



DOE Solar Energy Technologies Program Peer Review

**CSP Market Transformation: Solar Advisor
Support**

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Denver, Colorado

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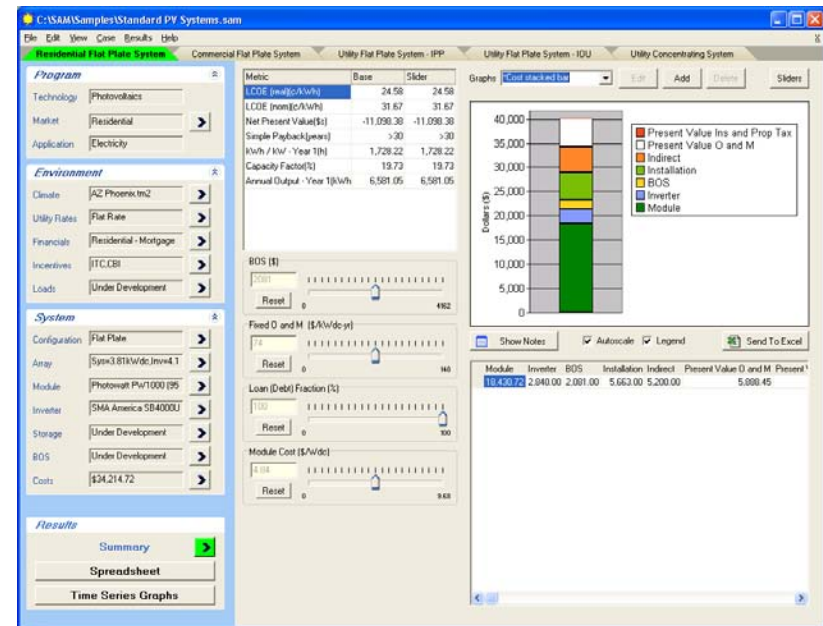


- **Primary Responsibilities of NREL:**
 - SAM model development
 - Implement new capabilities
 - Coordinate programming, version release, documentation
 - Technical monitor for several contracts
 - User support (DOE and industry support)
- **Budget: \$250K (FY08)**
- **Team (at NREL):**
 - Nate Blair, Sr. Energy Analyst, Team Lead
 - Craig Christensen, Solar Buildings
 - Bolko Von Roedern, NCPV
 - Aron Dobos, Software Programmer/ Engineer
 - Paul Gilman, Contract Writer/User Support
 - Steve Janzou, External Programmer
 - Mark Mehos, CSP Program Director
 - Craig Turchi, CSP Analyst
 - Mike Wagner, CSP Analyst



Vision

- Combine PV, CSP, thermal solar technologies into a single model
- Make high-quality performance models developed by NREL, Sandia, and other partners available to a wider audience
- Facilitate comparison by handling performance, costs and financing consistently across technologies
- Facilitate calculating the impact of R&D on LCOE, NPV, etc. in various markets.
- Provide sensitivity analysis and graphing capabilities



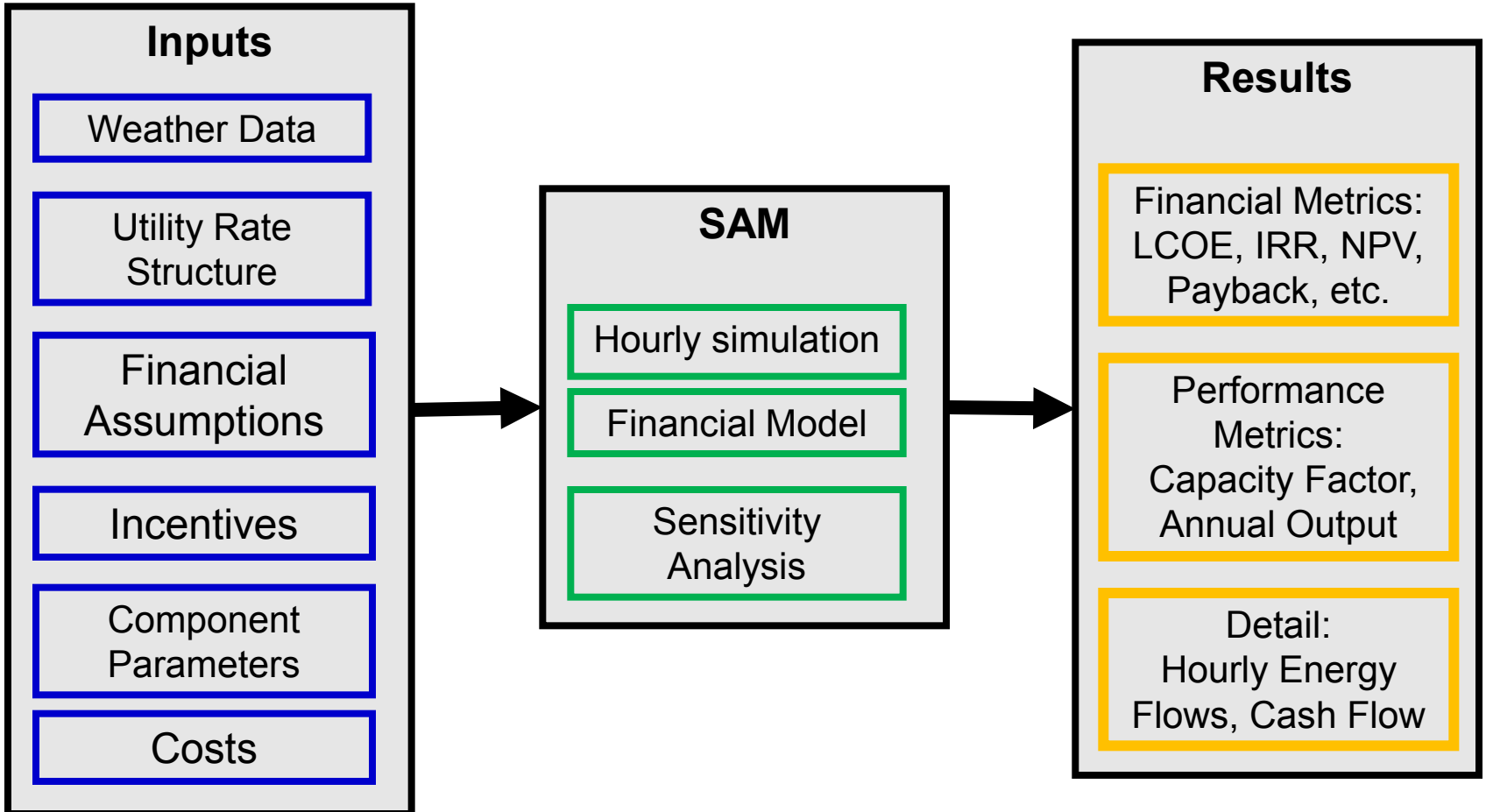


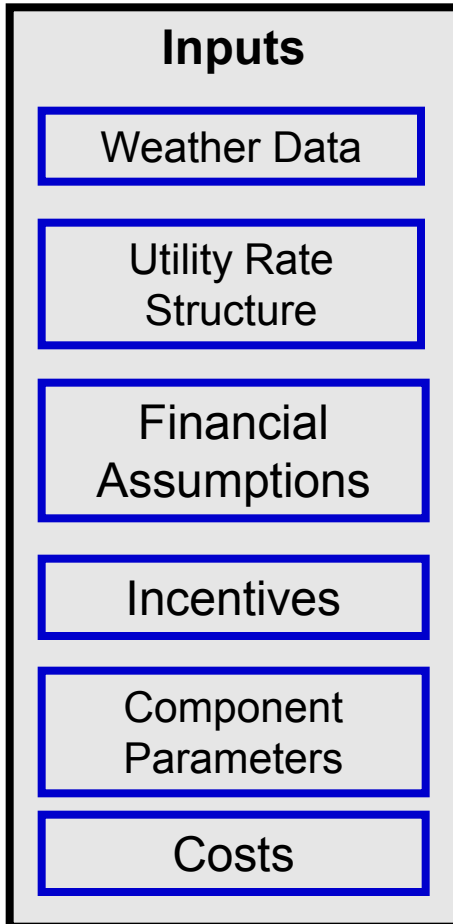
Prior Accomplishments

- Created a framework for modeling solar systems from performance through financing and incentives for PV and CSP troughs
- Supported Solar America Initiative TPP's

Major Recent Accomplishments (roughly FY08) (details to follow)

- Released new SAM versions with:
 - Added ability to model dish Stirling systems within SAM based on model developed for SAM by Univ. of WI grad student (now working for a dish Stirling firm)
 - Added representation of dry cooling vs. wet cooling
 - Detailed O&M inputs (annual \$, \$/MW, \$/MWh options)
 - Enhanced GUI and greater graphical output capability
 - Added time-of-use utility rates and automated IPP financing optimization to SAM
- SAM finance model with incentives operational and externally-reviewed
- Conducted first annual SAM user forum at ASES Solar 2008 Conference
- Conducted online SAM user survey
- Hired at NREL an engineer that just developed a power tower model for
with SAM will be used in this project





- Built-in data sets for:
 - Weather data
 - Utility rate structure
 - Component parameters
- Sample default values for:
 - System parameters
 - Financial assumptions
 - Incentives
 - Costs
- Additional data on the Web for:
 - Weather data (TMY2, EPW format, satellite data sets)

Input variables can be linked to Excel spreadsheets



Download and use of recent solar satellite data

The screenshot shows a GIS web application interface. On the left is a 'Layers' panel with a tree view of GIS Layers. The 'Download' layer is selected. The main map area shows a color-coded solar resource map with a red rectangular selection box. Above the map are navigation tools: Zoom Box, Pan, Query, Download, and Clear. A 'Download Window' is open on the right, containing two sections: '1. Select Formats:' with 'TMY Format' and 'CSV Format' options, and '2. Select Years' with a list of years from 1998 to 2004. The 'Selected' column contains '2001', '2005', and 'TDY'. 'Submit' and 'Close' buttons are at the bottom of the window. At the bottom of the map, a slider indicates 'Display Month: APR'.

Layers

- GIS Layers
 - Solar Resources
 - Average DNI (1998 - 2005)
 - Resource Classes
 - Slope Filters
 - Infrastructure
 - Transportation
 - Interstates
 - US Highways
 - Rails
 - Hydrology
 - Land Ownership
 - Boundaries
 - Base Data
 - Shaded Relief
 - Satellite Imagery
 - Download
 - Download Grid

Map

Zoom Box Pan Query **Download** Clear

Download Window

1. Select Formats:

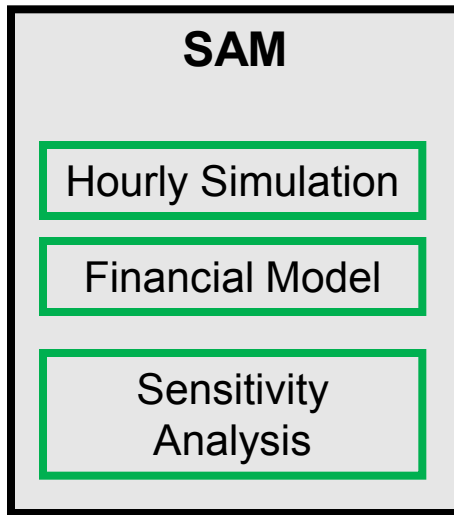
- TMY Format
- CSV Format

2. Select Years

Available	Selected
1998	2001
1999	2005
2000	TDY
2002	
2003	
2004	

Submit Close

Display Month: APR



- Processes input data to calculate hourly output and cash flow
- TRNSYS simulation engine
 - Uses component models developed by the SAM team to incorporate best available models for components/systems
- Sensitivity analysis: multiple





- Detailed cashflow model
- Output
 - LCOE, NPV, IRR, revenue, taxes, etc.
- Residential
 - Cash, loan, or mortgage
- Commercial
 - Cash, loan, or 3rd-party owner
- Utility scale

Type of Financing

General

Analysis Period years
Inflation Rate %
Real Discount Rate %

Taxes and Insurance

Federal Tax %/year
State Tax %/year
Property Tax %/year
Sales Tax %
Insurance %

Power Purchase Agreement (PPA)

PPA Escalation Rate %
 Optimize PPA escalation rate to minimize LCOE.

Constraining Assumptions

Specify minimum equity Internal Rate of Return (IRR) and minimum Debt Service Coverage Ratio (DSCR) and Positive Cashflow requirement

Minimum Required IRR %
Minimum Required DSCR
Positive Cashflow

Loan

Amount
Term years
Rate %/year
 Loan (Debt) Fraction %
 Optimize debt fraction to minimize LCOE.

Federal Depreciation

No Depreciation
 MACRS Mid-Quarter Convention
 MACRS Half-Year Convention
 Straight Line years

State Depreciation

No Depreciation
 MACRS Mid-Quarter Convention
 MACRS Half-Year Convention
 Straight Line years



- Incentive types
 - Tax credits
 - Investment
 - Production
 - Investment-based incentives (buy-downs)
 - Capacity-based incentives
 - Production-based incentives
- Separate possible entries
 - Federal
 - State
 - Utility
 - Other
- Modify tax implications

Show Tax Details

			Taxable Incentive	Incentive Reduces ITC Basis	Incentive Reduces Depreciation Basis
			Federal	State	Federal
- Investment Tax Credit (ITC)					
Amount (\$)					
<input type="checkbox"/> Federal	<input type="text" value="0"/>		n/a	no	n/a n/a
<input type="checkbox"/> State	<input type="text" value="0"/>		no	n/a	n/a n/a
%					
Maximum (\$)					
<input checked="" type="checkbox"/> Federal	<input type="text" value="10"/>	<input type="text" value="1E99"/>	n/a	no	n/a n/a
<input type="checkbox"/> State	<input type="text" value="0"/>	<input type="text" value="1E99"/>	no	n/a	n/a n/a
+ Production Tax Credit (PTC)					
- Investment Based Incentive (IBI)					
Amount (\$)					
<input type="checkbox"/> Federal	<input type="text" value="0"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
<input type="checkbox"/> State	<input type="text" value="0"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
<input type="checkbox"/> Utility	<input type="text" value="0"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
<input type="checkbox"/> Other	<input type="text" value="0"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
%					
Maximum (\$)					
<input type="checkbox"/> Federal	<input type="text" value="0"/>	<input type="text" value="1E99"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
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<input type="checkbox"/> Utility	<input type="text" value="0"/>	<input type="text" value="1E99"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
<input type="checkbox"/> Other	<input type="text" value="0"/>	<input type="text" value="1E99"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
+ Capacity Based Incentive (CBI)					
+ Production Based Incentive (PBI)					

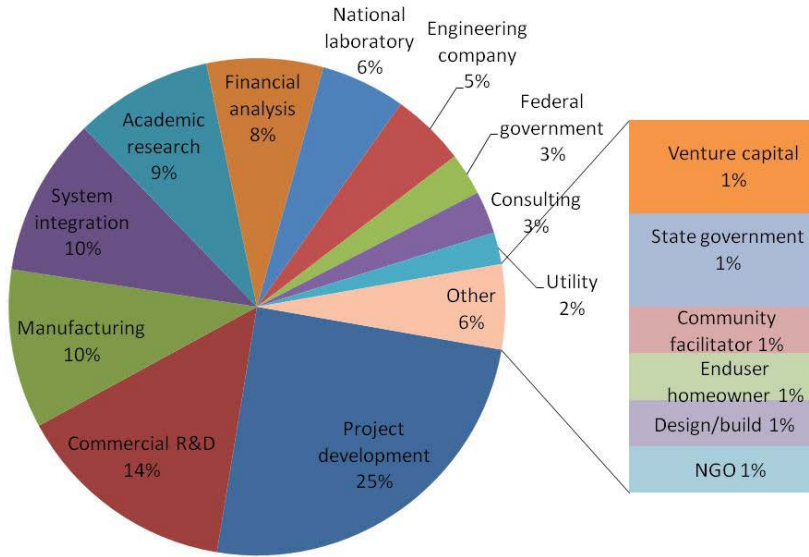


- PV modules
 - Single-point efficiency with temp. coefficient
 - Single-point efficiency for concentrating PV
 - Sandia PV Array Performance Model
 - CEC/Wisc 5-Parameter Model
- Inverters
 - Single-point efficiency inverter model
 - Sandia Inverter Performance Model
- CSP
 - Parabolic trough (based on NREL's Excelergy model)
 - Dish Stirling
 - Power towers (March 2009)
- Generic
 - Very simple (capacity) * (capacity factor) model for comparison with non-solar technologies



Future Work Survey Results

Survey Respondents by Type of Organization



Add financing options.

Show derated output in hourly results.

Improve the solar-hybrid (fossil-backup) model.

Improve dry- and hybrid-cooling performance model.

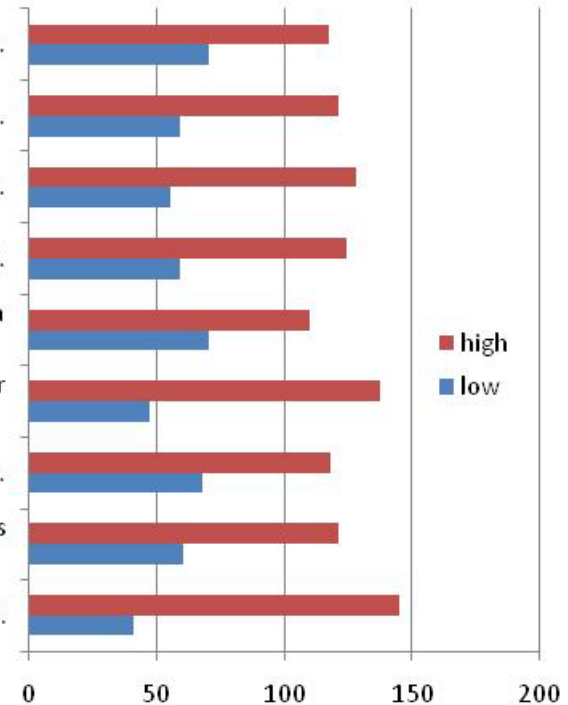
Replace current power plant model with a thermodynamic model.

Add trough configurations such as direct steam or other.

Add user-defined heat transfer fluids (HTF).

Replace current coefficient-based component models with ones that use physical parameters.

Improve thermal storage dispatch model.





CORE ACTIVITIES

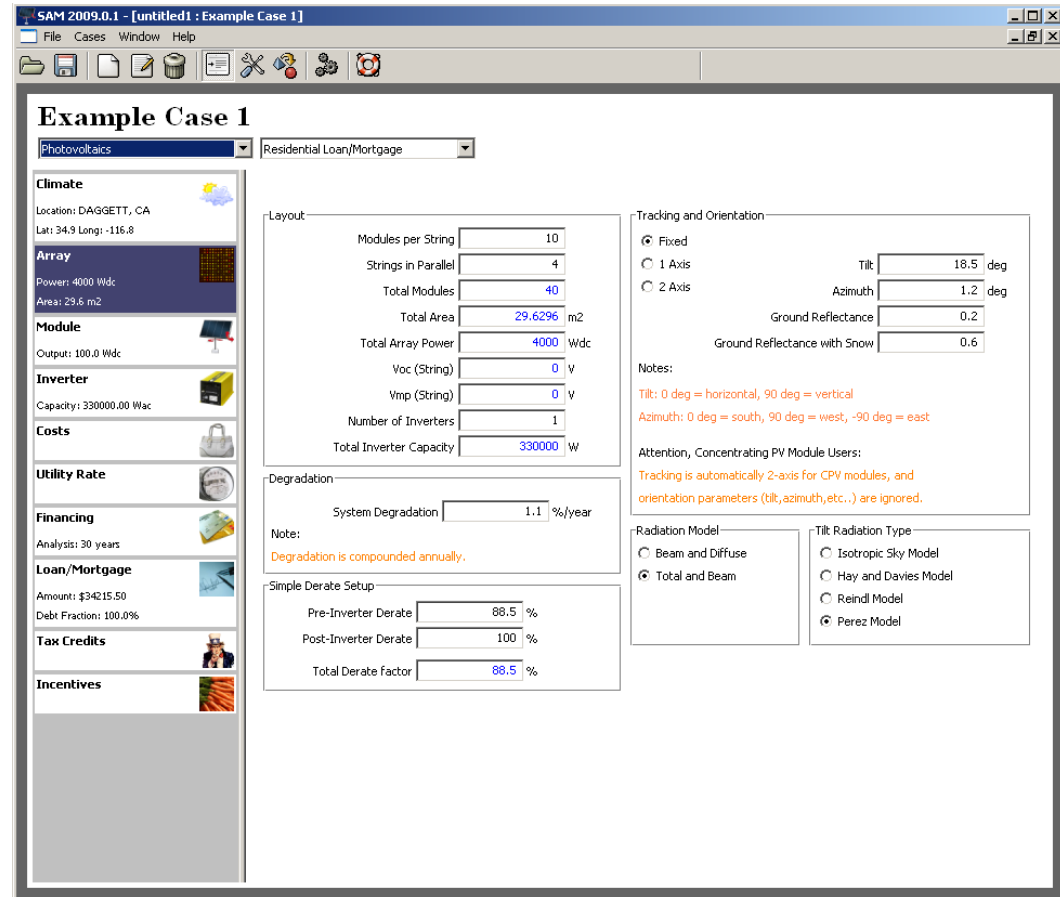
- Several activities to create a communication pathway from users to the SAM development team
- Several activities in user support area to improve and augment SAM documentation
- Link to database of incentives based on the DSIRE Website
- Rewriting SAM in C++ with a structure to allow multiple platforms, subsystem aggregation, risk analysis (behind @Risk/CrystalBall)

Specific CSP Activities:

- Support student project on modeling power tower systems and future enhancements
- Release SAM version 3.0 with the following:
 - A major update of the user manual with documentation
 - Power tower model
 - Updated dish / Sterling model
 - Updated Rankine cycle model
 - Improved power dispatch algorithm
- Release SAM version 3.5 with the following:
 - Applets for user-defined coefficients for trough systems
 - Case studies of one or more operating plants
 - Greater dish/Stirling system library
- Eventually want to add generic optical mapping capability to incorporate wide variety of collector configurations



- C/C++ implementation – more commonplace than Delphi
- Modular components
- New framework allows for rapid integration of new technologies and simulation models
- Allows simulation engine to be invoked from any application (Excel-VBA, PHP, C/C++, Delphi, etc)
- Faster than existing implementation
- Allows for use by @Risk or CrystalBall through Excel
- Will run on Windows, Mac, Unix
- Easily used as a web-app (already running in prototype)





- Over 3,500 copies downloaded by
 - Manufacturers
 - Engineering consulting and R&D firms
 - Utilities
 - Developers
 - Venture capital firms
- Examples of SAM applications
 - Xcel Energy: Use of SAM for resource planning for CSP and PV
 - In New Jersey, promoted as standard analytical tool for the state's clean energy program
 - Federal Energy Management Program: feasibility studies
 - PowerLight: compare with internal financial models
 - Arizona Public Service: verify energy production estimates
 - University graduate research projects



Publications

- Cameron, C.; Cornelius, C. (2007). "A Systems-Driven Approach to Solar Energy R&D". *IEEE International Conference on Systems of Systems Engineering*; 6 pp.
- Gilman, P.; Blair, N.; Mehos, M.; Christensen, C.; Janzou, S.; Cameron, C. (2008). *Solar Advisor Model User Guide for Version 2.0*. 133 pp.
- Blair, N.; Mehos, M.; Christensen, C. (2008). "Sensitivity of Concentrating Solar Power Trough Performance, Cost and Financing with Solar Advisor Model." *2008 14th Biennial CSP SolarPACES (Solar Power and Chemical Energy Systems) Symposium*, 4-7 March 2008, Las Vegas
- Blair, N.; Mehos, M.; Christensen, C.; Cameron, C. (2008). *Modeling Photovoltaic and Concentrating Solar Power Trough Performance, Cost, and Financing with the Solar Advisor Model*
- Blair et al., Chapter on Solar Advisor Model for Wiley *Solar Cells and Their Applications*, 2nd ed., in preparation

Presentations

- User Forum, American Solar Energy Society Conference, May 2008
- Riley et al, "Comparison of PV System Performance-Model Predictions with Measured PV System Performance," 3rd Annual Solar Metering and Performance Monitoring Expo, February, 2009

Webinars on the Solar Advisor Model

- NREL Strategic Energy Analysis Center Seminar, March 2008
- Solar Electric Power Association, December 2008