Photovoltaic Modeling and Analysis at NREL and Sandia

Nate Blair (NREL) and Joshua S. Stein (Sandia)

SYSTEMS INTEGRATION

Modeling and Analysis Activities at the National Renewable Energy Lab

1. Transferring data and algorithms from research organizations to the solar industry via ready-to-use tools.
2. Filling knowledge gaps in modeling with original research.
3. Reducing market risk and uncertainty with a credible third-party software solution.
4. Supporting R&D program planning with software to evaluate R&D improvements impact on LCOE.

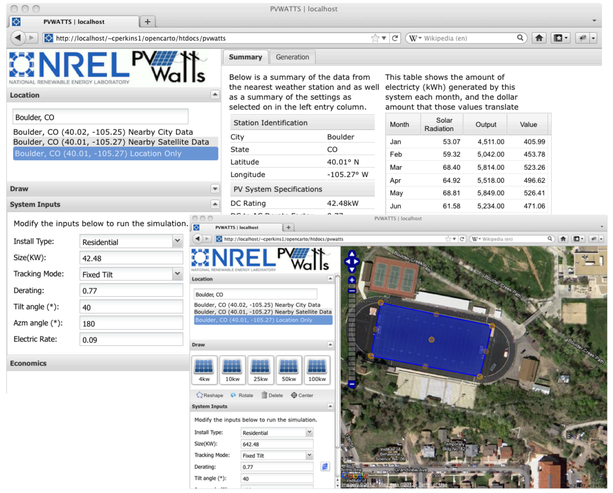
SAM Development and Support

The System Advisor Model (SAM) calculates renewable energy project metrics by combining time series modeling of system performance with cash flow modeling of project finances. SAM implements models and algorithms developed by research organizations, and presents them in a robust user interface for use by the solar energy industry. SAM's flexible performance models, detailed cost model, and extensive range of incentive and financial structures allow analysts to evaluate many types of projects.

SAM's twelve performance models can model PV, CPV, parabolic troughs, towers, linear fresnel, and dish Stirling CSP systems and non-solar systems, while its eight financial models can model single owner or more complex multi-partner financial structures. SAM's users include project developers, equipment manufacturers, academic researchers, utility companies, and consultants from around the world.

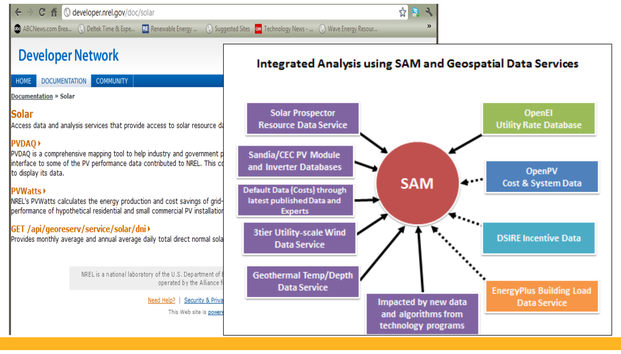
PVWatts and IMBY Combined

PVWatts is a map-based web application for non-experts to rapidly calculate basic performance and cost metrics for grid-connected PV systems. This year, NREL has added a basic financial model, and integrated PVWatts with IMBY (In My Back Yard, another NREL web application) using a drag-and-drop interface. NREL plans to continue integrating its models into a single web application to facilitate basic performance and financial analysis. SAM will serve as the "engine" behind this web application.



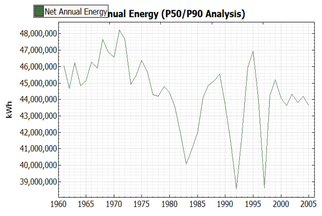
Web Services and Linkages

NREL is developing application programming interfaces (API) and web services to allow private industry to develop their own tools using NREL/Sandia's data and algorithms. This allows industry to leverage the labs' greatest strength, provides a way for industry members to communicate more transparently, and speeds technology development. SAM's PVWatts performance model and residential financing model run as a web service in the IMBY platform. Future work will expand this kind of web service and SAM's existing links to other NREL products including the Solar Prospector, the OpenEI Utility Rate Database, the DSIRE incentives database, with others planned.



Modeling P50/P90 and Monte Carlo

SAM's statistical modeling capabilities allow for modeling of uncertainty in the renewable resource (P50/P90 analysis) and costs (Monte Carlo analysis). Both have been used by NREL and other analysts to assist with broad analysis question and specific site analysis.



Recent Papers

•Gilman, P.; Dobos, A.; System Advisor Model, SAM 2011.12.2: General Description. NREL Technical Report, NREL/TP-6A20-53437, February 2012.
•Gilman, P.; General Survey of SAM Users. February 2011. Results obtained via an online survey and email correspondence with sam.support@nrel.gov
•Neises, Ty; Development and Validation of a Model to Predict the Temperature of a Photovoltaic Cell.; Master's Thesis, University of Wisconsin-Madison, 2011.
•Dobos, A. An Improved Coefficient Calculator for the California Energy Commission 6 Parameter Photovoltaic Module Model. J. Sol. Energy Eng. 134, 2012.
•Dobos, A.; Modeling of Annual DC Energy Losses due to Off Maximum Power Point Operation in PV Arrays. Upcoming in Proc. of IEEE Photovoltaic Specialists Conf. 2012.
•Dobos, A.; Gilman, P.; Kasberg, M.; P50/P90 Analysis for Solar Energy Systems Using the System Advisor Model. Proc. of the ASES/WREF Conf., 2012.
•Ho, C.; Dobos, A.; Stochastic Modeling of Concentrating Solar Power Plants Using the Solar Advisor Model (SAM). Proc. of the SolarPaces Conf. 2010
•Blair, N.; Sather, N.; Dobos, A.; Case Studies Comparing System Advisor Model (SAM) Results to Real Performance Data. Proc. of the ASES/WREF Conf. 2012.

Modeling and Analysis Activities at Sandia National Laboratories

1. Promoting standards and transparency in PV performance modeling
2. Identifying and reducing sources of uncertainty
3. Developing methods and tools for validating PV performance models
4. Field validation of models and algorithms at multiple locations

Web site: *pv.sandia.gov*

Defining Standard Modeling Steps

PV performance modeling applications are used to choose between technologies, optimize system designs, and ultimately estimate the amount of energy a PV system is expected to produce. Such estimates form the basis for determining the value of the system and are used as the basis for financing. Sandia is promoting the benefits of adopting a more standard set of modeling steps in order that various production estimates can more readily be compared and validated.

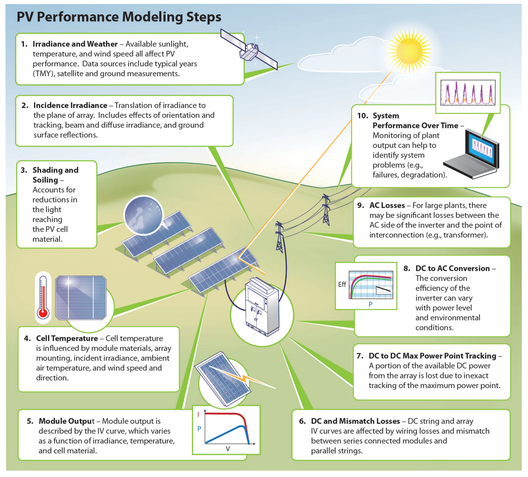


Figure 2. PV Performance Modeling Steps

PV Performance Modeling Collaborative

Existing information about available PV system modeling algorithms is not easy to find. Much of this knowledge is scattered across years of conference proceedings, journal papers, internal reports, and implemented in sparsely-documented modeling applications. This general lack of transparency contributes to diminished confidence in modeling results and increased uncertainty. In an effort to bring light to this information, Sandia National Laboratories is developing a website (www.pvpmc.org) that will host a range of information on PV performance modeling algorithms.

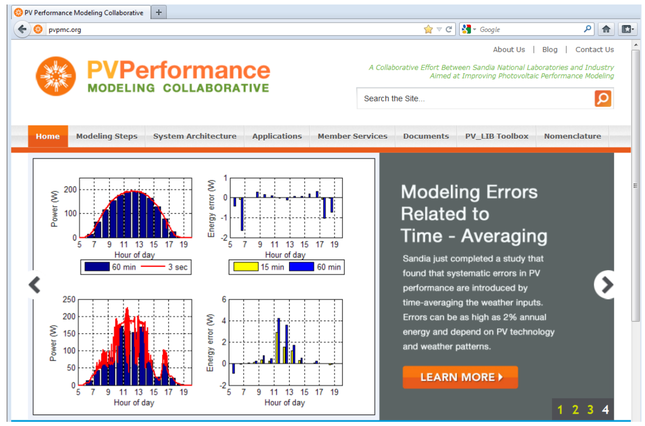


Figure 1. Example PVPMC.ORG homepage (in development)

PV_LIB Toolbox for Matlab

Sandia has developed a PV performance modeling toolbox (PV_LIB) for Matlab. It contains a set of well-documented, transparent functions and example scripts that allow model users and developers to better understand how PV performance is predicted and independently validate commercial modeling packages. This toolbox is meant to help make the multi-step process of modeling a PV system accessible for beginning to advanced model users. The toolbox includes the following function categories:

•Time and Location Functions
•Irradiance Functions
•Irradiance Translation Functions
•Photovoltaic System Functions

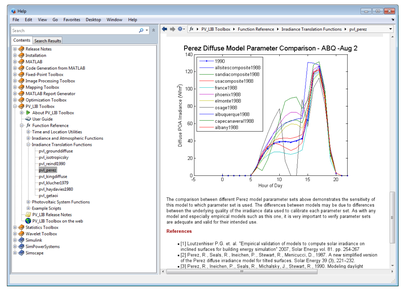
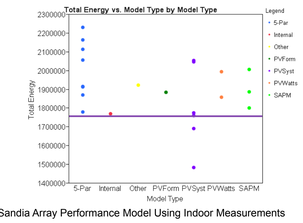


Figure 3. Example of PV_LIB Toolbox Help.

Modeling Uncertainties

Sandia sponsored the PV Performance Modeling Workshop in 2010 and conducted a blind modeling study. Each participant tried to model 3 PV systems for a year. Measured weather and systems designs were provided. Results varied significantly.



Recent Papers

- Hansen, C., D. Riley and M. Jaramillo (2012). Calibration of the Sandia Array Performance Model Using Indoor Measurements IEEE Photovoltaic Specialists Conference, Austin, TX.
- Hansen, C. and J. Stein (2012). Effect of Time Averaging on Estimation of Photovoltaic System Performance. World Renewable Energy Forum, Denver, CO.
- Hansen, C., J. Stein and D. Riley (2012). Effect of Time Scale on Analysis of PV System Performance. Albuquerque, NM, Sandia National Laboratories, SAND2012-1099.
- Stein, J. (2012). The Photovoltaic Performance Modeling Collaborative IEEE Photovoltaic Specialists Conference, Austin, TX.
- Cameron, C., J. Stein and C. Hansen (2011). Evaluation of PV Performance Models and Their Impact on Project Risk. 1st PV Rollout Conference, Boston, MA.
- Cameron, C., J. Stein and C. Tasca (2011). PV Performance Modeling Workshop Summary Report. Albuquerque, NM, Sandia National Laboratories, SAND2011-3419.
- Hansen, C., J. Stein, S. Miller, E. E. Boyson, et al. (2011). Parameter Uncertainty in the Sandia Array Performance Model for Flat-Plate Crystalline Silicon Modules. IEEE Photovoltaics Specialists Conference, Seattle, WA.
- Cameron, C., C. Crawford, J. Foresi, D. King, et al. (2010). Performance Model Assessment for Multi-Junction Concentrating Photovoltaic Systems. 6th International Conference on Concentrating Photovoltaic Systems, Freiberg, Germany
- Stein, J., C. Cameron, B. Bourne, A. Kimber, et al. (2010). A Standardized Approach to PV System Performance Model Validation. IEEE Photovoltaics Specialists Conference, Honolulu, HI.
- Stein, J., R. Perez and A. Parkins (2010). Validation of PV Performance Models using Satellite-Based Irradiance Measurements: A Case Study. American Solar Energy Society SOLAR2010, Phoenix, AZ

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U.S. DEPARTMENT OF ENERGY

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