DOE Solar Energy Technologies Program Peer Review

CSP Market Transformation: Solar Advisor Support

Nate Blair

Denver, Colorado

March 9-10, 2009

This presentation does not contain any proprietary or confidential information.

Quality, Productivity, Accomplishment

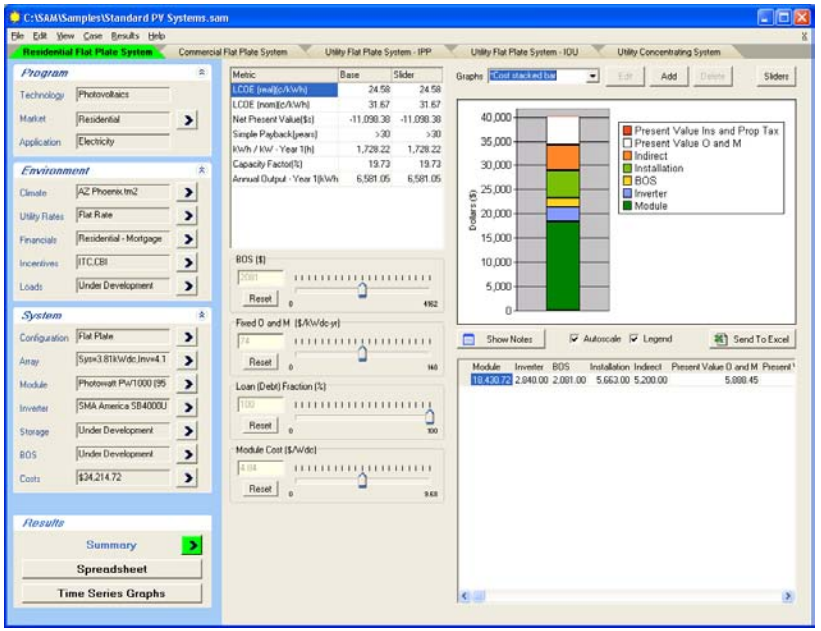
- Primary Responsibilities of NREL:
  - SAM model development
    - Implement new capabilities
    - Coordinate programming, version release, documentation
    - Technical monitor for several contracts
  - User support (DOE and industry support)
- Budget: $250K (FY08)
- Team (at NREL):

- 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

SAM

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



Quality, Productivity, Accomplishment

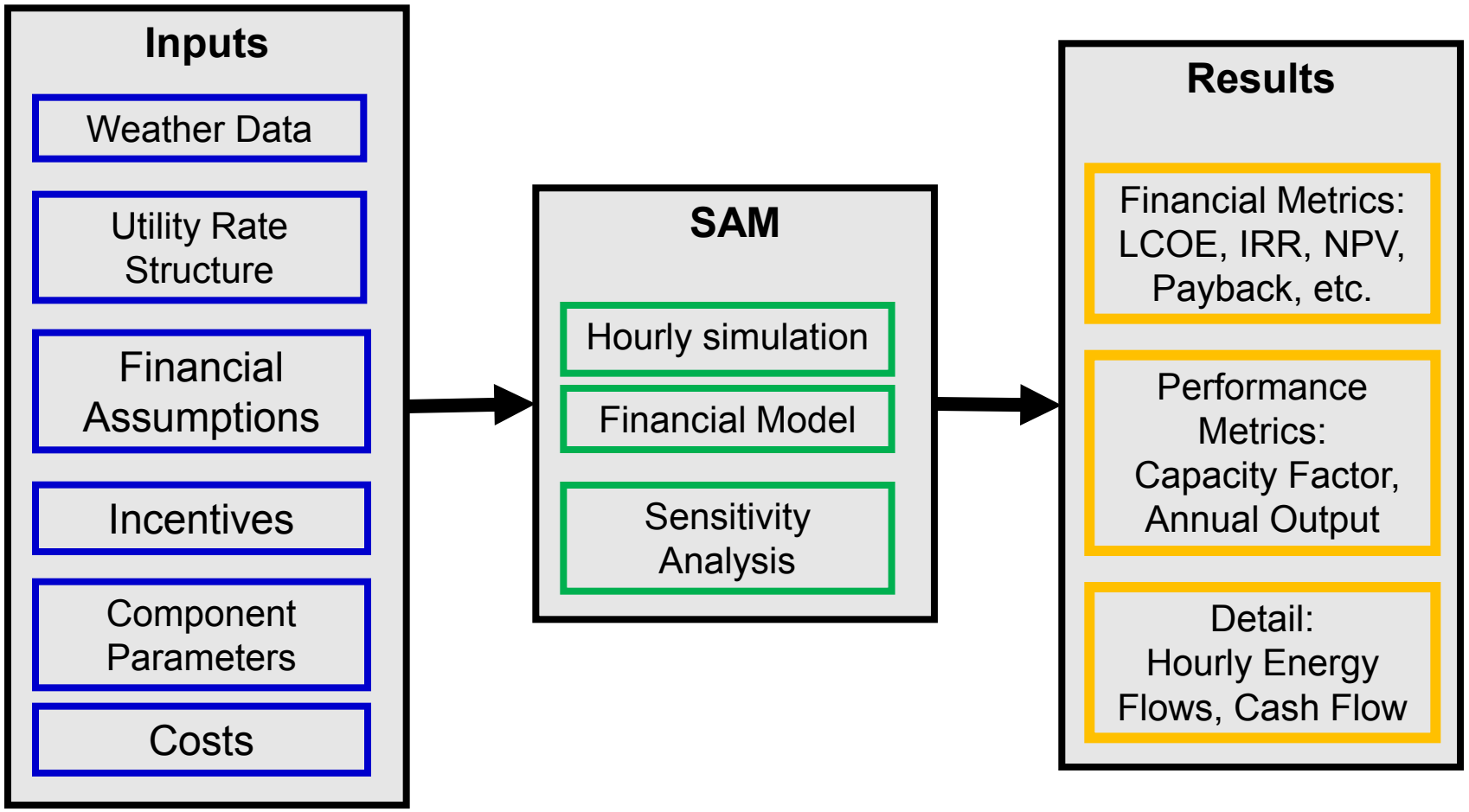
Prior Accomplishments

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

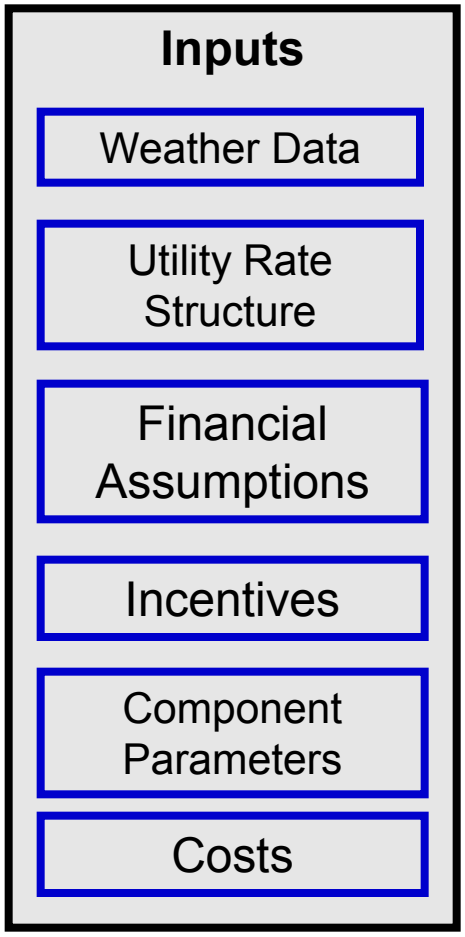
Major Recent Accomplishments (roughly FY08) (details to follow)

- 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

Block


Inputs
Weather Data
Utility Rate Structure
Financial Assumptions
Incentives
Component Parameters
Costs
SAM
Hourly simulation
Financial Model
Sensitivity Analysis
Results
Financial Metrics: LCOE, IRR, NPV, Payback, etc.
Performance Metrics: Capacity Factor, Annual Output
Detail: Hourly Energy Flows, Cash Flow

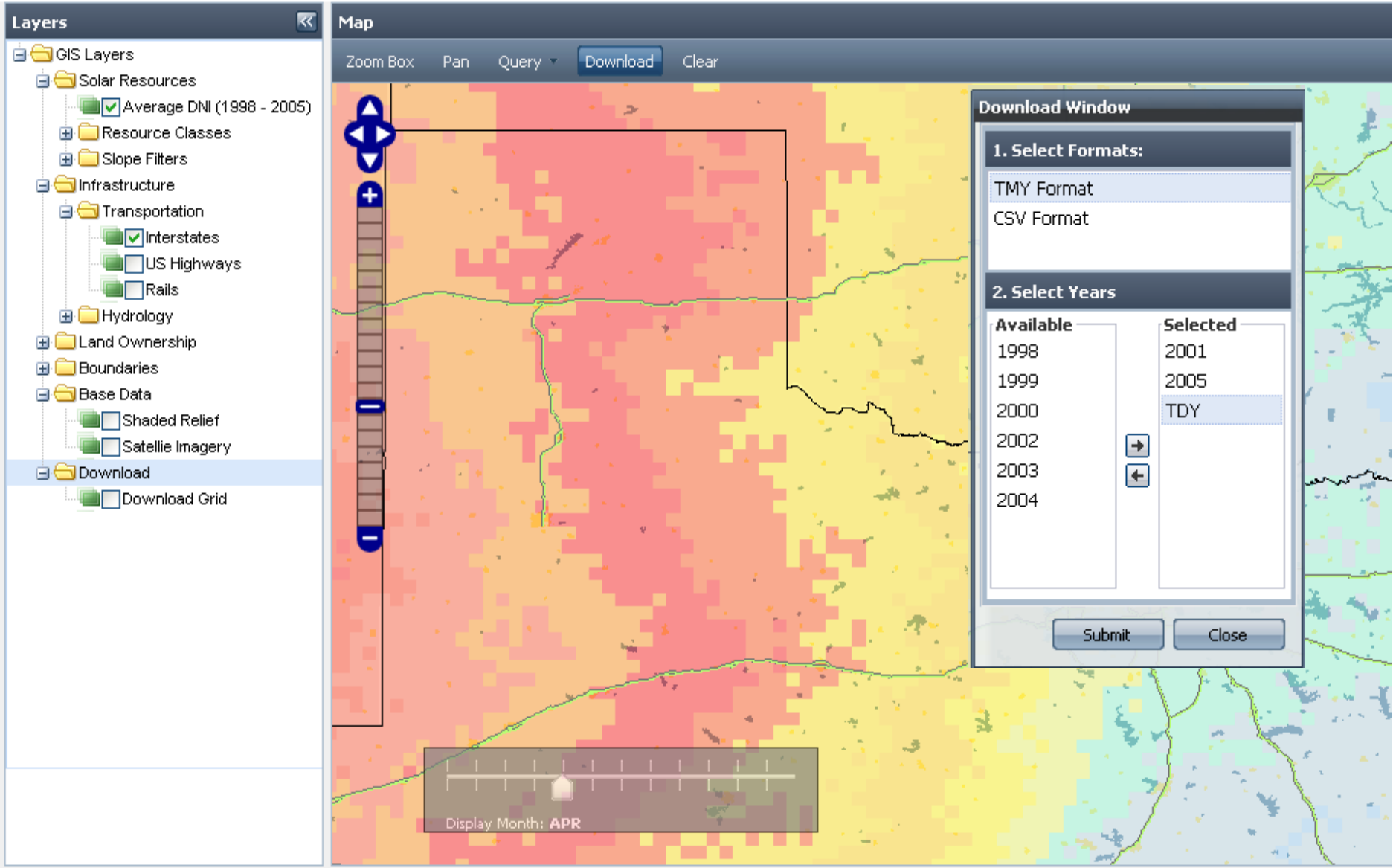
Input Data Sources



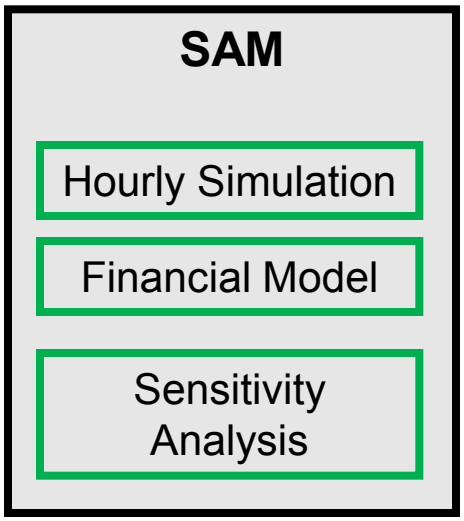
- Built-in data sets for:
  - Weather data
  - Utility rate structure
  - Component parameters
- Sample default values for:
  - System parameters
  - Financial assumptions
  - Incentives
  - Costs
- Additional data on the Web for:
  - Weather data (TMY2, EPW format, satellite data sets)

Input variables can be linked to Excel spreadsheets

Download and use of recent solar satellite data



SAM Core

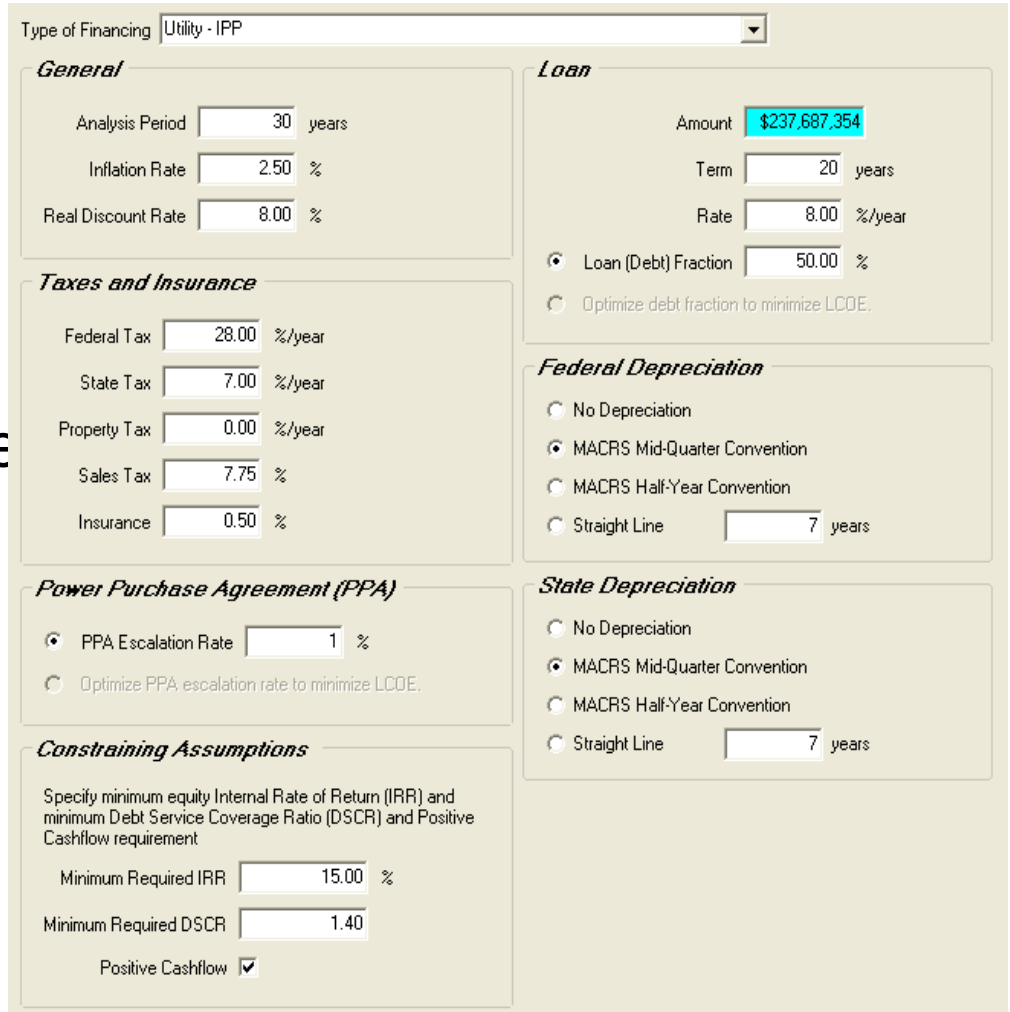


- Processes input data to calculate hourly output and cash flow
- TRNSYS simulation engine
  - Uses component models developed by the SAM team to incorporate best available models for components/systems
- Sensitivity analysis: multiple

TRNSYS is developed and maintained by the Solar Energy Laboratory of the University of Wisconsin at Madison.
http://sel.me.wisc.edu/trnsys/

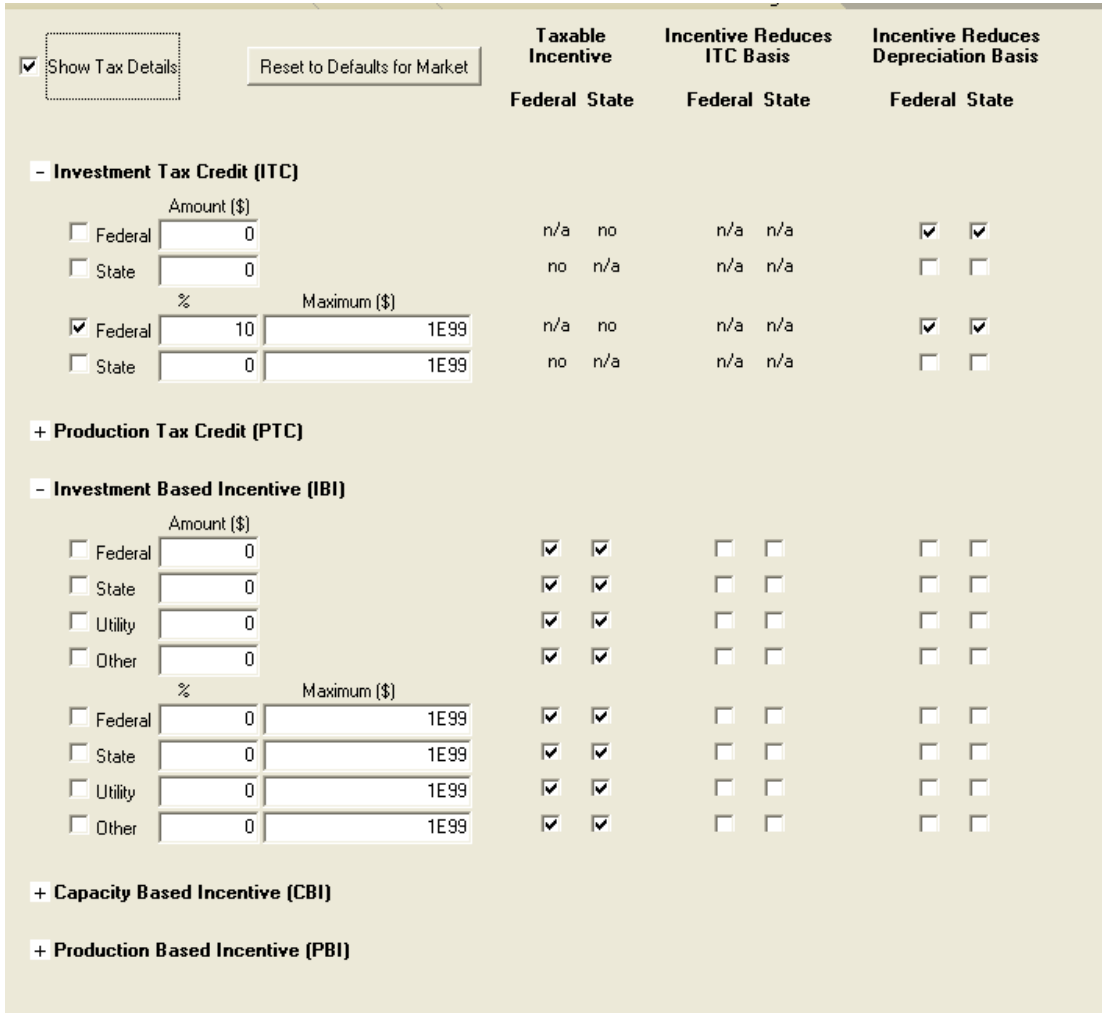
Finance Model

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



Financial Incentives

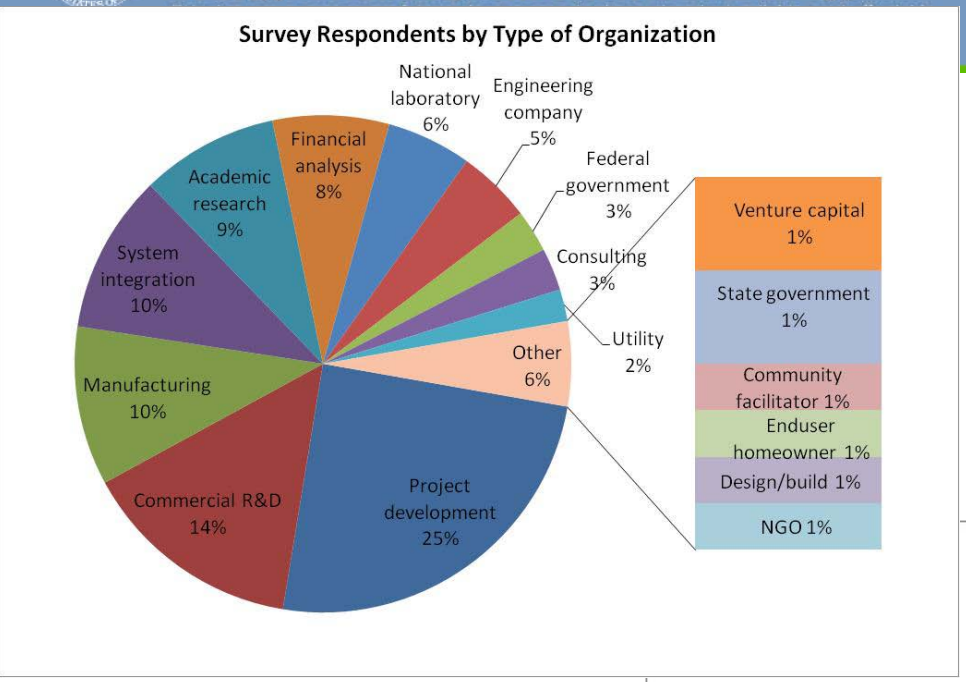
- Incentive types
  - Tax credits
    - Investment
    - Production
  - Investment-based incentives (buy-downs)
  - Capacity-based incentives
  - Production-based incentives
- Separate possible entries
  - Federal
  - State
  - Utility
  - Other
- Modify tax implications

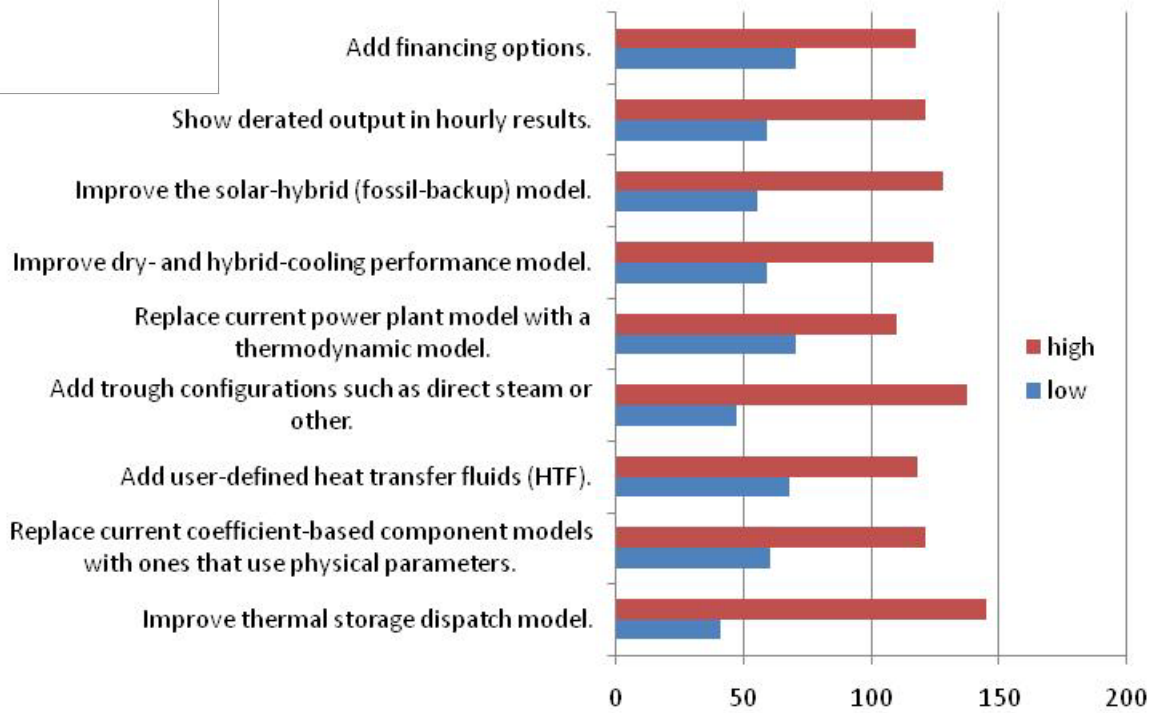


SAM Solar Performance Models

- 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





Future Work (Primarily FY09)

CORE ACTIVITIES

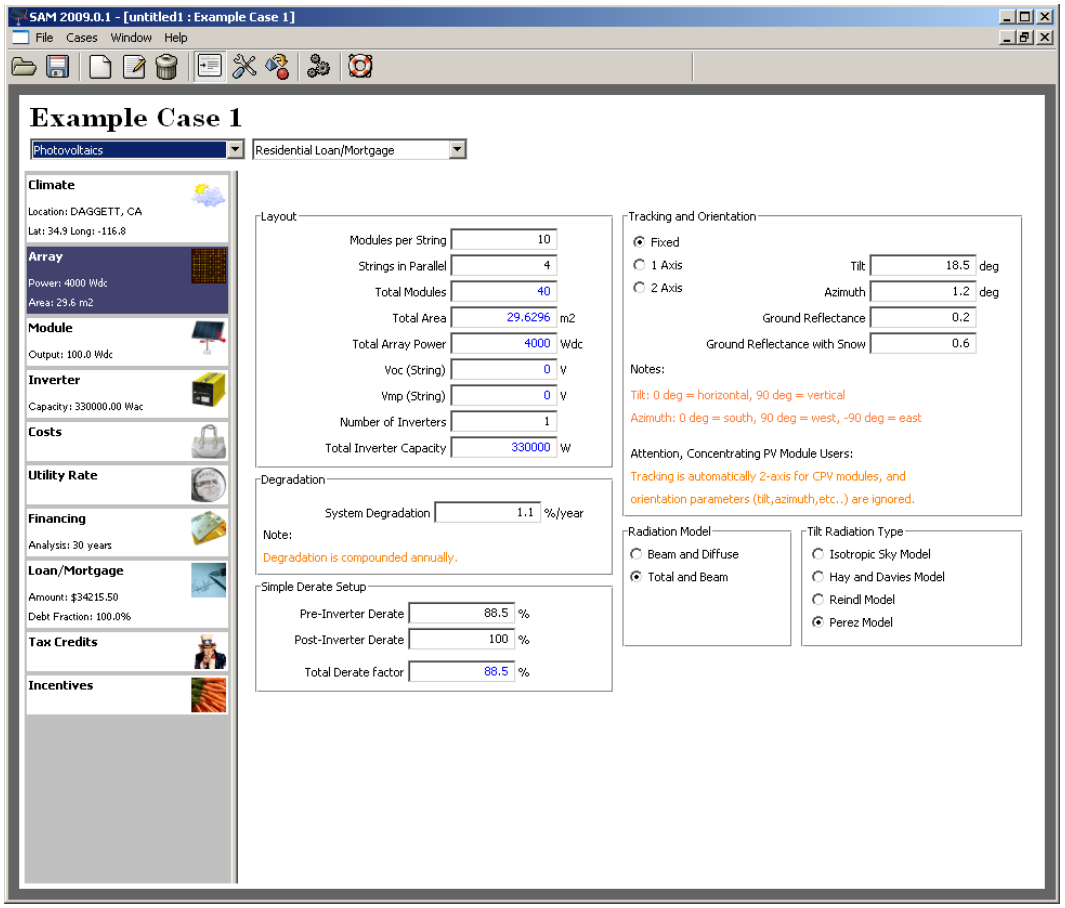
- Several activities to create a communication pathway from users to the SAM development team
- Several activities in user support area to improve and augment SAM documentation
- Link to database of incentives based on the DSIRE Website
- Rewriting SAM in C++ with a structure to allow multiple platforms, 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

SAM 2009

- 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



Relevance

- 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

Key Publications

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