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The 2013 PV Performance Modeling Workshop: Welcome and Purpose

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SunShot Goals and PV Performance

- DOE SunShot Goal: Cost-competitive solar energy by 2020 (\$0.06 per kW-hr LCOE)
 - Solar Energy 14% by 2030; 27% by 2050 (Source: SunShot Vision Study)
- LCOE depends on cost, performance, reliability, and O&M
- Solar fuel is “free” – most of the cost is up front – financing is very important!
- Accurate PV Performance Modeling is critical for SunShot goals to be achieved.
 - Reduce uncertainty to reduce cost of capital
 - Standard methods for characterizing technology and simulating performance
- Collaborative and inclusive approach

Agenda Topics

- Welcome and Background
- Wed 1-5 PM: Module Models: Generating performance coefficients
- Wed 7-9PM - PV System Performance Models (What's new?)
- Thurs 8-10AM - Solar Resource Data
- Thurs 10AM-2:30 - PM System Losses and Derates
- Thurs 3-4:30PM - Modeling in the Real World
- Thurs 4:30-5 PM - Summary and Next Steps....

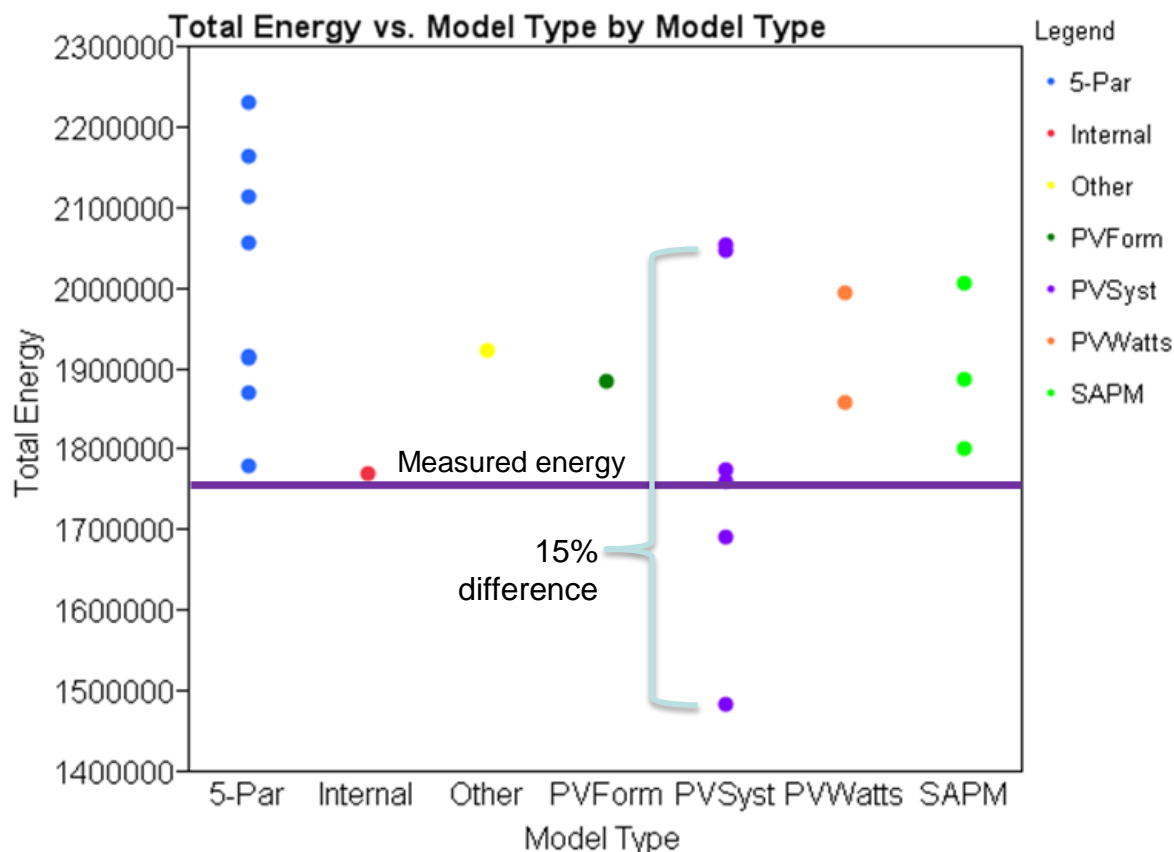
What is PVPMC? – A little history...

- In September 2010, Sandia National Laboratories held a PV Performance Modeling Workshop
 - Invite only (50 participants)
 - Model developers, Independent engineers, integrators, PV manufacturers, financiers, researchers.
 - Pre-workshop “homework” modeling assignment
 - Blind modeling exercise (predict PV system production)
 - Workshop report available at <http://pv.sandia.gov> (PV Publications)
- Workshop results:
 - Models do not agree (lots of inputs) (uncertainty ignored)
 - Models are quite different (PVWATTS to PVsyst)
 - Few standards or best practices are available
 - Non-standard data sources (module and inverter databases)
 - These factors contribute to significant perceived risk and high cost of capital.

Blind Modeling Study Example

Blind Study Facts

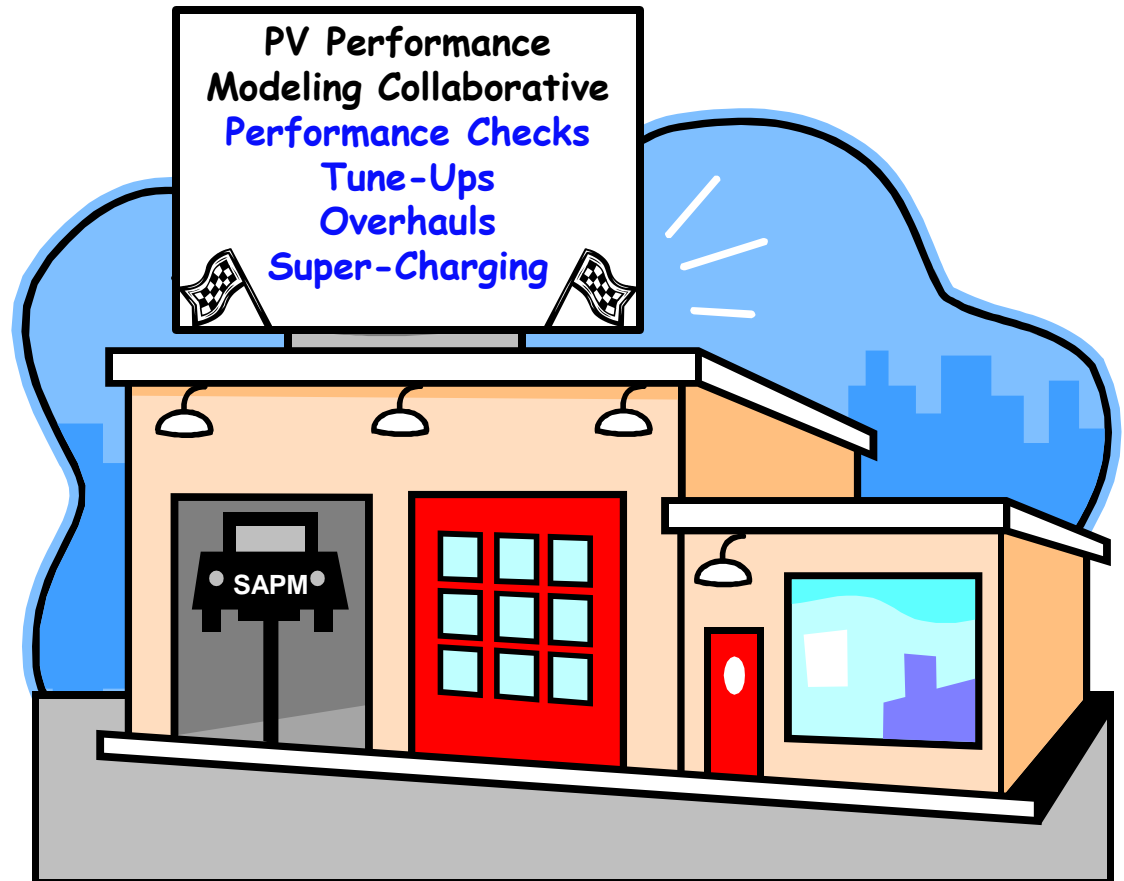
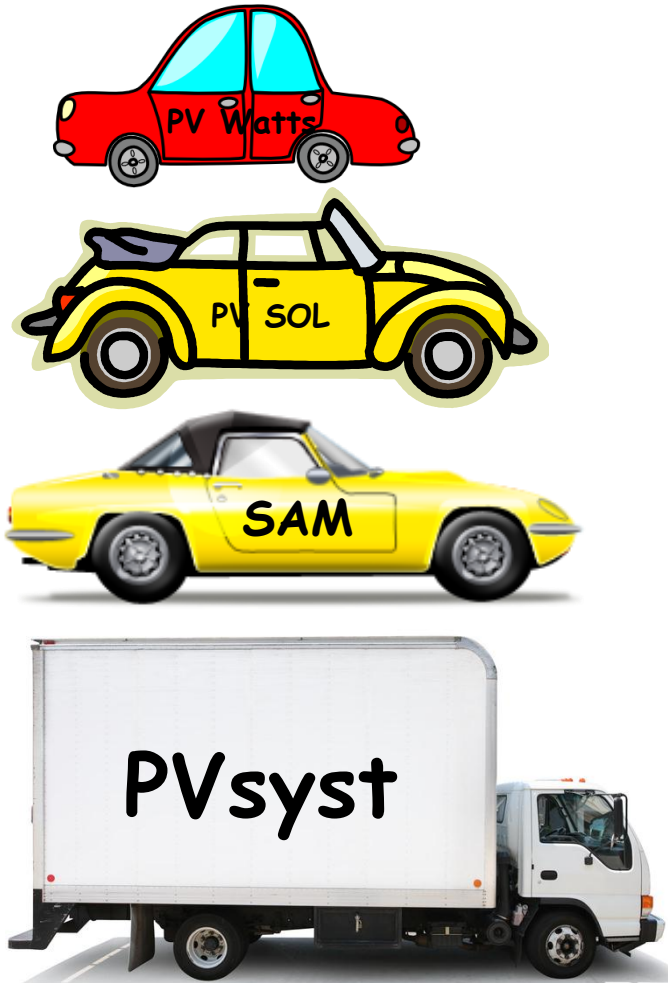
- ~20 participants
- Each given measured weather and irradiance
- Each given 3 PV system designs
- Asked to predict annual energy from systems
- Results compared with measured annual energy
- Most results over-predicted annual energy
- Differences were significant even when same model was used.



Lesson Learned: Greater consistency and transparency in modeling is needed.

- PV modelers working together to increase confidence in the predictability of PV system performance.
- Transparent science, algorithms, validation, process
- Collect and organize accurate information
- Provide access to advanced algorithms and submodels
- Organize periodic meetings, webinars, conference sessions, workshops.
- Start industry working groups to create standards and best practices for PV performance modeling.
 - Model results generated with validated models, presented in a consistent format, uncertainty is quantified.
 - Increased confidence in model predictions = more money for investment in PV.

Our Approach: Open the Hood and Work Together

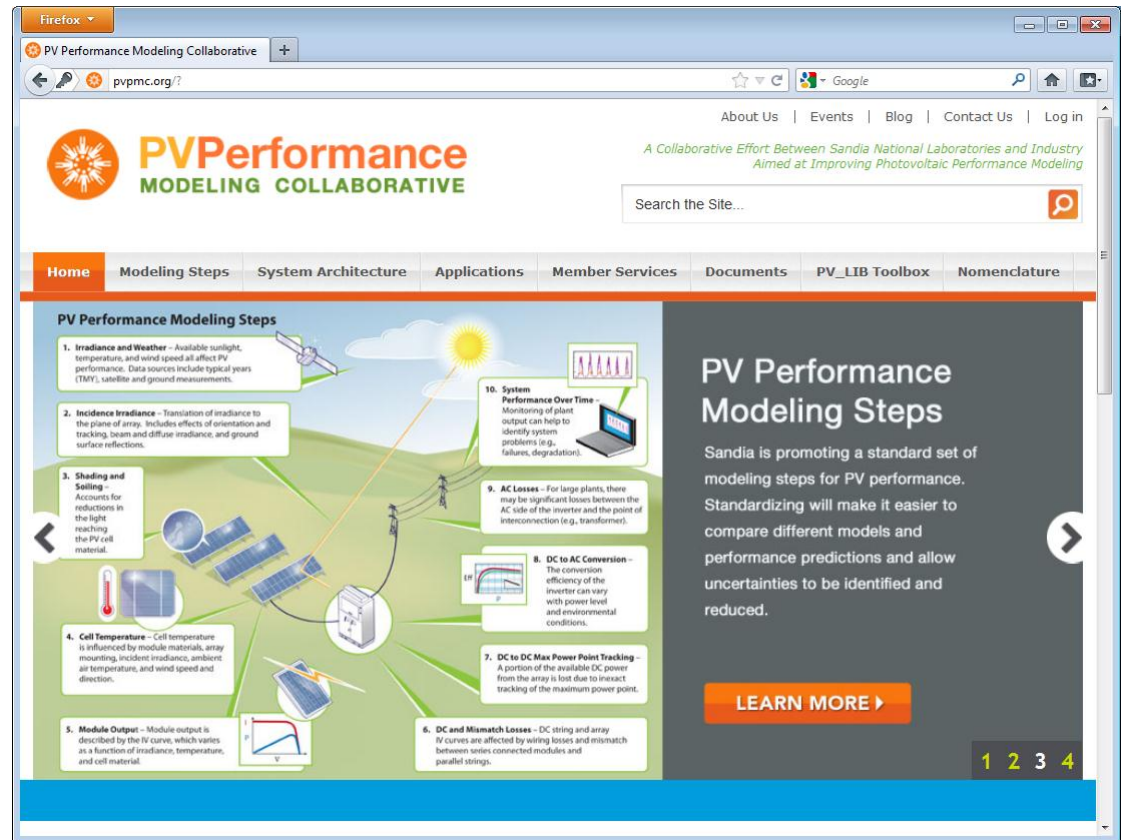


The Challenge:

Model Users Don't Know What is Under the Hood and
Model Developers Don't Know How the Model Will Be Operated

Website: <http://pvpmc.org>

Initial login = sandia



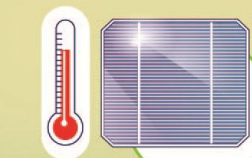
When you join you will set up a username and password

PV Performance Modeling Steps

1. Irradiance and Weather – Available sunlight, temperature, and wind speed all affect PV performance. Data sources include typical years (TMY), satellite and ground measurements.

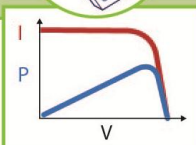
2. Incidence Irradiance – Translation of irradiance to the plane of array. Includes effects of orientation and tracking, beam and diffuse irradiance, and ground surface reflections.

3. Shading and Soiling – Accounts for reductions in the light reaching the PV cell material.

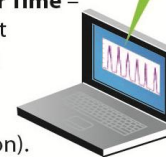
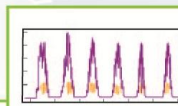


4. Cell Temperature – Cell temperature is influenced by module materials, array mounting, incident irradiance, ambient air temperature, and wind speed and direction.

5. Module Output – Module output is described by the IV curve, which varies as a function of irradiance, temperature, and cell material.

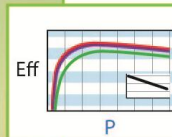


10. System Performance Over Time – Monitoring of plant output can help to identify system problems (e.g., failures, degradation).



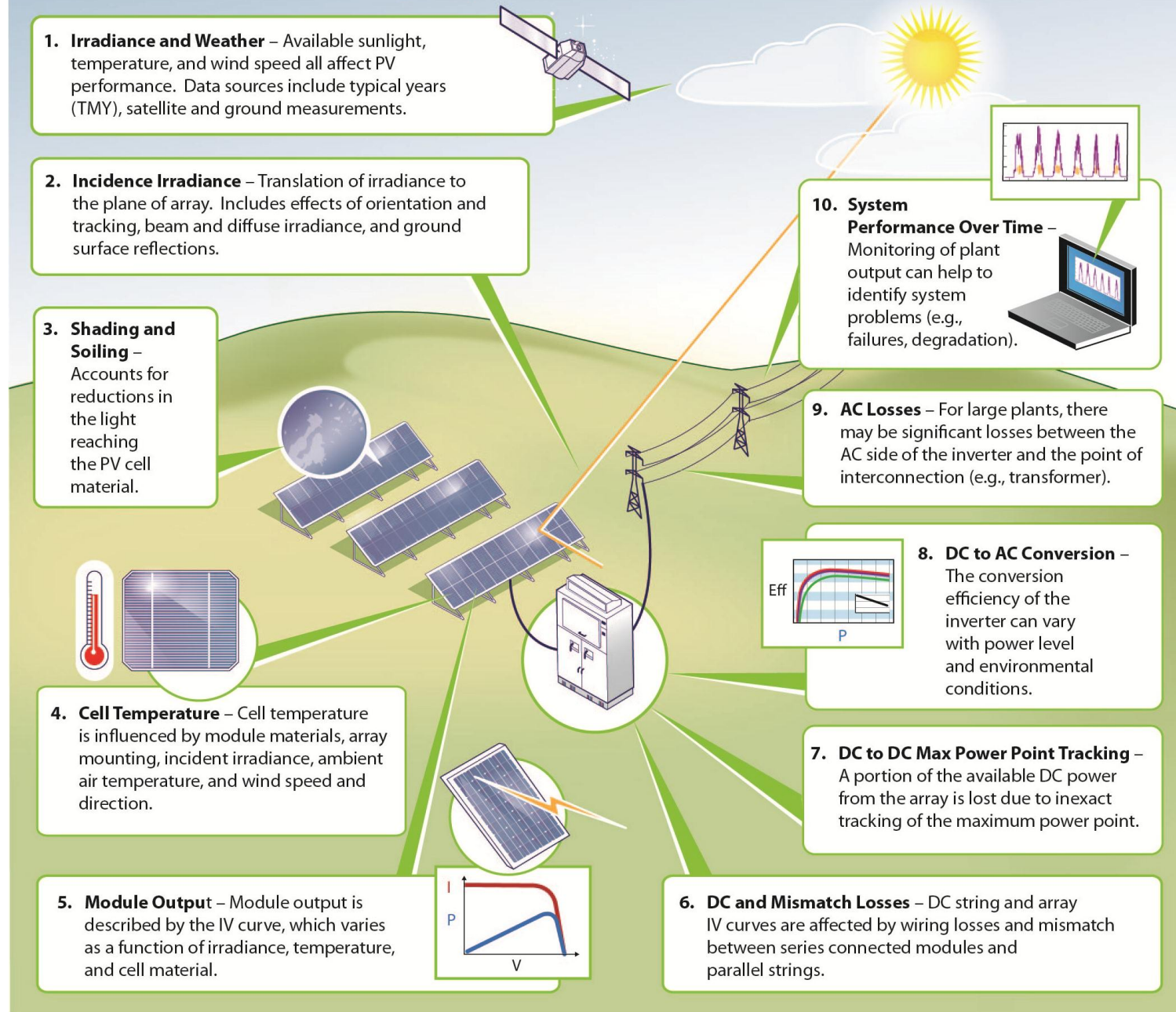
9. AC Losses – For large plants, there may be significant losses between the AC side of the inverter and the point of interconnection (e.g., transformer).

8. DC to AC Conversion – The conversion efficiency of the inverter can vary with power level and environmental conditions.



7. DC to DC Max Power Point Tracking – A portion of the available DC power from the array is lost due to inexact tracking of the maximum power point.

6. DC and Mismatch Losses – DC string and array IV curves are affected by wiring losses and mismatch between series connected modules and parallel strings.

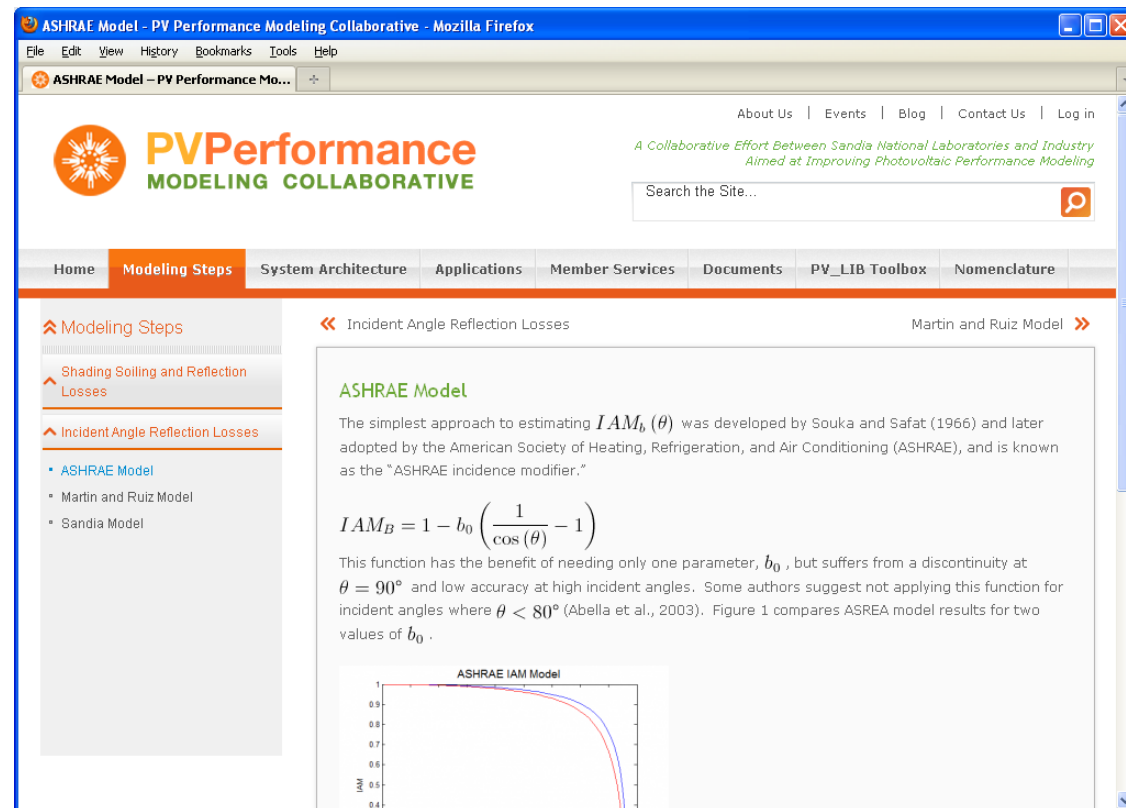


Modeling Steps

- Detailed outline covering the 10 Steps to Modeling a PV System.

This section will eventually become an online, multimedia textbook on PV performance modeling theory and practice.

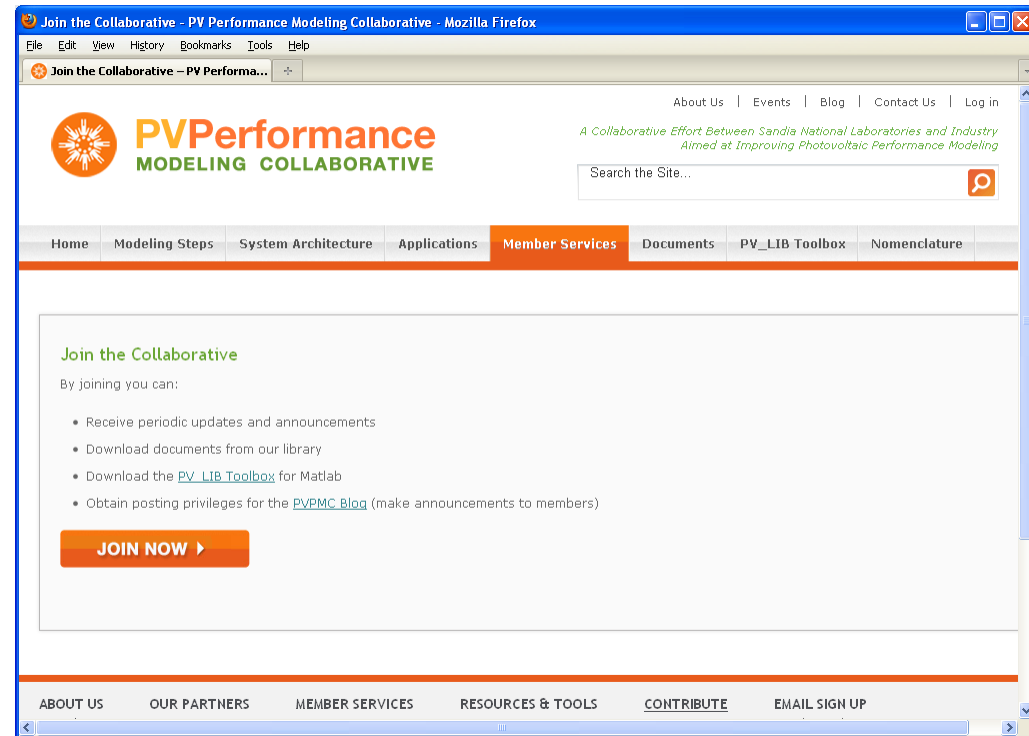
Contributors will be acknowledged at base of page.



The screenshot shows the PVPerformance Modeling Collaborative website in a Mozilla Firefox browser. The page is titled "ASHRAE Model - PV Performance Modeling Collaborative - Mozilla Firefox". The website has a navigation bar with links: Home, Modeling Steps, System Architecture, Applications, Member Services, Documents, PV_LIB Toolbox, and Nomenclature. The "Modeling Steps" section is active, showing a sidebar with links to "Shading Soiling and Reflection Losses" and "Incident Angle Reflection Losses". Under "Incident Angle Reflection Losses", there are links to "ASHRAE Model", "Martin and Ruiz Model", and "Sandia Model". The main content area is titled "Incident Angle Reflection Losses" and "Martin and Ruiz Model". It features the "ASHRAE Model" section, which describes the simplest approach to estimating $IAM_b(\theta)$ developed by Souka and Safat (1966) and later adopted by the American Society of Heating, Refrigeration, and Air Conditioning (ASHRAE). The equation for the ASHRAE IAM model is shown:
$$IAM_B = 1 - b_0 \left(\frac{1}{\cos(\theta)} - 1 \right)$$
 The text explains that this function has the benefit of needing only one parameter, b_0 , but suffers from a discontinuity at $\theta = 90^\circ$ and low accuracy at high incident angles. Some authors suggest not applying this function for incident angles where $\theta < 80^\circ$ (Abella et al., 2003). Figure 1 compares ASREA model results for two values of b_0 . A graph titled "ASHRAE IAM Model" shows the IAM value on the y-axis (ranging from 0.4 to 1.0) versus the incident angle θ on the x-axis (ranging from 0 to 90 degrees). Two curves are plotted: a red curve and a blue curve, both showing a sharp drop in IAM as the angle approaches 90 degrees.

Join for More Access

- Some features and resources are only available if you Join.
 - Documents
 - PV_LIB Toolbox
 - List of members?
- Need to provide name, email, affiliation, etc.
- Receive periodic email announcements

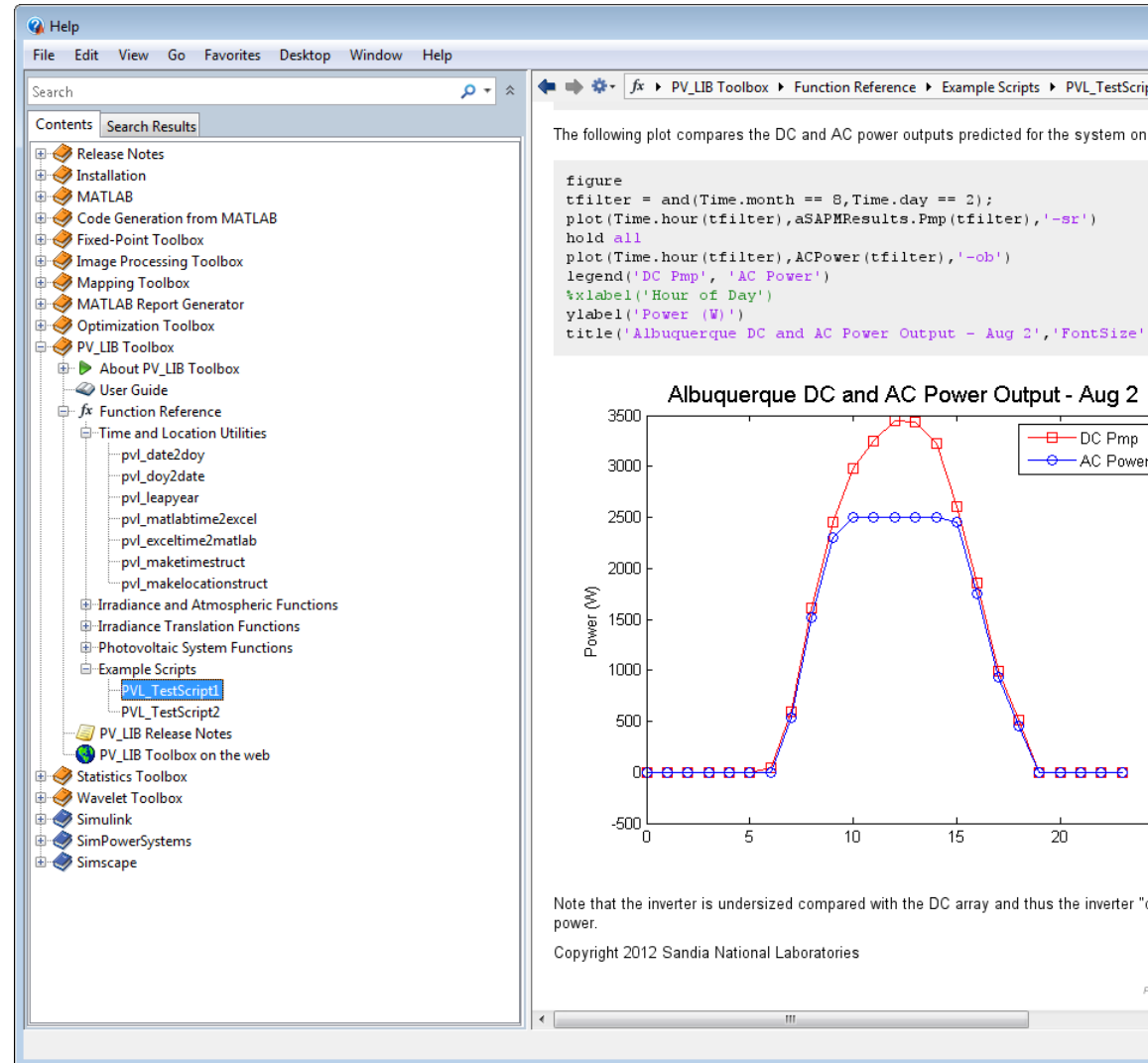


Documents, Nomenclature, Blog

- Document library
 - Documents, reports, and papers (no copyright violations)
 - Presentations
 - Datasets (databases, performance, testing, etc)
- Nomenclature
 - A to Z Listing of technical terms
- PVPMC Blog and Events (in development)
 - PV Modeling News and Events (reviews, conferences, etc)
 - Send announcements for me to post
 - Significant contributors can request posting privileges

PV_LIB Toolbox for Matlab

- Over 30 functions
 - Example scripts
 - Time and Location Utilities
 - Irradiance and atmospheric functions
 - Irradiance translation functions
 - Photovoltaic system functions
- Education, model validation, transparency
- License agreement



Summary

- Performance modeling is a key component of PV project bankability.
- Currently models are opaque. Uncertainty is significant.
- Solution: “Open the Hood”, develop and promote best practices, work across the PV field
- PV Performance Modeling Collaborative provides a venue to
 - “Write the book” on PV performance modeling methods and practice.
 - Communicate to a wide PV performance modeling community
 - Share methods and tools needed for model validation
 - Establish PV performance modeling as a “discipline”
- Join, Contribute, and Help Increase Confidence in PV System Performance!

Thank You!

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<http://solar.sandia.gov>

<http://PV.sandia.gov>

<http://pvpmc.org>