



System Advisor Model (SAM) Introduction Slides

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NREL System Modeling Tools

PVWatts Calculator

Get Started:

NREL's PVWatts Calculator

Estimate the energy production and cost of energy of grid-connected photovoltaic (PV) energy systems throughout the world. It allows homeowners, small building owners, installers and manufacturers to easily develop estimates of the performance of potential PV installations.

PVWatts Calculator

My Location: 06220
+ Change Location

RESULTS

5,835 kWh per Year

Month	Solar Radiation (kWh / m ² / day)	AC Energy (kWh)	Energy Value (\$)
January	4.40	426	58.93
February	4.89	417	57.94
March	6.05	564	79.72
April	6.10	550	77.05
May	6.00	525	74.23
June	6.10	500	70.18
July	6.07	500	70.28
August	6.28	519	73.11
September	6.28	516	72.68
October	6.07	500	70.28
November	4.89	419	59.12
December	4.38	412	58.16
Annual	5.55	5,835	\$ 525

Download Results: Monthly | Hourly

REC1803 Single Diode Model

Module test data (according to IEC-61851)

Input: Irr(W/m²), Tc(°C), Pmp(W), Vmp(V), Voc(V), Isc(A)

Output: Pmax(W), Isc(A), Vmp(V), Voc(V), Pmp(V), Voc(V), Isc(A)

STC parameters (from test data): Power (Pmp) 171.6 W, Voltage (Vmp) 32.4 V, Current (Imp) 1.02 A, Open circuit voltage (Voc) 47 V, Short circuit current (Isc) 1.11 A, Efficiency 8.4002 %

Installation and thermal behavior: Area 0.70 m², Nominal operating cell temp 44.0 °C, Standoff height Ground or rack mounted

Optical and spectral behavior: Module cover: Standard glass, Air mass coefficient: GM17, 0.34019, -0.00020, 0.80219, -0.1e-6

Additional information for parameter calibration: Number of cells in series 118, Type Cells

Calculated module parameters from IEC-61851 test data:

STC parameters: Diode factor (n) 1.6071, Light current (I₀) 1.1891 A, Saturation current (I₀₁) 0.06020e-859 A, Bandgap voltage (E_g) 0.75788 eV

STC temp coeffs: alpha 0.00042001 A/°C, beta -0.277 V/°C, gamma -0.20888 V/°C

Sub parameters: C1 1998.75, C2 -674.64, C3 1.48748

Ro parameters: R1 10.1064, R2 -0.076670, R3 0.237027

EF curves: Graph showing Current (A) vs Voltage (V) for various irradiance and temperature conditions.

File + Add untitled

Photovoltaic, Single owner

Summary | Data tables | Losses | Graphs | Cash flow | Time series | Profiles | Statistics | Heat map | PDF / CDF

Location and Resource

Module

Inverter

System Design

Shading and Snow

Losses

Lifetime

Battery Storage

System Costs

Financial Parameters

Time of Delivery Factors

Incentives

Depreciation

Simulate > Parameters Stochastic P50 / P90 Macro

Summary:

Metric	Value
Annual energy (year 1)	37,570.88 kWh
Capacity factor (year 1)	25.3%
Energy yield (year 1)	1,579 kWh/kW
Performance ratio (year 1)	0.76
Battery efficiency	0.98%
PPA price (year 1)	0.07 \$/kWh
PPA price escalation	1.00 %/year
Levelized PPA price (nominal)	0.07 \$/kWh
Levelized PPA price (real)	7.18 \$/kWh
Levelized COE (nominal)	0.03 \$/kWh
Levelized COE (real)	0.75 \$/kWh
Net present value	\$2,009,389
Internal rate of return (IRR)	12.39 %
Year 50% is achieved	20
IRR at end of project	12.85 %
Net capital cost	\$39,888,126
Payoff	\$24,939,389
Size of debt	\$14,948,746

Energy Losses: Bar chart showing various loss components like PDC shading loss, PDC soiling loss, DC module mismatch loss, etc.

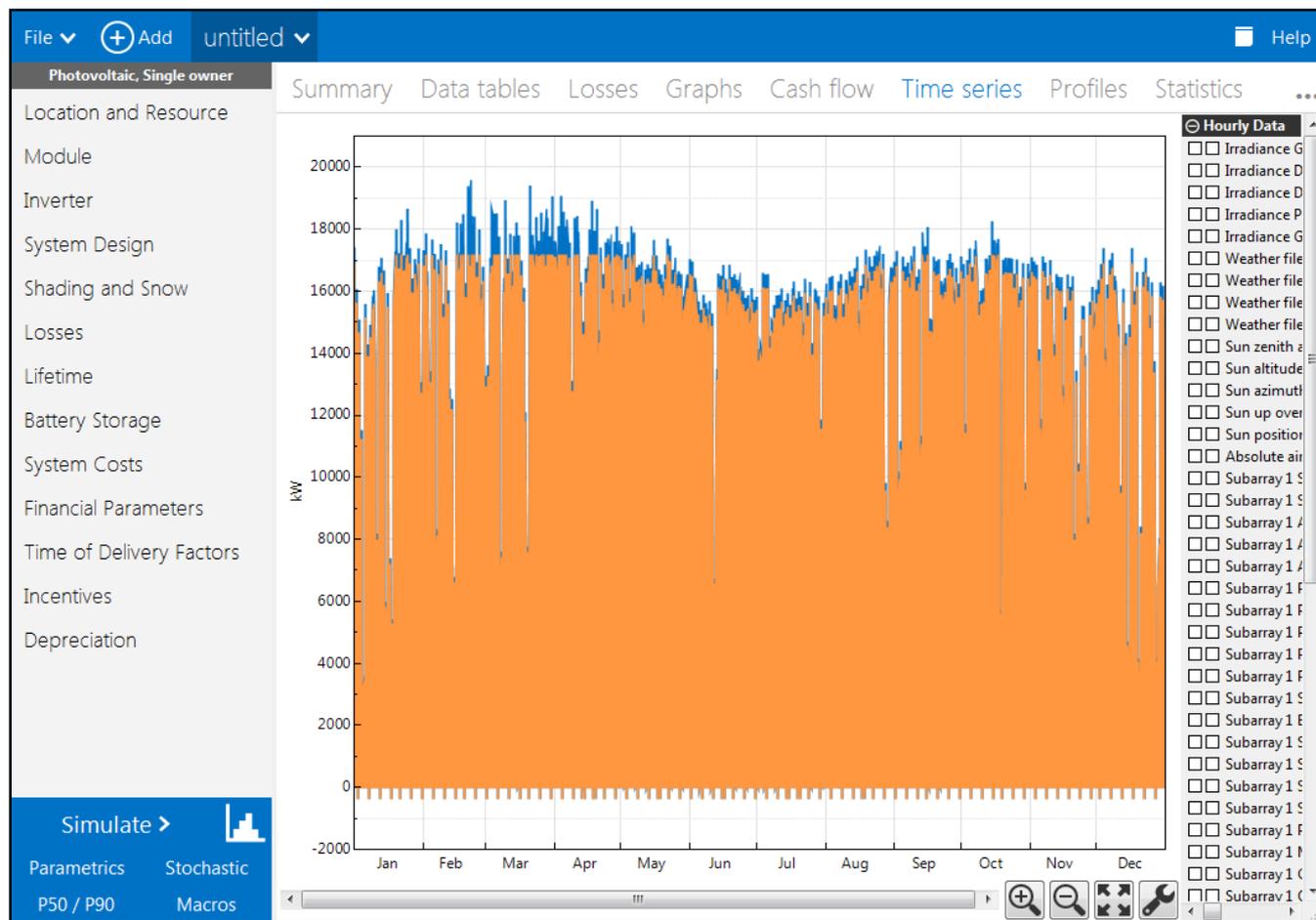
Monthly Energy Production: Bar chart showing monthly energy production in kWh.

Annual Energy Production: Bar chart showing annual energy production in kWh.

System Advisor Model (SAM)

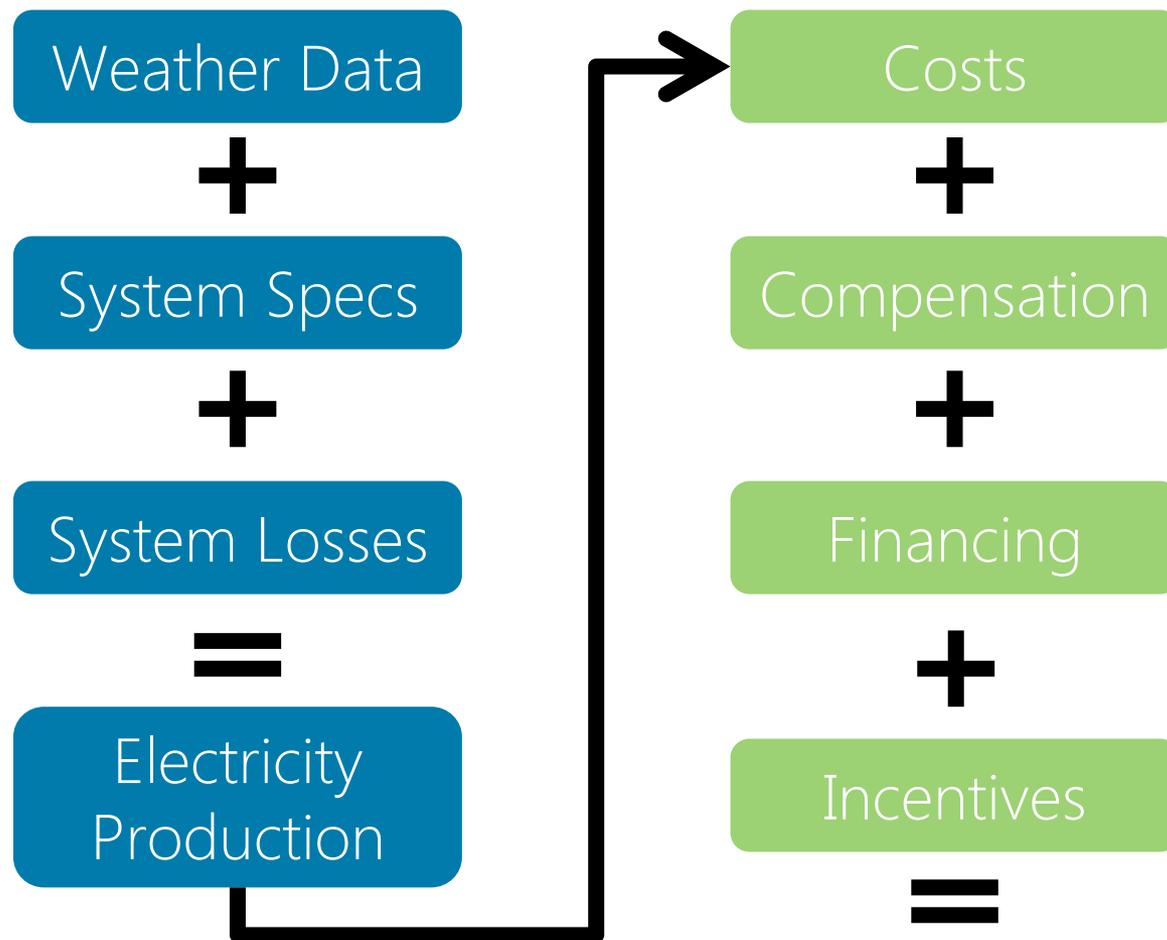


Free software that enables detailed performance and financial analysis for renewable energy systems



<http://sam.nrel.gov/download>

Steps to Modeling Renewable Energy



Results

Annual, Monthly, and Hourly Output, LCOE, NPV, Payback, Revenue, Capacity Factor



Technologies

Photovoltaics

- Detailed & PVWatts

- Battery Storage

Wind

- Concentrating solar power

- Geothermal

- Biomass

- Solar water heating



Financial Models

Behind-the-meter

- residential

- commercial

- third-party ownership

Power purchase agreements

- single owner

- equity flips

- sale-leaseback

Simple LCOE calculator



- **Lawmakers and Utilities**
 - ... to study how a policy would affect the economics of a typical system
 - ... to analyze different types of utility rate structures for renewables
- **Developers and Engineers**
 - ... to compare technologies, sites, or configurations
 - ... to estimate the Levelized Cost of Energy for a system
- **Researchers**
 - ... to examine how an innovative concept might be able to lower the Levelized Cost of Energy
 - ... to estimate the technical potential of a technology in a region
- **Students**
 - ... to learn about renewable energy
 - ... to explore financing structures for renewable energy



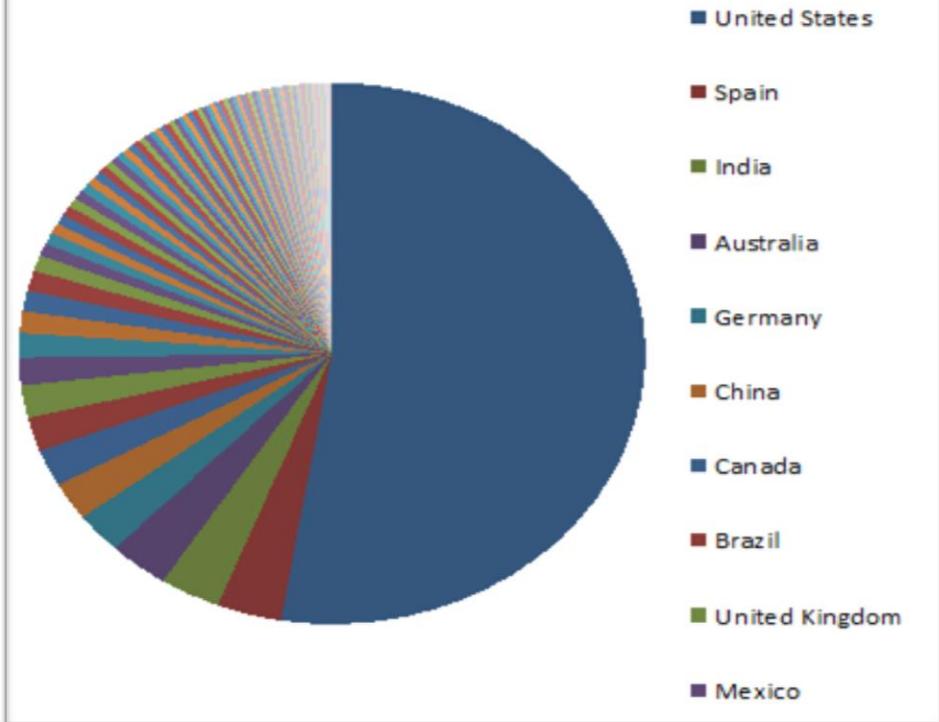
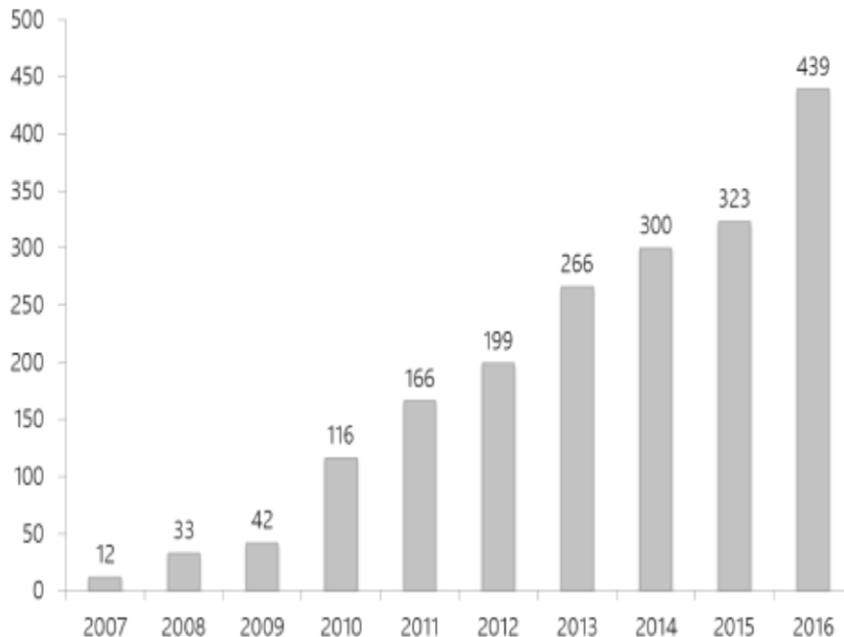
Over **35,000** active users in **130+** countries

SAM is started ~**every 2 ½ minutes** (> 600 times per day)

90+ webinars with **113,346 views**

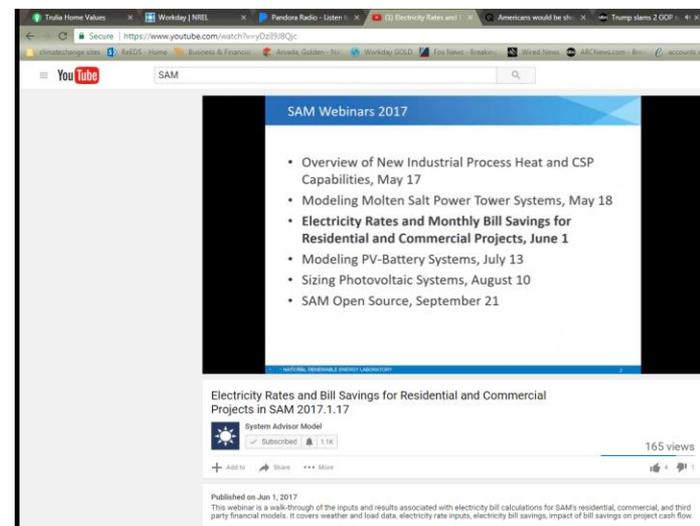
Users include Xcel Energy, Southern Company, EPRI, & more

Google Scholar Citations



How to Interact with the SAM team and get help?

- Website – <http://sam.nrel.gov>
 - Support Forum – Ask your question!
 - General info/ online help file / contact info
- YouTube Channel
 - <https://www.youtube.com/user/SAMDemoVideos>
 - All prior webinars and seminars
- Bi-Monthly Round Table sessions
 - SAM team asks questions live and interactively
- Email Support
 - SAM support can provide email support if question/bug is involved



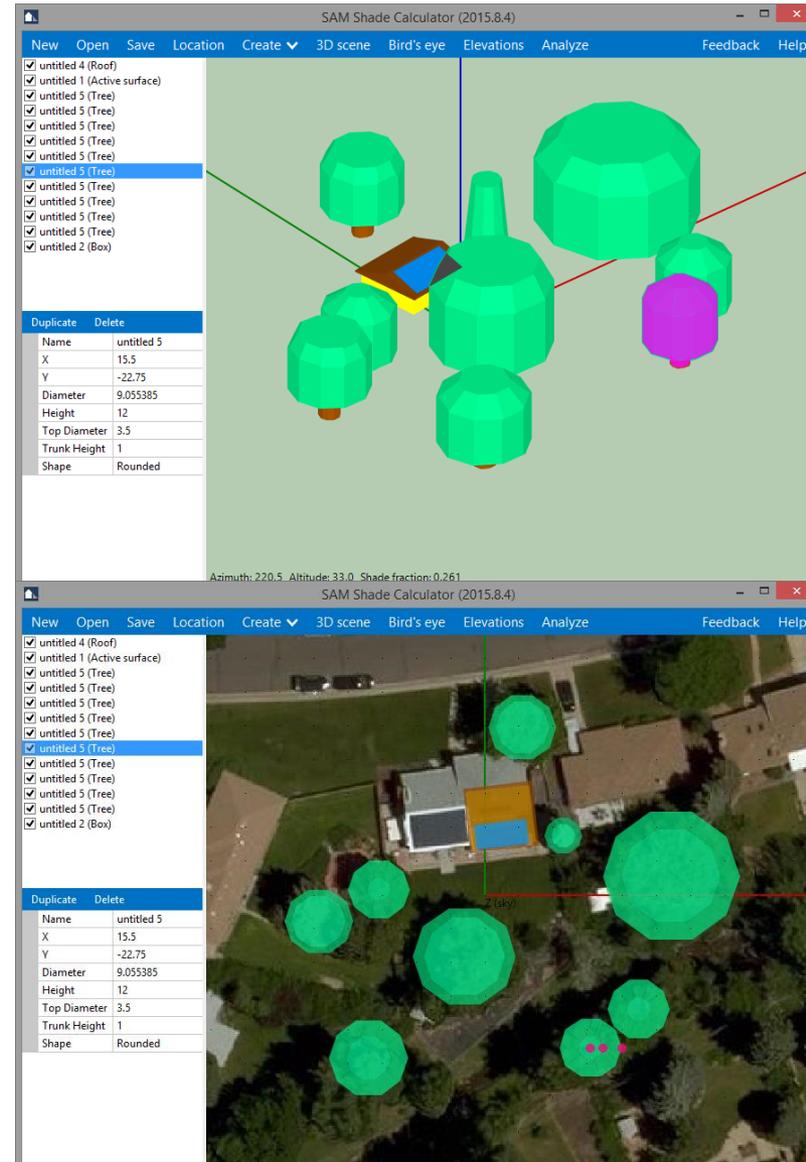
Recent Addition: Battery Model

- Designed primarily for behind-the-meter analysis (residential and commercial scale systems)
- Lithium ion and lead acid chemistries including submodels for cell voltage, capacity, thermal, degradation, and replacements
- Highly configurable manual dispatch controller
- Integrated with PV system lifetime analysis to capture economic effects of capacity degradation and costs of replacement
- Incentives, complex utility tariff structures, and financing costs included in analysis.
- Validated with laboratory measured test data for two systems.



Complex Feature: 3D shading calculator

- Fully integrated into SAM
- Calculates linear beam shading losses and sky diffuse view factor loss
- Imports 2D mapping underlays from Bing maps
- Diurnal or hourly/subhourly time series shade simulation
- Estimation of nonlinear losses for shaded parallel strings
- Scripting to automate panel layout and import/export geometry data



Deeper Dive: Detailed photovoltaic model

Irradiance

Transposition using Isotropic, HDKR, or Perez
Measured plane of array (POA) input

Shading

Irregular obstruction shading from 3D scene
Self-shading for regularly spaced rows
External input from SunEye, Solar Pathfinder
Snow cover loss model

Module

Simple efficiency model
Single diode model (CEC database or datasheet)
Extended single diode model (for IEC-61853 tests)
Sandia PV Array Performance Model

Inverter

Sandia/CEC grid-tied inverter model
Datasheet part-load efficiency curve

System

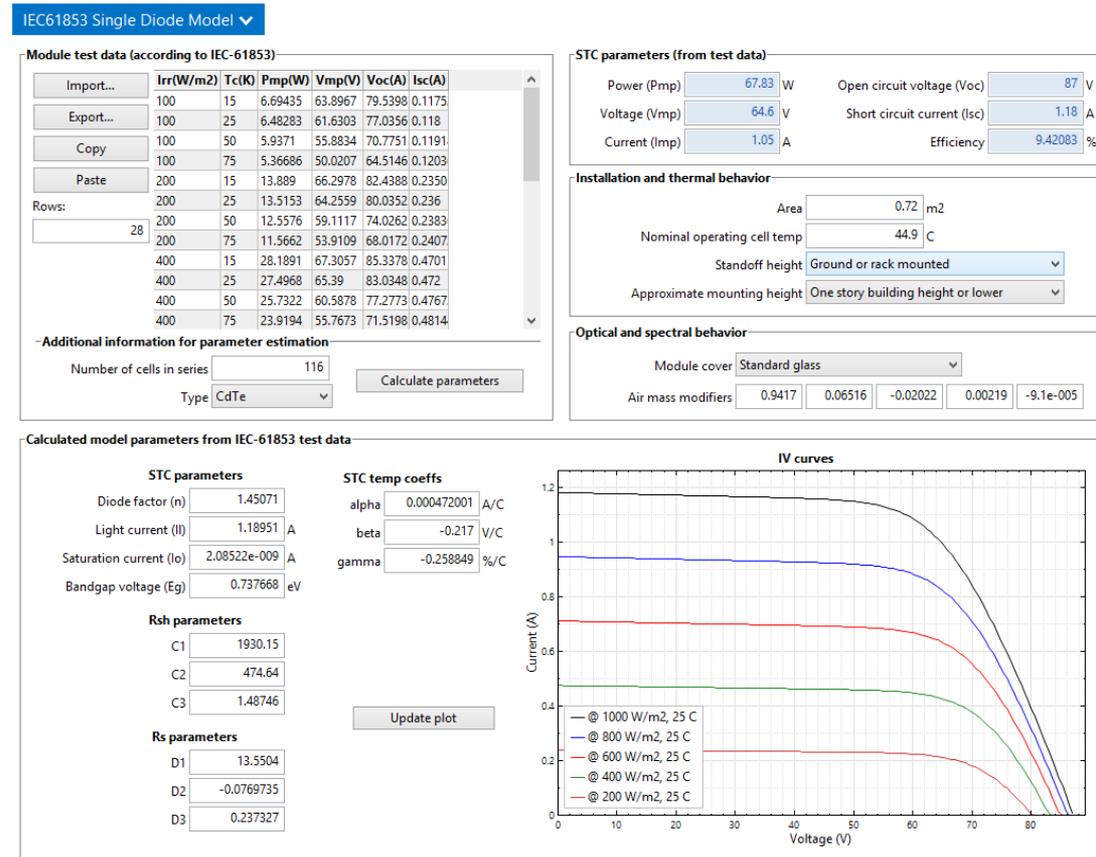
Sizing wizard or electrical layout
Multiple subarrays
Fixed, 1 axis, backtracking, azimuth axis, 2 axis
Battery storage

Degradation

Extrapolated single year
Lifetime simulation of all years

Simulation

1 minute to 1 hour time steps



Complex utility rate model options

Additional net metering options have been added and implemented to help users understand the impact of different scenarios currently implemented in several states.

Metering options

Net metering rollover monthly excess energy (kWh)
 Net metering rollover monthly excess dollars (\$)
 Non-net metering monthly reconciliation
 Non-net metering hourly reconciliation

Year end sell rate \$/kWh

Non-net metering sell rate option

Sell excess at energy charge sell rates
 Sell excess at specified sell rate

Single TOU sell rate \$/kWh

New data browser categorizes and consolidates results.

The screenshot shows a web interface for utility rate data. On the left is a search bar and a list of filters under 'Utility Rate Data by Tier/Period'. The 'Energy charge with system (TOU) Jul (\$)' filter is selected. The main area displays four data tables in a 2x2 grid:

	Tier 1	Total
Period 1	62.84	62.84
Period 2	50.53	50.53
Total	113.37	113.37

	Tier 1	Total
Period 1	235.47	235.47
Period 2	606.77	606.77
Total	842.23	842.23

	Tier 1	Total
Period 1	-9.24	-9.24
Period 2	18.03	18.03
Total	8.80	8.80

	Tier 1	Total
Period 1	-34.61	-34.61
Period 2	216.56	216.56
Total	181.95	181.95

Linkage with OpenEI rate database improved and expanded for some international rates.

Several ways to enter building load data

Calculate Load Data ▾

Building Energy Load Profile Estimator

- Building Characteristics

Floor area sq ft
Year built
Number of stories
Number of occupants
Energy retrofitted
Occupancy schedule fraction/hr

- Temperature Settings

Heating setpoint °F
Cooling setpoint °F
Heating setback point °F
Cooling setup point °F
Temperature schedule on/off

- Electric Appliances

Cooling system Dishwasher
 Heating system Washing machine
 Range (stove) Dryer
 Refrigerator Misc. electric loads

- Monthly Load Data

Jan	<input type="text" value="725.00"/> kWh	Jul	<input type="text" value="1,925.00"/> kWh
Feb	<input type="text" value="630.00"/> kWh	Aug	<input type="text" value="1,730.00"/> kWh
Mar	<input type="text" value="665.00"/> kWh	Sep	<input type="text" value="1,380.00"/> kWh
Apr	<input type="text" value="795.00"/> kWh	Oct	<input type="text" value="1,080.00"/> kWh
May	<input type="text" value="1,040.00"/> kWh	Nov	<input type="text" value="635.00"/> kWh
Jun	<input type="text" value="1,590.00"/> kWh	Dec	<input type="text" value="715.00"/> kWh

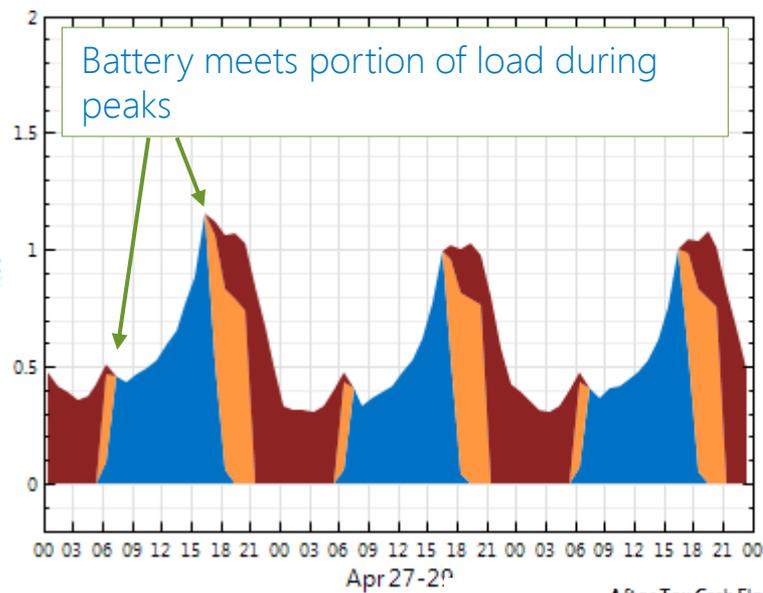
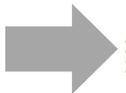
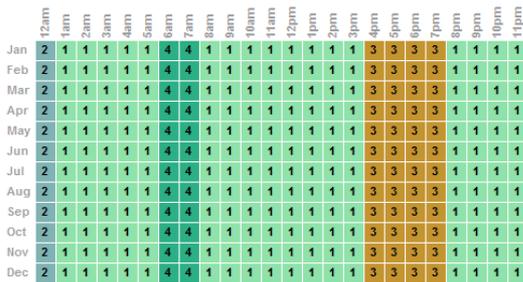
Annual Adjustment

Load growth rate %/yr

In Value mode, the growth rate applies to the previous year's annual kWh load starting in Year 2. In Schedule mode, each year's rate applies to the Year 1 kWh value. See Help for details.

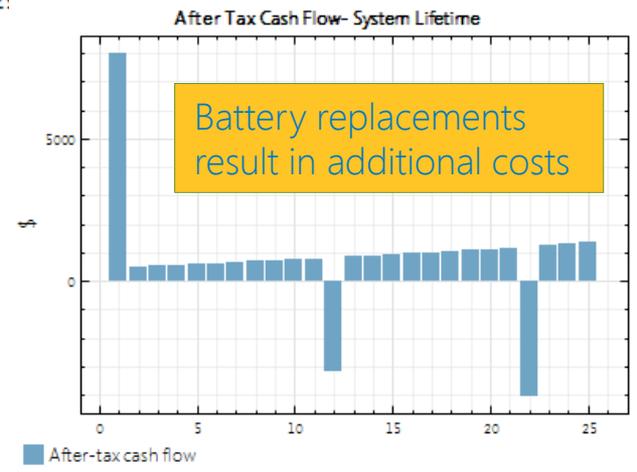
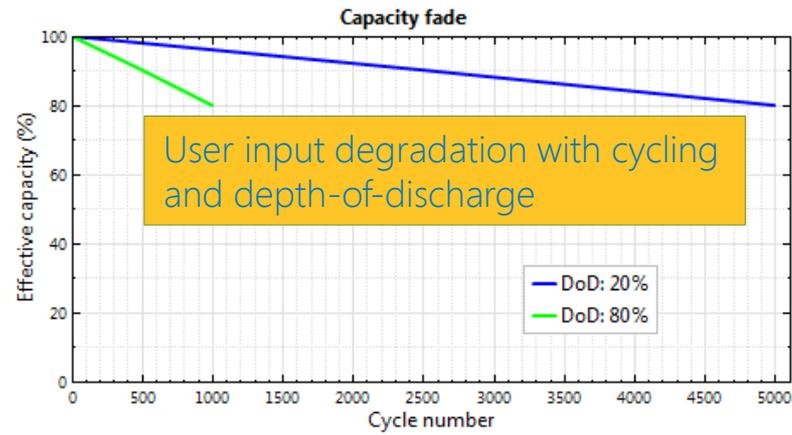
- Load profile in a file that can be scaled for monthly values.
- Use data about the building to create load data with consistent weather data

Putting it all together: Dispatch and degradation



- Power to load from PV (kW)
- Power to load from battery (kW)
- Power to load from grid (kW)

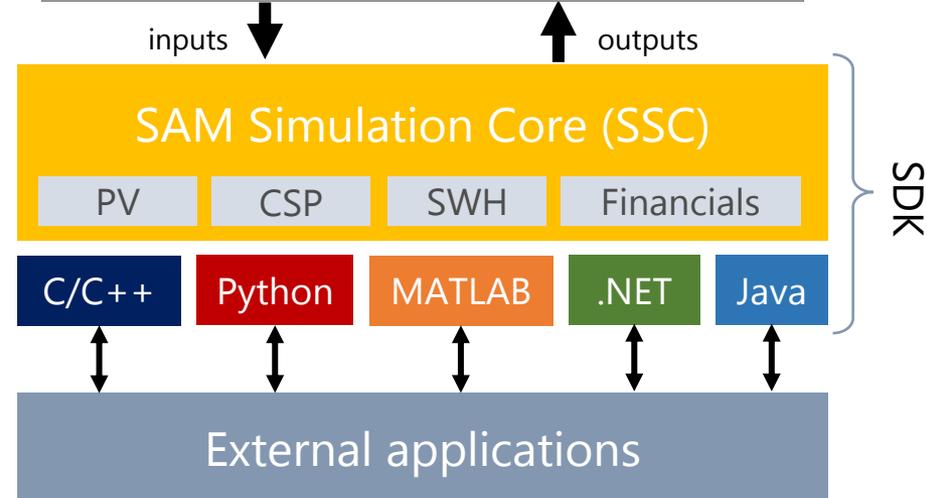
4 kW PV system
2 kW peak load



Extending SAM

- Desktop Application
- Advanced Analysis Features
 - Parametric
 - Stochastic (and for O&M)
 - P50/P90
- Built-in Scripting Language
- Macros
 - Written with SAM scripting language
- Software Development Kit (SDK)
 - C/C++, Python, C#, Java
 - Matlab, VBA
 - PHP
 - iOS And Android (NEW!!!)
- Web Services API (PVWatts Only)
- Open-sourced SAM code (NEW!!!)

SAM project file → Code



Thank you! Questions?

Janine Freeman - project lead, photovoltaic and wind models

Nick DiOrio - code architecture, battery storage models

Nate Blair - emeritus lead, financials, costs, systems

Steve Janzou - programming, utility rate structures (subcontractor)

Paul Gilman - user support and documentation (subcontractor)

Ty Neises - concentrating solar power models

Mike Wagner - concentrating solar power models

www.nrel.gov
<http://sam.nrel.gov>

