testing

Appendix E: Draft Validation Plan

The below list presents examples of data that could be collected and analyzed at the RTCs.

Commissioning

Method	Technology	Parameter	Level	Sample	Commissioning Criteria	Comments
Simulator IV	Flat-plate	Pmax, Isc, Voc, FF	Module	20 or according to IEC60410?	1. After accounting for the light induced degradation as per IEC 61215 (crystalline silicon) or IEC 61646 (thin film), the measured average power shall be equal to or higher than the nominal nameplate power rating at STC (standard test conditions) and no individual module power shall be more than 3% below nominal. In addition, the modules shall be rated at a minimum at the four other reference conditions given in IEC 61853-1 standard. 2. Coefficient of Variation (Stdev/average) <5%	In case of CPV modules, may need to do outdoor measurements. May only be able to test 5-10, depending on the size.
Simulator IV	Flat-plate	Pmax, Isc, Voc, FF	Module	40	5% < CoV <15%	If CoV > 15% → revisit w/manufacturer
Simulator IV	CPV	Pmax, Isc, Voc, FF	Cell	IEC 60410?	IEC 62670 Draft Concentrator photovoltaic (CPV) module and assembly performance testing and energy rating	CoV specifications? Do we have enough data/experience for that?
Field IV	Flat-plate	Pmax, Isc, Voc, FF	Module	All	Just documentation; no acceptance criterion	Same modules as simulator; plus all strings. Question: do installers usually detect bad modules in the field?

Method	Technology	Parameter	Level	Sample	Commissioning Criteria	Comments
IR	Flat-plate		Module, String	For modules that were measured plus strings or array		Looking for things that might get worse
EL	Flat-plate		Module	For modules that were measured above		Looking for things that might get worse

Performance

Parameter	System Level	Technology	Analysis Frequency	Automated analysis	Comments
Energy	System		Monthly	Yes	
Energy yield =kWh/kWp	System		Monthly	Yes	
PR	System		Monthly	Yes	
AC efficiency	System	Flat-plate & CPV	Monthly	Yes	
Commercial Model (PVSYST, SAM, PVWatts)	System		Quarterly	?	Accuracy of models
Manufacturer Model	System		Quarterly	?	
Sandia Model	System		Quarterly	Yes	
Degradation Rate	System		Quarterly	Yes	
P90	System		Yearly	Yes	

Reliability

Parameter	Level	Frequency	Sample	Comments
Visual inspection	Systems	Monthly	all	Take photographs
Field IV	Strings	Semiannually	All/representative sample?	Further inspection depending on findings
IV as a function of irradiance & T & AOI according to IEC 61853	Module	Beginning & end	3	Simulator or field IV depending on technology
Simulator IV	Module	Annually	Same 20 that were measured the first time. Measure others if signs of failure	Depending on degradation observed, taken from different parts of field.
IR	Strings	Quarterly	All/representative sample?	Further inspection depending on findings

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