

GETEM in the System Advisor Model (SAM)

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Agenda

- 1** Introduction to SAM

- 2** Who uses SAM?

- 3** Advanced SAM features

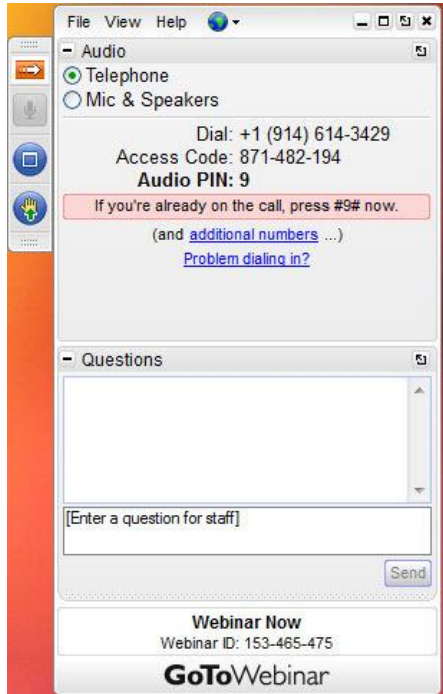
- 4** Introduction to GETEM

- 5** SAM GETEM inputs and outputs

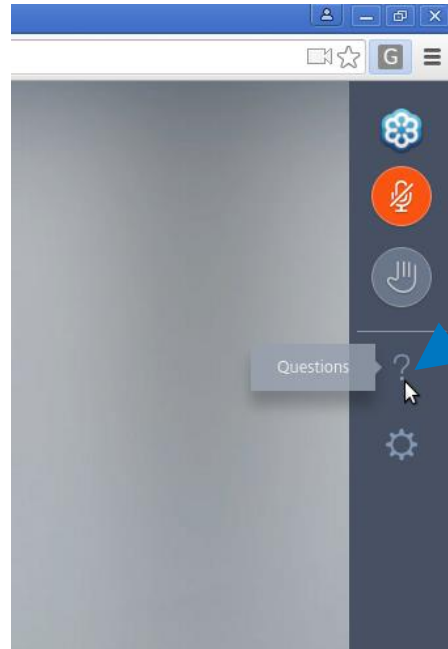
- 6** Live SAM Demonstration

- 7** Q&A

Questions and Answers



Desktop application



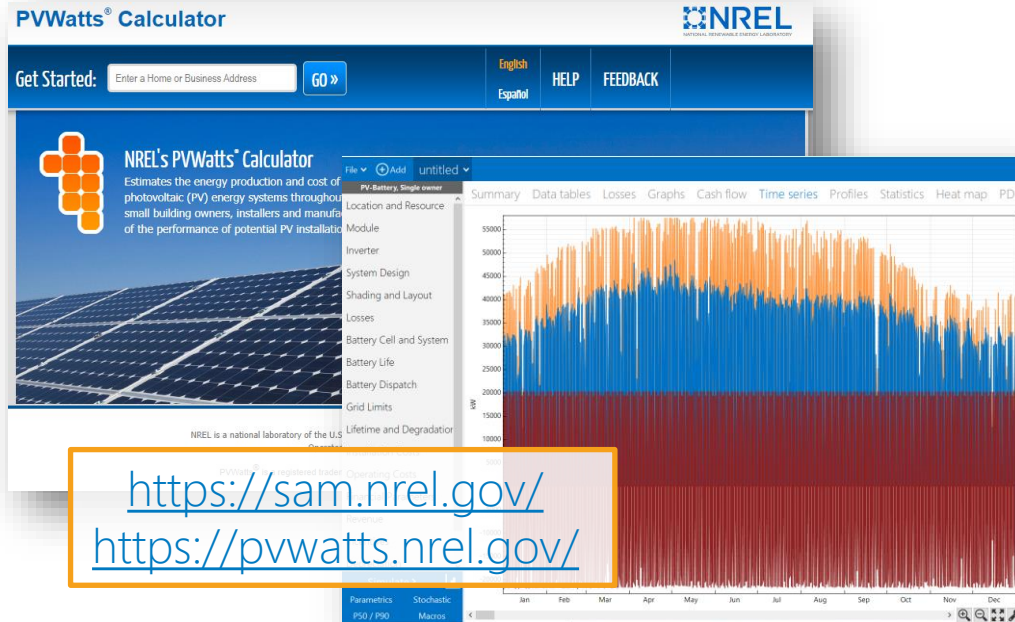
Instant Join Viewer

We will either type an answer to your question or answer it at the end of the presentation.

Find webinar recordings at <https://sam.nrel.gov/>

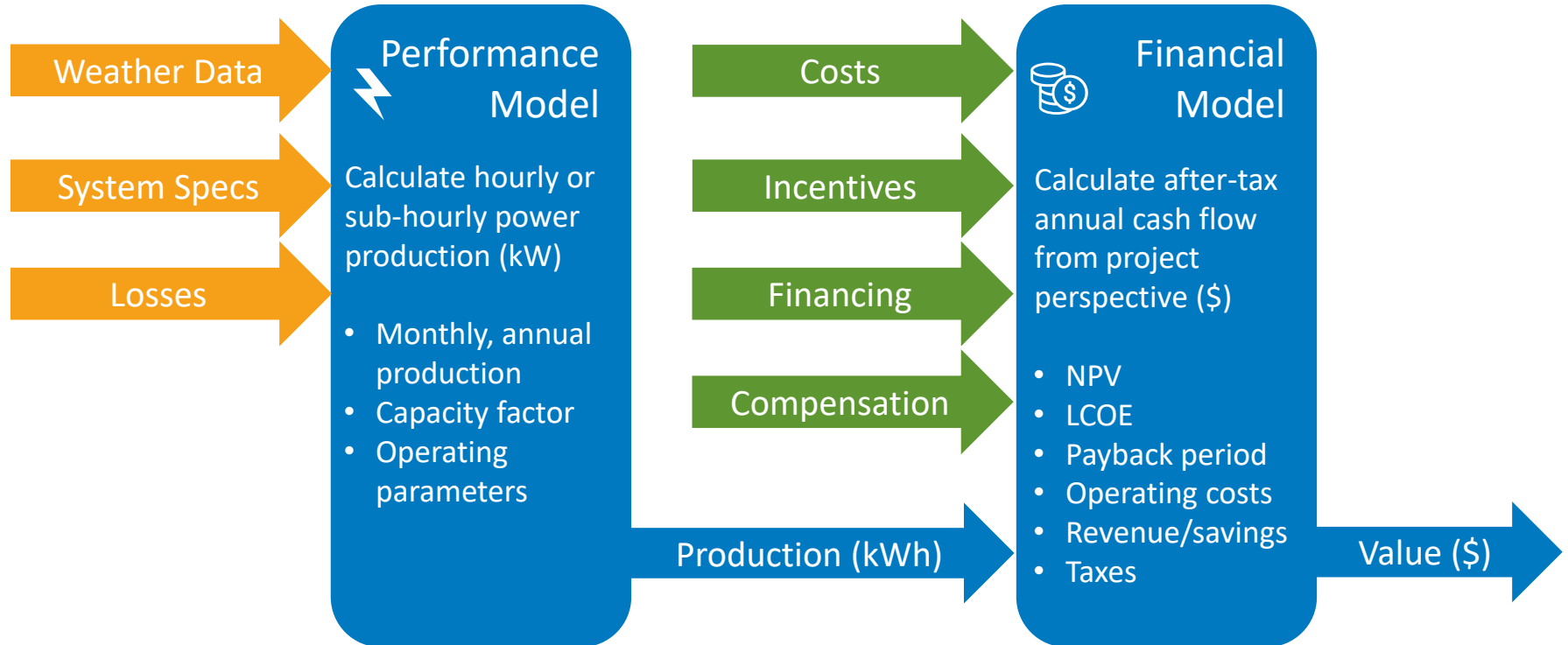
System Advisor Model (SAM) & PVWatts

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



- ✓ Desktop application
- ✓ PVWatts web tool & API
- ✓ Software development kit
- ✓ PySAM Python package
- ✓ Open source code
- ✓ Extensive documentation
- ✓ User support

Model Structure





Technologies

- Photovoltaic
- Energy storage
 - Electric battery
 - Electric thermal storage
- Concentrating solar power
- Industrial process heat
- Marine energy
- Wind power
- Fuel cell
- Geothermal power
- Solar water heating
- Biomass combustion
- Generic system

Financial Models

- Power purchase agreements
 - Single owner
 - Partnership flips
 - Sale leaseback
- Residential
- Commercial
- Third party ownership
- Merchant plant
- Community solar
- Simple LCOE calculator

History

Developed by

- Department of Energy
- National Renewable Energy Laboratory
- Sandia National Laboratories

Original vision in 2004

- Allow DOE to make R&D choices based on analysis of the entire system including costs
- Model different renewable energy projects in a single platform
- Facilitate technology comparison by handling performance, costs and financing consistently across technologies

Some Applications

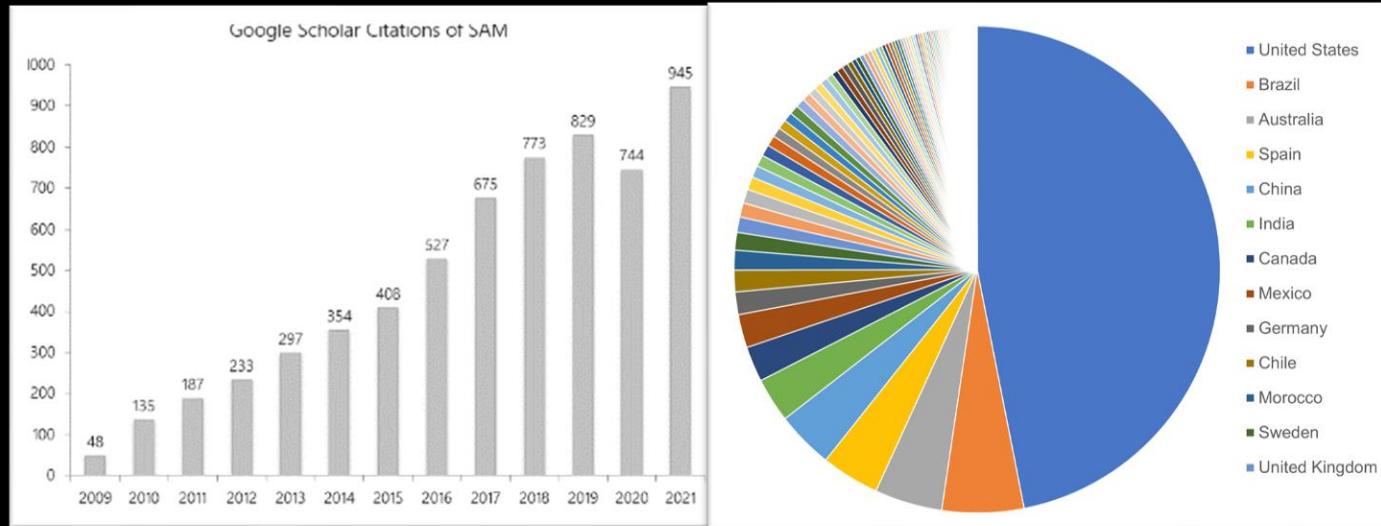
- Feasibility studies, benchmarking for other models, research projects, plant acceptance testing, evaluation of grant proposals



SAM Users

SAM is started **once every 1.4 minutes**
PVWatts receives over **17.5 million hits per month**
Over **150,000** users in 190+ countries
120+ webinars with **over 280,000 views**

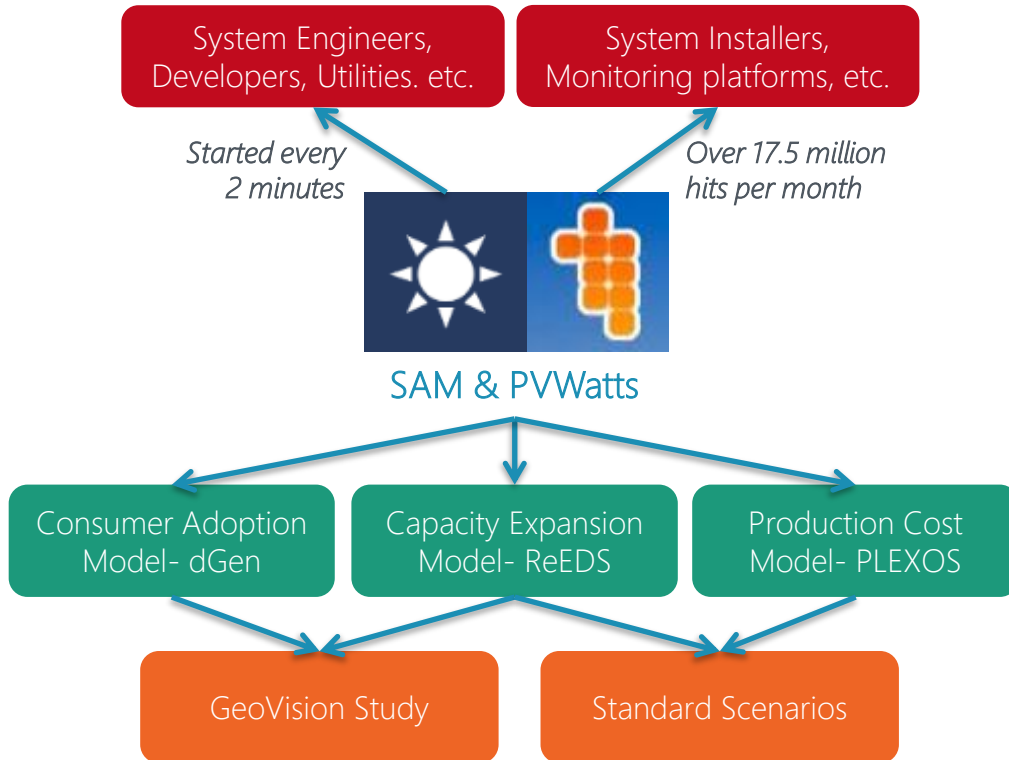
Users include Sunrun, Enphase, AEP, Southern Company, EPRI, & more



Who Uses SAM? Why?

- **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

How SAM Fits in at NREL and Externally



- ✓ Grid integration studies
- ✓ Renewable energy futures
- ✓ LCOE of breakthrough technologies
- ✓ Policy and utility rate design
- ✓ Technical potential studies
- ✓ Commercial applications (e.g. Southern Company, AEP, Sunrun)

How can you access SAM models?

- Desktop Application
- Advanced Analysis Features
 - Parametric
 - Stochastic
 - P50/P90
- Built-in Scripting Language
- Macros
- Software Development Kit (SDK)
 - Python (PySAM package)
 - C/C++
 - Matlab
 - PHP
 - C#
 - Java
 - VBA
 - iOS / Android
- Web Services API (PVWatts Only)
- **Open-source SAM code**

Built in Scripting Language and Macros

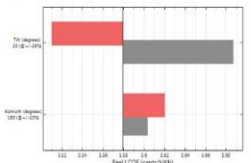
```
New Open Save Save as Find Run >
21 <li> Press 'Run macro' to perform the simulations and create the tornado chart.
22 </li> You can right click on the plot window that pops up to export the data or figure.
23 </ol>
24 @*/
25 // Macro user interface widgets
26 // @ name=inputs;type=inputs;Label=Input variables\nto consider;;meta=true;prompt=Specify
27 // @ name=output;type=svoutput;Label=Output metric:
28 // @ name=percent;type=number;Label=% adjustment;;value=10
29 // @ show_save_load_buttons=true
30
31
32 if ( typeof(macro) == 'unknown' ) {
33     msgbox('This macro must be run from within
34     exit;
35 }
36
37 outvar = macro.output;
38 percent = macro.percent;
39 vars = macro.inputs;
40 if ( #vars == 0 )
41 {
42     msgbox('No input variables selected. ');
43     exit;
44 }
45
46 if ( outvar == '' ) {
47     msgbox('Please choose an output variable to
48     exit;
49 }
50
51 vi = varinfo(outvar);
52 outlabel = vi.label;
53 if ( strlen(vi.units) > 0 ) outlabel = outlabel
54
```

Append Snow Data
Subarray Layout Optimization
System Sizing
Download Electric Load
Value of RE System
Combine Cases
Create a Tornado Chart
Download Weather Files
Siting Considerations
Solar Resource File Checker
Solar Resource File Converter
Solar Resource Interpolation

Create a Tornado Chart

Tornado charts can be a helpful way to visualize sensitivities of a model to various inputs. Creating a tornado chart involves running several simulations decreased and increased independently to see how much a particular output metric changes.

This macro creates a tornado chart like this one based on input ranges you specify:



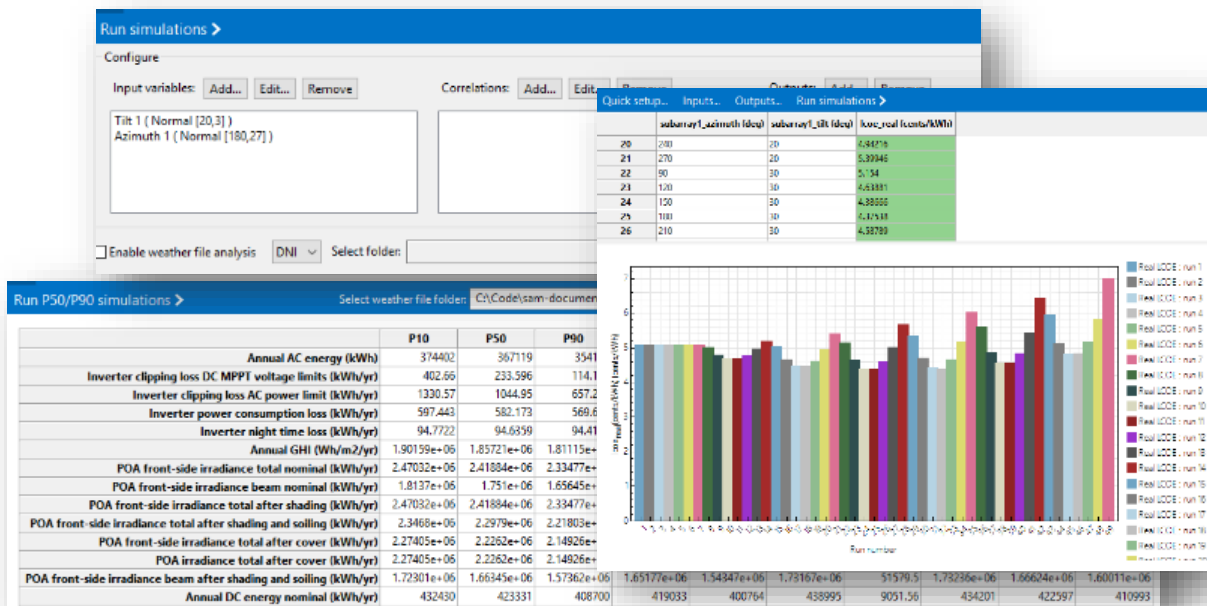
Instructions:

- Using the interface at the right, select one or more input variables to consider.
- Select an output metric to plot on the tornado chart.
- Specify the percentage change (decrease and increase) to apply to each input variable.
 - A custom percentage decrease and increase, such as "10%" or "23%".
 - A custom absolute change, such as "5". If the base case input has a value of 30, values of 25 and 35 will be used.
 - A custom absolute changes in both directions, such as "4, 7". If the base case input has a value of 30, values used will be 26 and 37.
- Press 'Run macro' to perform the simulations and create the tornado chart.
- You can right click on the plot window that pops up to export the data or figure.

Flexible, lightweight scripting language built in to the SAM desktop tool, allowing users to quickly run custom analyses and read/write to other files

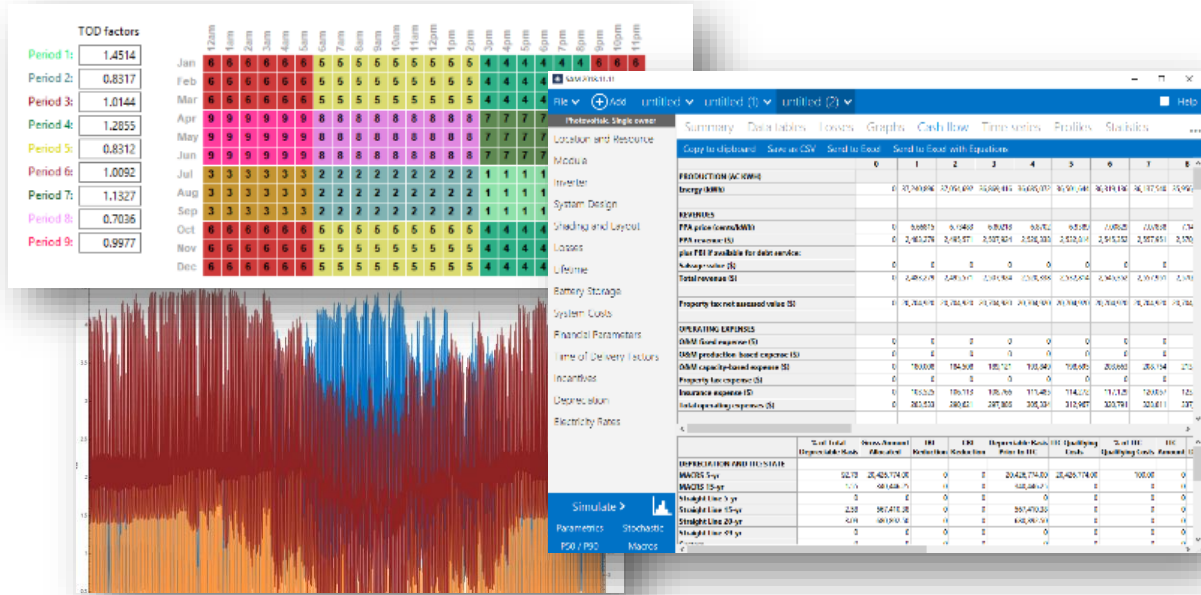
Advanced Analysis Features

Built-in parametric, stochastic, probability of exceedance (P50/P90), and scripting features enable complex questions to be answered quickly and easily



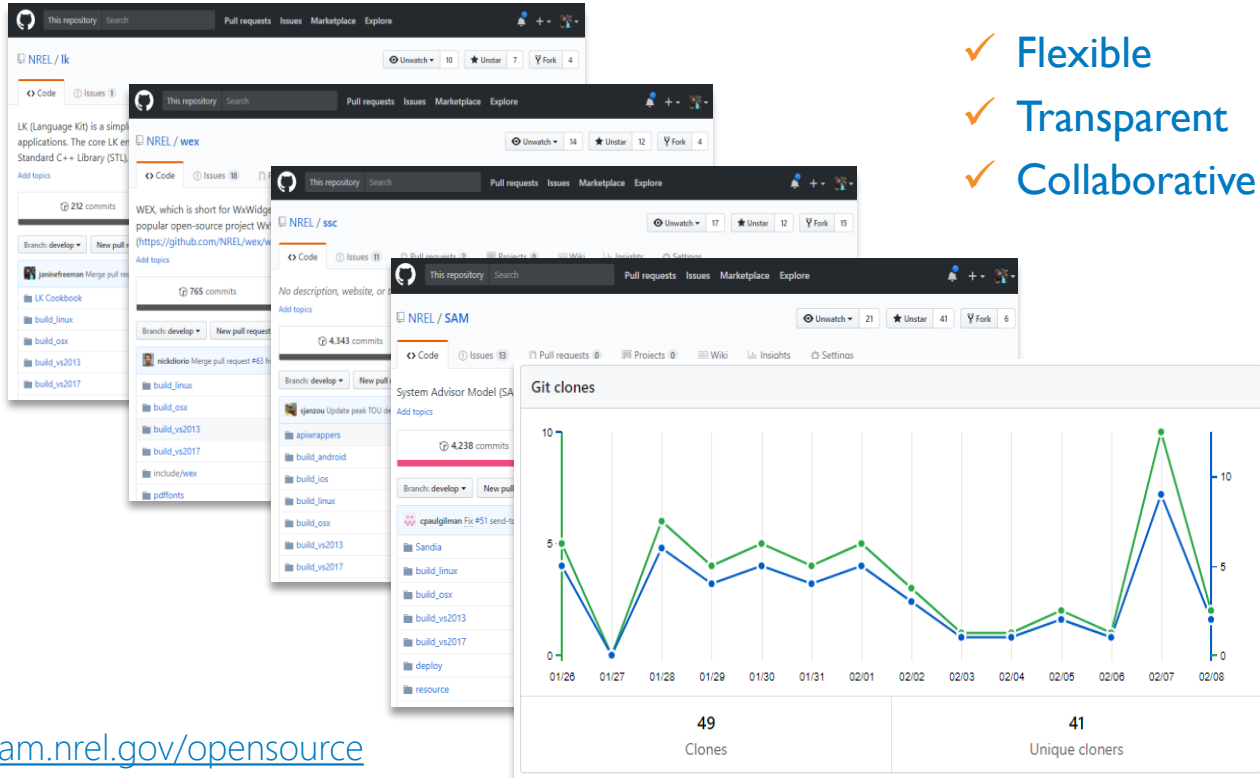
Detailed Cash Flow Financial Models

No other tool provides detailed, *time-based* financial modeling across multiple market sectors, including complex utility rates, combined with detailed performance modeling



Open Source Code

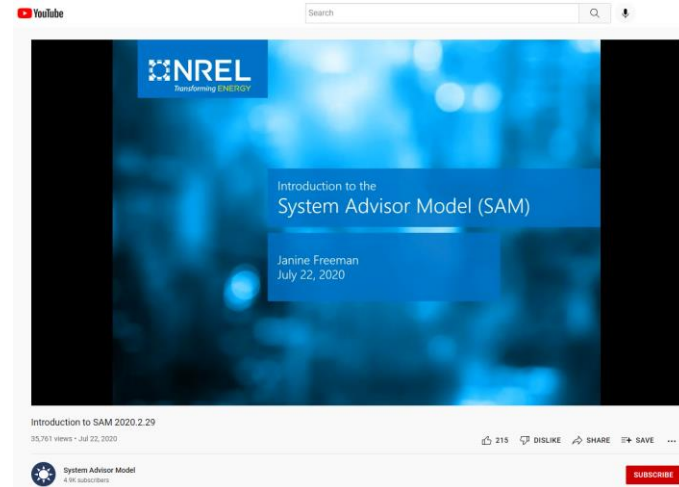
- ✓ Flexible
- ✓ Transparent
- ✓ Collaborative



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

Extensive Help Documentation

- 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



Geothermal Electricity Technology Evaluation Model

- Performance and Financial calculations for geothermal power projects
- Excel model with LCOE calculations
- Greenfield and Brownfield projects
- Developed by Greg Mines (INL)

| LEVELIZED COST OF ELECTRICITY | | Revised Scenario | GETEM Default |
|-------------------------------|--|------------------|---------------|
| NET POWER SALES | | 9.84 €/ kWh | 9.71 |
| | | 25,000 kW | 25,000 |

The cells with the yellow background are input cells. Some have dropdown lists - select from that list, or leave blank to use the default value. The units have dropdown units are changed, the default values should change to be displayed in the units selected.

Do you wish to evaluate a Hydrothermal or EGS resource? **EGS**

What is the resource temperature? **175 C**

What is the resource depth? **2,500.0 meter**

At the indicate temperature, GETEM defaults to the indicated conversion system - you may change below

Type of Conversion System to be Used **Binary**

If GETEM defaults to Binary, or if a Binary conversion system is selected - run the optimize macro for default scenario by clicking on button to the right. This must be done to obtain a LCOE estimate.

DONE - Resource Definition

If you wish to review and/or revise GETEM default values, click on hyperlink below

If you do make changes and a binary plant is being used - run the optimization macro again to re-establish plant performance & cost

| Revised Scenario Value/Cost (w/o Contingency) | MW |
|--|--------------|
| Power Sales | 25.0 |
| Economic | |
| Permitting | |
| Exploration | |
| Drilling | \$18,556,985 |
| Field Gathering System & Pumping | \$23,294,639 |
| Reservoir Performance | \$7,075,195 |
| Operating & Maintenance | 5.33 |
| Power Plant | \$4,888,497 |
| | \$77,924,810 |

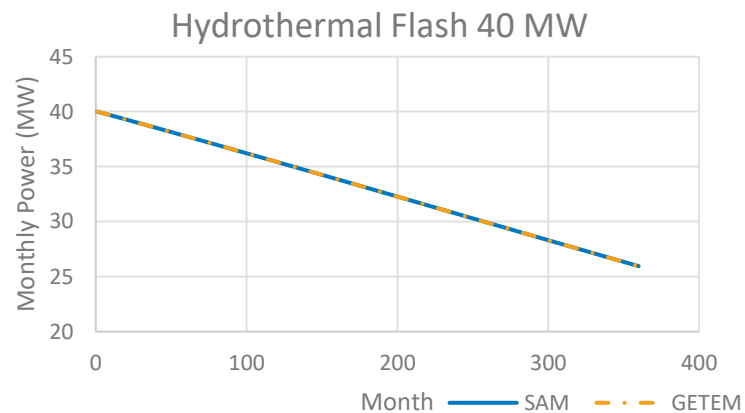
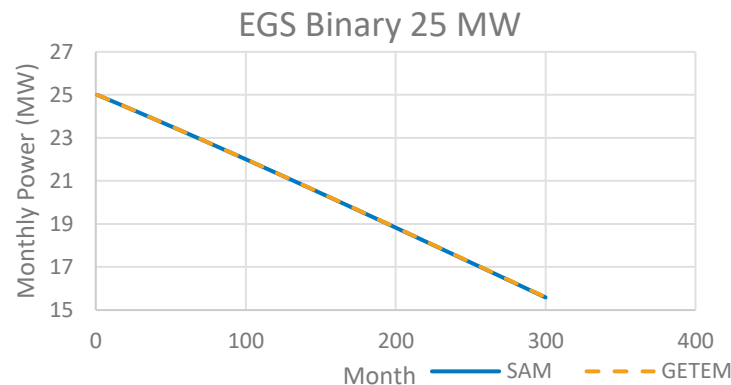
GETEM determines the input used for the Default the resource type selected, and the resource tem that are specified. The LCOE for the GETEM defau these 3 inputs

The default conversion system is based on the resourc elect to change the conversion system, the type select Default and the Revised Scenarios - if blank the default that Binary not be used above 200C and Flash not below

The macro does not come to the same solution for the default consequence the plant costs, total flow, number of wells, pun vary slightly when the default inputs are used for the revised A1, and enter the same level of performance for both scenari count will be the same.

GETEM in SAM

- GETEM implemented in SAM for technoeconomic analysis
- Updated in 2021-2022 to latest version of Excel model
 - Pump work calculations
 - User-defined reservoir model
 - Temperature loss in well bore
- Potential for future development
- Validated for power output in key example cases



GETEM SAM – Geothermal Resource

- Define geothermal reservoir
- Pressure, temperature changes in reservoir
- Hydrothermal or EGS resource
- New: User-entered reservoir tables
- New: Default system spec dropdown list

Resource Characterization

Hydrothermal
 Total Resource Potential MW
 Enhanced Geothermal System (EGS)
 Resource Temperature °C
Resource Depth m

[View the NREL Geothermal Prospector online](#)

Reservoir Parameters

Enter change in pressure across the reservoir in units of psi-h per 1000 lb:
 Calculate the reservoir pressure change using simple fracture flow (EGS only)
 Calculate the reservoir pressure change using permeability * area
 User-entered reservoir model

-Entered pressure change input-

Pressure change psi/(1000 lb/h)

-EGS Fracture model inputs-

| | | |
|---------------------------|--|---------------------|
| Fracture Spacing | <input type="text" value="50"/> | m |
| Fracture Length | <input type="text" value="1000"/> | m |
| Fracture Aperture | <input type="text" value="0.0004"/> | m |
| Number of Fractures | <input type="text" value="6"/> | |
| Fracture Width | <input type="text" value="175"/> | m |
| Fracture Angle | <input type="text" value="15"/> | deg from horizontal |
| Rock Density | <input type="text" value="2,600.000"/> | kg/m ³ |
| Rock Specific Heat | <input type="text" value="950.000"/> | J/kg-°C |
| Rock Thermal Conductivity | <input type="text" value="3.000"/> | W/m-K |
| Subsurface Water Loss | <input type="text" value="2"/> | % of water injected |

-Permeability inputs-

| | | | |
|---|-----------------------------------|-------------|--|
| Width | <input type="text" value="500"/> | m | |
| Height | <input type="text" value="100"/> | m | |
| Permeability | <input type="text" value="0.05"/> | Darcy units | |
| Distance From Injection to Production Wells | <input type="text" value="1500"/> | m | |

Calculated Design

| | | | | |
|--------------------------------------|---------------------------------------|-----|--------------------------------------|-----|
| Pressure Change Across Reservoir | <input type="text" value="349.212"/> | psi | <input type="text" value="24.077"/> | bar |
| Average Reservoir Temperature | <input type="text" value="392.000"/> | °F | <input type="text" value="200.000"/> | °C |
| Production Well Bottom Hole Pressure | <input type="text" value="2360.887"/> | psi | <input type="text" value="162.777"/> | bar |

Messages: No message

Default Type: Greenfield-Reference-Hydrothermal-Flash ▾

GETEM SAM – Plant and Equipment

- Binary and Flash technologies
- Specified plant output
- Thermal decline
- Pumping requirements (parasitic loads)
- New: equation for temperature loss in production well

Plant Configuration

Specify plant output: kW
 Use exact number of wells:

Conversion Plant Type: Binary Flash
 Plant efficiency set as percentage of max plant efficiency: %
 Subtype:

Number of Wells in Analysis: wells
 Actual Plant Efficiency: w-hr/lb
 Gross Plant Output: MW
 Net Plant Output: MW

Enter Plant Design Temperature (EGS only): °C
 Plant Design Temperature: °C
 Temperature Loss in Prod. Well: °C
 Calculate temperature loss in production well

System Availability

System availability losses reduce the system output to represent system outages or other events. [Edit losses...](#)

Constant loss: 0.0 %
 Lifetime losses: None
 Custom periods: None

Temperature Decline

Specify temp decline rate: %/yr
 Calculate temp decline rate (EGS only)

Max. temp decline before reservoir replacement: °C

Flash Technology

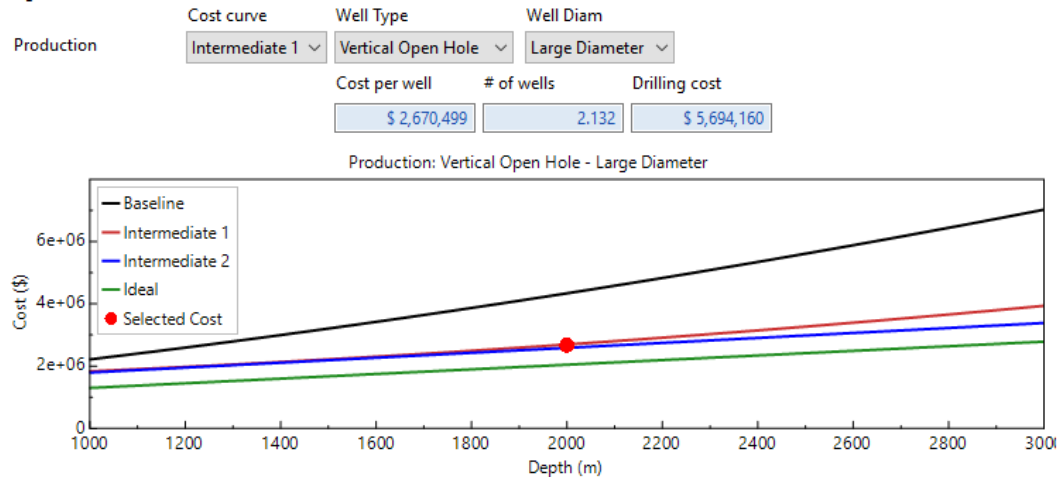
Wet Bulb Temperature: °C
 Ambient Pressure: psi

Pumping Parameters

| | | | |
|--|--|--|--|
| Production Well Flow Rate | <input type="text" value="110"/> kg/s per well | Pump Depth | <input type="text" value="1158.759"/> ft |
| Pump Efficiency | <input type="text" value="67.5"/> % | Pump Work | <input type="text" value="3.279"/> MW |
| Pressure Difference Across Surface Equipment | <input type="text" value="40"/> psi | Production Pump Size | <input type="text" value="756.926"/> hp |
| Excess Pressure at Pump Suction | <input type="text" value="50"/> psi | Injection Pump Size | <input type="text" value="1268.935"/> hp |
| Production Well Diameter | <input type="text" value="12.25"/> inches | <input type="checkbox"/> Specify Pump Work | |
| Production Pump Casing Size | <input type="text" value="9.625"/> inches | Specified Pump Work | <input type="text" value="0"/> MW |
| Injection Well Diameter | <input type="text" value="12.25"/> inches | | |
| Injection Pump Casing Size | <input type="text" value="11.5"/> inches | | |

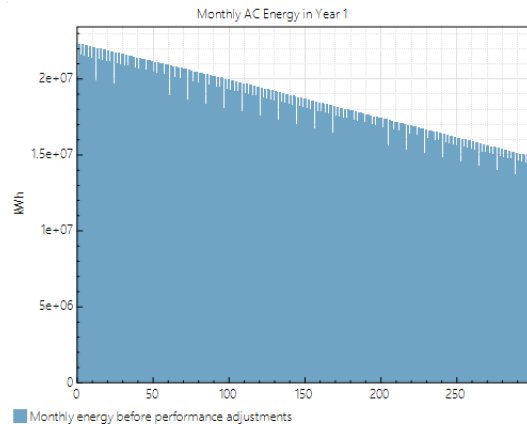
GETEM SAM – Costs

- Production and Injection drilling cost curves
- Plant cost calculator
- PPI Indices
- Drilling cost curves: generated from the Well Cost Simplified (WCS) model developed by Sandia
- GeoVision Reservoir Maintenance and Development taskforce report (<https://doi.org/10.2172/1394062>)

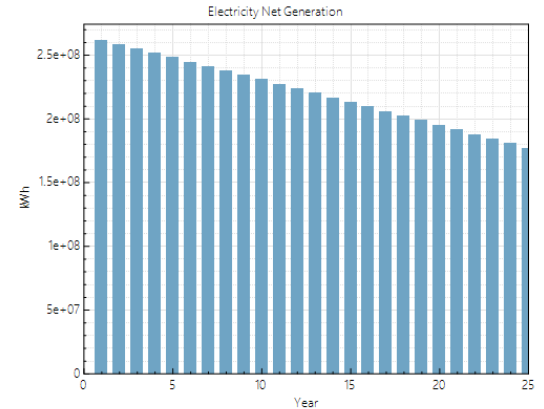


GETEM SAM – Energy Outputs

- Performance metrics: annual, monthly, hourly energy output
- Graph time series outputs, export data to csv or image files



| Lifetime Monthly Data | | |
|-----------------------|--------------------------------------|--------------------|
| | Monthly avg resource temperature (C) | Monthly power (kW) |
| 1 | 200 | 30000 |
| 2 | 199.917 | 29969 |
| 3 | 199.833 | 29937.9 |
| 4 | 199.75 | 29906.8 |
| 5 | 199.667 | 29875.7 |
| 6 | 199.584 | 29844.6 |
| 7 | 199.501 | 29813.4 |
| 8 | 199.417 | 29782.2 |
| 9 | 199.334 | 29751 |
| 10 | 199.251 | 29719.7 |
| 11 | 199.168 | 29688.5 |
| 12 | 199.085 | 29657.2 |
| 13 | 199.002 | 29625.8 |
| 14 | 198.919 | 29594.5 |
| 15 | 198.836 | 29563.1 |
| 16 | 198.754 | 29531.7 |
| 17 | 198.671 | 29500.3 |
| 18 | 198.588 | 29468.9 |
| 19 | 198.505 | 29437.4 |
| 20 | 198.423 | 29405.9 |
| 21 | 198.34 | 29374.4 |
| 22 | 198.257 | 29342.8 |
| 23 | 198.175 | 29311.3 |
| 24 | 198.092 | 29279.7 |
| 25 | 198.01 | 29248.1 |
| 26 | 197.927 | 29216.4 |
| 27 | 197.845 | 29184.8 |
| 28 | 197.762 | 29153.1 |
| 29 | 197.68 | 29121.4 |
| 30 | 197.597 | 29089.6 |
| 31 | 197.515 | 29057.9 |
| 32 | 197.433 | 29026.1 |
| 33 | 197.35 | 28994.3 |
| 34 | 197.268 | 28962.5 |
| 35 | 197.186 | 28930.6 |
| 36 | 197.104 | 28898.7 |
| 37 | 197.022 | 28866.8 |

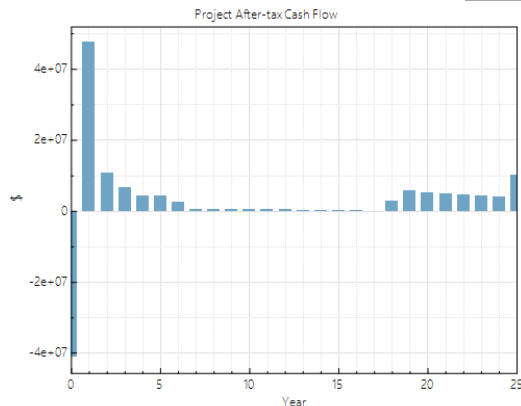


GETEM SAM – Financial Outputs

- Key metrics such as LCOE, NPV, IRR, etc...
- Detailed annual cash flows

| Metric | Value |
|---------------------------------------|-----------------|
| Annual AC energy (year 1) | 261,293,360 kWh |
| Capacity factor (year 1) | 99.4% |
| PPA price in Year 1 | 8.00 €/kWh |
| PPA price escalation | 1.00 %/year |
| LPPA Levelized PPA price nominal | 8.61 €/kWh |
| LPPA Levelized PPA price real | 6.95 €/kWh |
| LCOE Levelized cost of energy nominal | 7.23 €/kWh |
| LCOE Levelized cost of energy real | 5.83 €/kWh |
| NPV Net present value | \$31,716,692 |
| IRR Internal rate of return | 47.12 % |
| Year IRR is achieved | 20 |
| IRR at end of project | 47.13 % |
| Net capital cost | \$150,127,072 |
| Equity | \$41,219,976 |
| Size of debt | \$108,907,088 |
| Debt percent | 72.54% |

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|--|----------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Property tax net assessed value (\$) | 0 | 126,031,312 | 126,031,312 | 126,031,312 | 126,031,312 | 126,031,312 | 126,031,312 | 126,031,312 |
| OPERATING EXPENSES | | | | | | | | |
| O&M fixed expense (\$) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| O&M production-based expense (\$) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| O&M capacity-based expense (\$) | 0 | 5,823,764 | 5,969,358 | 6,118,592 | 6,271,556 | 6,428,346 | 6,589,054 | 6,753,780 |
| Electricity purchase (\$) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Property tax expense (\$) | 0 | 1,260,313 | 1,260,313 | 1,260,313 | 1,260,313 | 1,260,313 | 1,260,313 | 1,260,313 |
| Insurance expense (\$) | 0 | 630,157 | 645,910 | 662,058 | 678,610 | 695,575 | 712,964 | 730,788 |
| Total operating expenses (\$) | 0 | 7,714,234 | 7,875,582 | 8,040,963 | 8,210,479 | 8,384,234 | 8,562,331 | 8,744,882 |
| EBITDA (\$) | 0 | 13,189,235 | 12,970,898 | 12,742,768 | 12,504,747 | 12,256,733 | 11,998,622 | 11,730,310 |
| OPERATING ACTIVITIES | | | | | | | | |
| EBITDA (\$) | 0 | 13,189,235 | 12,970,898 | 12,742,768 | 12,504,747 | 12,256,733 | 11,998,622 | 11,730,310 |
| Interest earned on reserves (\$) | 0 | 111,624 | 111,582 | 111,519 | 111,434 | 111,328 | 111,200 | 111,051 |
| plus PBI if not available for debt service: | | | | | | | | |
| Federal PBI income (\$) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |



A satellite view of Earth at night, showing the curvature of the planet and the glowing lights of cities and infrastructure across the continents. The sun is visible on the left horizon, creating a bright glow and lens flare.

Live SAM Demo

www.nrel.gov

Photo from iStock-627281636

 **NREL**
Transforming ENERGY

45th
anniversary

Thank you! Questions?

Janine (Freeman) Keith – project lead, photovoltaic and wind models

Nate Blair – emeritus lead, financials, costs, systems

Darice Guittet – software development, battery models

Brian Mirlletz – software development, costs, battery models

Matt Prilliman – photovoltaic, geothermal, and marine energy models

Steve Janzou – programming, utility rates, financials (subcontractor)

Paul Gilman – user support and documentation (subcontractor)

Ty Neises – concentrating solar power models

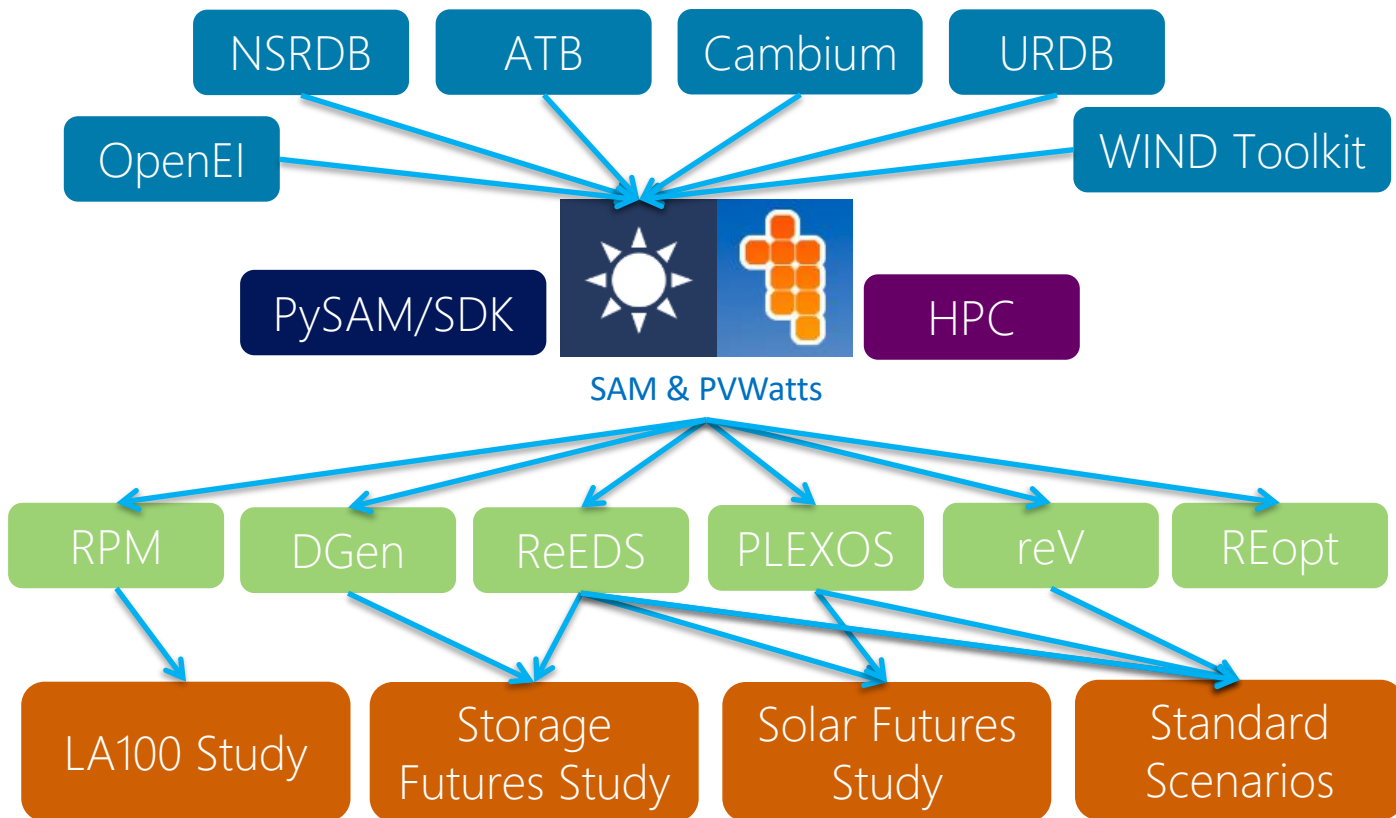
Matt Boyd – concentrating solar power models

Other Resources Online

The following information resources about SAM are available.

- [News](#)
- [Webinars](#) (mostly on the SAM YouTube channel)
- [Weather Data](#) (Description of various weather data sources)
- [Sample Files](#) (particularly scripting language examples)
- [Financial Model Documentation](#)
- [Performance Model Documentation](#) (detailed descriptions)
- [System Cost Data](#) (sources and latest cost data discussion)
- [Case Studies and Validation](#) (all data/files from our validations)
- [Libraries and Databases](#) (i.e. module and inverter specs)
- [Source Code](#) (linkages to Open Source code on GitHub)

A Partial Web of NREL Data & Tools



System Advisor 2017

The Welcome page displays news from the software development team at NREL, and is where you start your work in SAM

Start a new project >

Open a project file

New script

Open s...

Announcements

The National Renewable Energy Laboratory (NREL) Solar Technical Assistance Team (STAT) Network is hosting a one-day training for state decision-makers on how to use NREL's portfolio of solar tools, including SAM, to inform decisions. See the [NREL State](#)

Start a new project or open an existing one. Projects are stored as .sam files. Scripts are .lk files that store scripts for advanced analysis.

Would you like to meet the SAM team? This [webinar](#) is free. These 30-minute online sessions are held on Mountain time (GMT-6) -- all you need is an internet connection.

The latest version is SAM 2017.1.17 r4, SSC 174. To see complete version information for your SAM installation, click **About** in the lower left corner of this window.

Check here for updates, to open SAM's Help system, and to see Version number and registration information.

Quick start for new users >

Help contents

Check for updates...

Registration

About

Quit

C:\Users\gaobo\Desktop\Temp\tod factor test.sam

C:\Users\gaobo\Desktop\Temp\Marcou Mesa Project (200MW) - Disgen.sam

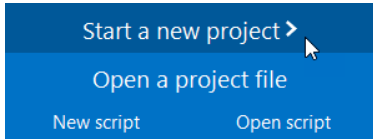
C:\Users\gaobo\Desktop\Temp\...

C:\Users\gaobo\Desktop\Temp\...

List of recent files: Double-click to open a file.

C:\Users\gaobo\Desktop\Temp\SAM Barksdale thin fix 20 080217.sam

C:\Users\gaobo\Desktop\Temp\test shading.sam



To create a new project, click Start a new project in the Welcome window, and then choose a performance model and financial model for your analysis.

SAM 2017.1.17

Choose a performance model, and then choose from the available financial models.

Photovoltaic (detailed)

Photovoltaic (PVWatts)

High concentration PV

Wind

Biomass combustion

Geothermal

Solar water heating

Generic system

List of performance models

(physical)

CFR parabolic trough (commercial)

Residential (distributed)

Commercial (distributed)

Third party ownership

PPA single owner (utility)

PPA part

Financial models

PPA partnership flip without debt (utility)

PPA sale leaseback (utility)

LCOE calculator (FCR method)

No financial model

SAM 2017.1.17

The Main window is where you do your work in SAM.

File Add untitled Help

Photovoltaic, No financial

Location and Resource

Module

Inverter

System Design

Shading and Snow

Losses

System S

Specify desired array size

Desired array size 4 kWdc

DC to AC ratio 1.20

Specify modules and inverters

Modules per string 7

Strings in parallel 2

Number of inverters 1

Configuration at Reference Conditions

Modules

Nameplate capacity 4.693 kWdc

Number of modules 14

Modules per string 7

Strings in parallel 2

Total module area 22.8 m²

Inverters

Total capacity 3.800 kW

Total capacity 3.928 kW

Number of inverters 1

Maximum DC voltage 600.0 Vdc

Minimum MPPT voltage 250.0 Vdc

Maximum AC voltage 480.0 Vdc

Maximum AC power 0.000 kWdc

Voltage and capacity ratings are at module reference conditions shown on the Module page.

Use these buttons to show different input pages. The highlight indicates we are now looking at the System Design input page.

To model a system with one array, specify properties for Subarray 1 and disable Subarrays 2, 3, and 4. To model a system with up to four subarrays connected in parallel to a single bank of inverters, for each subarray, check Enable and specify a number of strings and other properties.

| -String Configuration | Subarray 1 | Subarray 2 | Subarray 3 | Subarray 4 |
|--|--|--|--|--|
| Strings in array 2 | (always enabled) 2 | <input type="checkbox"/> Enable 0 | <input type="checkbox"/> Enable 0 | <input type="checkbox"/> Enable 0 |
| <input checked="" type="radio"/> Fixed | <input checked="" type="radio"/> Fixed | <input checked="" type="radio"/> Fixed | <input checked="" type="radio"/> Fixed | <input checked="" type="radio"/> Fixed |
| <input type="radio"/> 1 Axis | <input type="radio"/> 1 Axis | <input type="radio"/> 1 Axis | <input type="radio"/> 1 Axis | <input type="radio"/> 1 Axis |
| <input type="radio"/> 2 Axis | <input type="radio"/> 2 Axis | <input type="radio"/> 2 Axis | <input type="radio"/> 2 Axis | <input type="radio"/> 2 Axis |
| <input type="radio"/> Azimuth Axis | <input type="radio"/> Azimuth Axis | <input type="radio"/> Azimuth Axis | <input type="radio"/> Azimuth Axis | <input type="radio"/> Azimuth Axis |
| <input type="radio"/> Seasonal Tilt | <input type="radio"/> Seasonal Tilt | <input type="radio"/> Seasonal Tilt | <input type="radio"/> Seasonal Tilt | <input type="radio"/> Seasonal Tilt |
| <input type="checkbox"/> Tilt=latitude | <input type="checkbox"/> Tilt=latitude | <input type="checkbox"/> Tilt=latitude | <input type="checkbox"/> Tilt=latitude | <input type="checkbox"/> Tilt=latitude |
| Tilt (deg) 20 | Tilt (deg) 20 | Tilt (deg) 20 | Tilt (deg) 20 | Tilt (deg) 20 |
| Azimuth (deg) 180 | Azimuth (deg) 180 | Azimuth (deg) 180 | Azimuth (deg) 180 | Azimuth (deg) 180 |
| Ground coverage ratio (GCR) 0.3 | Ground coverage ratio (GCR) 0.3 | Ground coverage ratio (GCR) 0.3 | Ground coverage ratio (GCR) 0.3 | Ground coverage ratio (GCR) 0.3 |
| Tracker rotation limit (deg) 45 | Tracker rotation limit (deg) 45 | Tracker rotation limit (deg) 45 | Tracker rotation limit (deg) 45 | Tracker rotation limit (deg) 45 |

Use these buttons to run simulations, view results, or for advanced simulation options.

Simulate >

Parametrics Stochastic

P50 / P90 Macros

System Sizing

Specify desired array size

Desired array size: 4 kWdc

DC to AC ratio: 1.20

Specify modules and inverters

Modules per string: 7

Strings in parallel: 2

Number of inverters: 1

Configuration at Reference Conditions

Modules

Nameplate capacity: 4.693 kWdc

Number of modules: 14

Modules per string: 7

Strings in parallel: 2

Total module area: 22.8 m²

String Voc: 475.3 V

String Vmp: 401.1 V

Minimum MPPT voltage: 230.0 Vdc

Maximum MPPT voltage: 480.0 Vdc

Battery maximum power: 0.000 kWdc

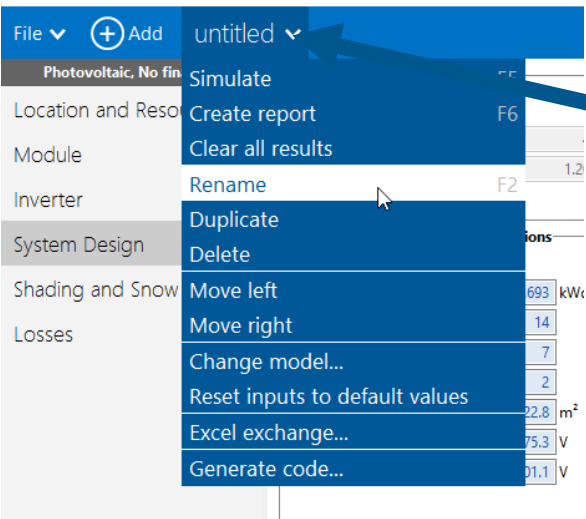
Voltage and capacity ratings are at module reference conditions shown on the Module page.

2, 3, and 4. To model a system with up to four subarrays specify a number of strings and other properties.

| | Subarray 2 | Subarray 3 | Subarray 4 |
|--|--|--|--|
| <input type="checkbox"/> Enable | <input type="checkbox"/> Enable | <input type="checkbox"/> Enable | <input type="checkbox"/> Enable |
| 0 | 0 | 0 | 0 |
| <input checked="" type="radio"/> Fixed | <input checked="" type="radio"/> Fixed | <input checked="" type="radio"/> Fixed | <input checked="" type="radio"/> Fixed |
| <input type="radio"/> 1 Axis | <input type="radio"/> 1 Axis | <input type="radio"/> 1 Axis | <input type="radio"/> 1 Axis |
| <input type="radio"/> 2 Axis | <input type="radio"/> 2 Axis | <input type="radio"/> 2 Axis | <input type="radio"/> 2 Axis |
| <input type="radio"/> Azimuth Axis | <input type="radio"/> Azimuth Axis | <input type="radio"/> Azimuth Axis | <input type="radio"/> Azimuth Axis |
| <input type="radio"/> Seasonal Tilt | <input type="radio"/> Seasonal Tilt | <input type="radio"/> Seasonal Tilt | <input type="radio"/> Seasonal Tilt |
| <input type="checkbox"/> Tilt=latitude | <input type="checkbox"/> Tilt=latitude | <input type="checkbox"/> Tilt=latitude | <input type="checkbox"/> Tilt=latitude |
| Tilt (deg) | 20 | 20 | 20 |
| Azimuth (deg) | 180 | 180 | 180 |
| Ground coverage ratio (GCR) | 0.3 | 0.3 | 0.3 |
| Tracker rotation limit (deg) | 45 | 45 | 45 |

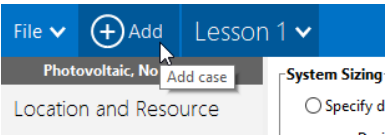
Callout 1: "Greyed out" inputs are inactive. In this case the Desired array size and DC to AC ratio inputs are inactive because Specify modules and inverters is selected.

Callout 2: Blue inputs are values that you cannot change on this input page. They either come from other pages, or are calculated by SAM. For example, the module Nameplate capacity is a value that comes from the Module page. SAM calculated Number of modules by multiplying Modules per string by Strings in parallel.

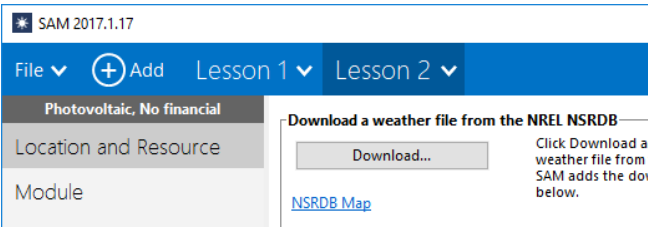


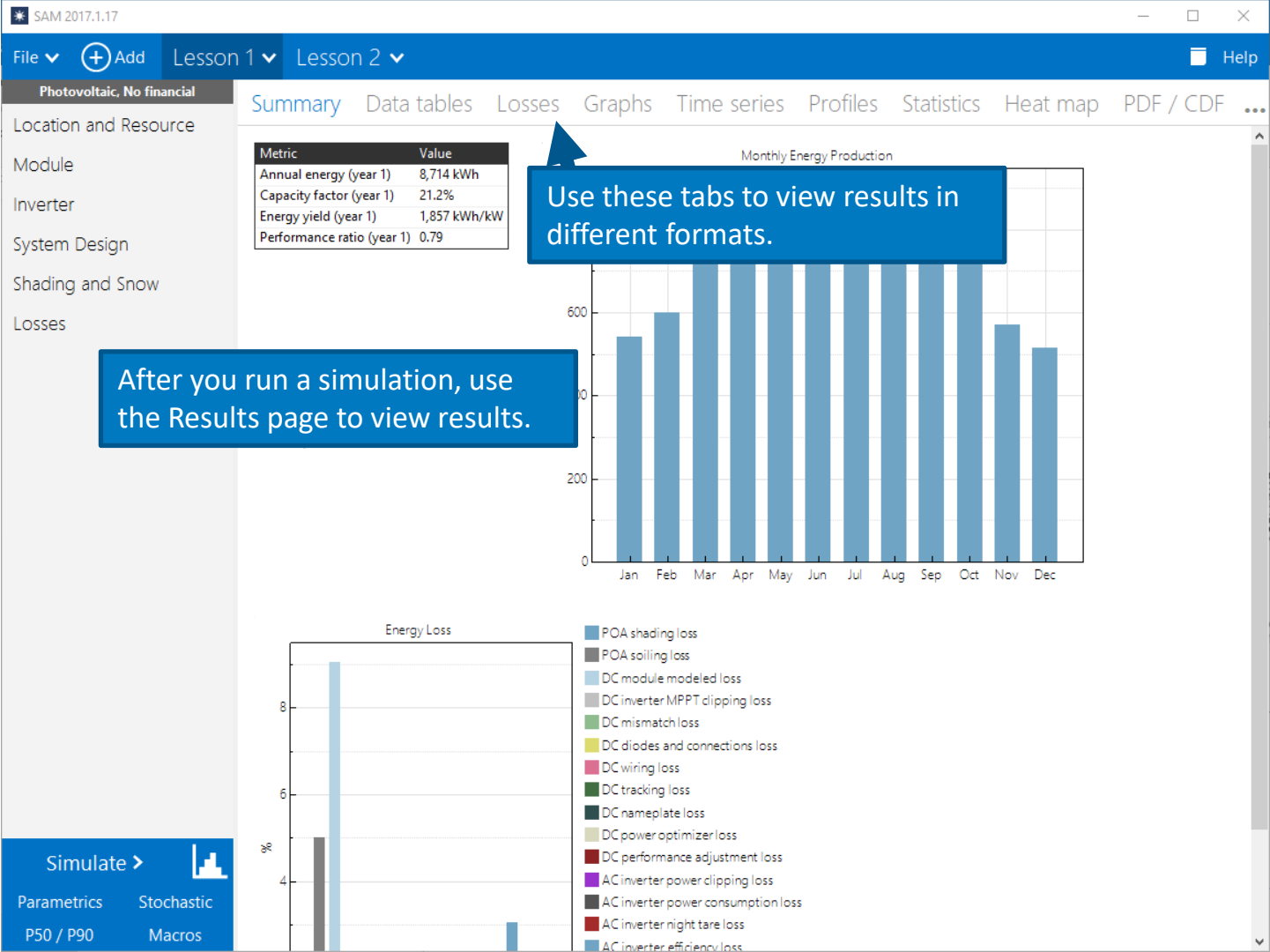
The Case menu lists commands for the current case. Click v to see the menu.

A case is like a worksheet in an Excel workbook, it is a complete set of inputs and results. A project can have one or more cases.



Click Add to add a case to your project. You can use multiple cases for comparison or to model a complex system.





Summary Data tables Losses Graphs Time series

Copy to clipboard Save as CSV... Send to Excel...

Q sys

Single Values x Hourly Data x

System power generated (kW)

| Time | System power generated (kW) |
|-----------------|-----------------------------|
| Jan 1, 12:00 am | -0.0009999 |
| Jan 1, 01:00 am | -0.0009999 |
| Jan 1, 02:00 am | -0.0009999 |
| Jan 1, 03:00 am | -0.0009999 |
| Jan 1, 04:00 am | -0.0009999 |
| Jan 1, 05:00 am | -0.0009999 |
| Jan 1, 06:00 am | -0.0009999 |
| Jan 1, 07:00 am | 0.00195785 |
| Jan 1, 08:00 am | 0.304673 |
| Jan 1, 09:00 am | 1.95423 |
| Jan 1, 10:00 am | 2.65753 |
| Jan 1, 11:00 am | 3.22503 |
| Jan 1, 12:00 pm | 3.48084 |
| Jan 1, 01:00 pm | 3.03581 |
| Jan 1, 02:00 pm | 1.50000 |

Use these buttons to export data from tables to your documents.

Right-click (or Control-click) graphs to export images or data from graphs.

Summary Data tables Losses Graphs Time series Profiles Statistics Heat map

Subarray 1 Surface azimuth (deg)
 Subarray 1 Angle of incidence (deg)
 Subarray 1 Axis rotation for 1 axis trackers (deg)
 Subarray 1 Axis rotation ideal for 1 axis tracker
 Subarray 1 POA beam irradiance after shading
 Subarray 1 POA diffuse irradiance after shading
 Subarray 1 POA total irradiance nominal (W/m²)
 Subarray 1 POA total irradiance after shading
 Subarray 1 POA total irradiance after shading and soiling
 Subarray 1 Soiling beam irradiance factor (fraction)
 Subarray 1 External shading and soiling beam irradiance
 Subarray 1 Self-shading linear beam irradiance
 Subarray 1 Self-shading non-linear sky diffuse
 Subarray 1 Self-shading non-linear ground diffuse
 Subarray 1 Self-shading non-linear DC factor
 Subarray 1 Partial external shading DC factor
 Subarray 1 Module efficiency (%)
 Subarray 1 Cell temperature (C)
 Subarray 1 Operating voltage (V)
 Subarray 1 Open circuit voltage (V)
 Subarray 1 Short circuit current (A)
 Array POA total radiation nominal (kW)
 Array POA beam radiation nominal (kW)
 Array POA total radiation after shading only (kW)
 Array POA total radiation after shading and soiling (kW)
 Array POA beam radiation after shading and soiling (kW)
 Array DC power loss due to snow (kW)
 Array DC power (kW)
 Inverter DC input voltage (V)
 Inverter efficiency (%)
 Inverter clipping loss DC MPPT voltage limits

SAM 2017.1.17

File Add Lesson 1 Lesson 2 Help

Photovoltaic, No financial

Location and Resource

Module

Inverter

System Design

Shading and Snow

Losses

Irradiance Losses

Soiling losses apply to the total solar irradiance incident on each module. See the Soiling Losses page in the SAM Help for more information.

Shading and Snow page.

Subarray 1

| Loss Type | Value | Value | Value | Value |
|-----------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
| Monthly soiling loss | <input type="text" value="5"/> | <input type="text" value="5"/> | <input type="text" value="5"/> | <input type="text" value="5"/> |
| Average annual soiling loss | <input type="text" value="5"/> | <input type="text" value="5"/> | <input type="text" value="5"/> | <input type="text" value="5"/> |

array and account for losses not calculated by the module performance model.

| | | | | |
|-----------------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|
| DC wiring (%) | <input type="text" value="2"/> | <input type="text" value="2"/> | <input type="text" value="2"/> | <input type="text" value="2"/> |
| Tracking error (%) | <input type="text" value="0"/> | <input type="text" value="0"/> | <input type="text" value="0"/> | <input type="text" value="0"/> |
| Nameplate (%) | <input type="text" value="0"/> | <input type="text" value="0"/> | <input type="text" value="0"/> | <input type="text" value="0"/> |
| DC power optimizer loss (%) | <input type="text" value="0"/> | <input type="text" value="0"/> | <input type="text" value="0"/> | <input type="text" value="0"/> |
| Total DC power loss (%) | <input type="text" value="4.440"/> | <input type="text" value="4.440"/> | <input type="text" value="4.440"/> | <input type="text" value="4.440"/> |

Total DC power loss = 100% * [1 - the product of (1 - loss/100%)]

with default values.

ing inverters Microinverters DC optimizers

Notes

AC losses apply to the electrical output of the inverter and assume a power factor of 1. The transformer capacity is equal to the total inverter AC power rating.

Transformer Losses

The transformer loss model is intended for distribution or substation transformers in large PV systems. Losses apply to the electrical output of the inverter and assume a power factor of 1. The transformer capacity is equal to the total inverter AC power rating.

Transformer no load loss % Transformer load loss %

Curtailment and Availability

Curtailment and availability losses reduce the system output to represent system outages or other events. Curtailment and availability losses may be applied either on the DC or AC side of

-DC Losses-

Edit losses... Constant loss: 0.0 % Hourly losses: None Custom periods: None

-AC Losses-

Edit losses... Constant loss: 0.0 % Hourly losses: None Custom periods: None

Simulate >

Parametrics Stochastic

P50 / P90 Macros

Add notes to pages you want to make notes for yourself or colleagues.

The yellow icon indicates there is a note for this page.

To remove a note, delete all of the text (including spaces) in the note box.

Don't forget to change losses if we change from an central inverters to microinverters.

Source:

The image shows the SAM 2017.1.17 software interface. The main window has a menu bar with 'File', 'Add', 'Lesson 1', 'Lesson 2', and 'Help'. Below the menu bar, there's a 'Photovoltaic, No financial' section and a 'CEC Performance Model with Module Database' dropdown. A search bar and a table of module data are visible. A blue callout box with an arrow pointing to the 'Help' menu item contains the text: 'Click Help, or press the F1 key to display help.'

The 'System Advisor Model Help' window is open, displaying the 'Module' page. The left sidebar of the help window lists various topics like 'Excel Exchange Libraries', 'Simulation', 'Weather Data', and 'Photovoltaic Systems'. The main content area of the help window has a blue header 'Module' and contains the following text:

The Module page allows you to choose a model to represent the photovoltaic module's performance. For each time step of the simulation, the module model calculates the DC electrical output of a single module based on the design parameters and the incident solar radiation (plane-of-array irradiance) calculated from data in the [weather file](#).

SAM assumes that the system is made up of an array of identical modules, which can be wired into up to four [DC subarrays](#). The photovoltaic array's electric output depends on the number of modules in the system and the orientation, tracking, shading, and other parameters on the [System Design](#) page, and any losses you specify on the [Shading and Snow](#) and [Losses](#) pages. The array's electrical output is fed to a bank of one or more inverters, whose characteristics appear on the [Inverter](#) page.

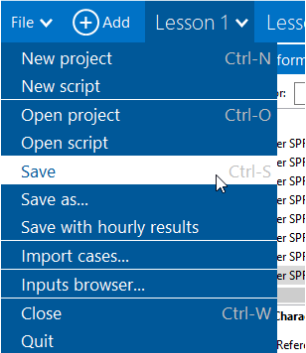
SAM displays the name of the active module model at the top of the Module page. Click the model name to choose a different model:

- CEC Performance Model with Module Database
- Simple Efficiency Module Model
- CEC Performance Model with User Entered Specifications
- Sandia PV Array Performance Model with Module Database
- IEC61853 Single Diode Model

You can choose from five different module performance models:

- [Simple Efficiency Module Model](#) is a simple representation of module performance that requires you to provide the module area, a set of conversion efficiency values, and temperature correction parameters. The simple efficiency model is the least accurate of the three models for predicting the performance of specific modules, but is useful for analyses involving explorations of the relationship between module efficiency and the system's performance and cost of energy because it allows you to

At the bottom of the help window, there are configuration options for 'Heat transfer dimensions', 'Mounting structure orientation', 'Module width', 'Columns of modules in array', and 'Temperature behind the module'.



Use the File menu to save your project files as .sam files.

If your project has more than one case, use the inputs browser to compare inputs.

System Advisor Model Help

Back Home Web site Forum Email support Release notes Scripting reference About Close

Models and Databases

Getting Started

- Welcome Page
- Create a Project
- Choose Models
- Main Window
- Input Pages
- Performance Model Inputs
- System Costs
- Financial Model Inputs
- Run Simulation
- Results
- Videos

Reference

- File Menu
- Case Menu
- Manage Cases
- Export Data and Graphs
- Reports
- Inputs Browser
- Time Series Data Viewer
- Edit Schedule
- Notes
- Excel Exchange
- Libraries
- Macros and Scripting

File Menu

SAM's File menu provides access to commands for managing projects and scripts, and opening the inputs browser.

File ▾

- New project Ctrl-N
- New script
- Open project Ctrl-O
- Open script
- Save
- Save as...
- Save with hourly results
- Import cases...
- Inputs browser...
- Close Ctrl
- Quit

New project
Create a new project file using default input values. SAM opens a project with a single case and no results.

New script
Open the script editor for a new new [LK script](#).

Open project
Open an existing SAM project file (.sam) file.

Save with hourly results
Save the project as a SAM (.sam) file in its current location, and include hourly results.
Use this option if you want hourly data to be available on

See the “Getting Started” and “Reference” topics in Help for more details about SAM’s user interface.