

# GETEM in the System Advisor Model (SAM)

Matt Prilliman

[Matthew.Prilliman@nrel.gov](mailto:Matthew.Prilliman@nrel.gov)

January 19<sup>th</sup>, 2023

# Agenda

- 1** Introduction to SAM

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- 2** Who uses SAM?

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- 3** Advanced SAM features

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- 4** Introduction to GETEM

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- 5** SAM GETEM inputs and outputs

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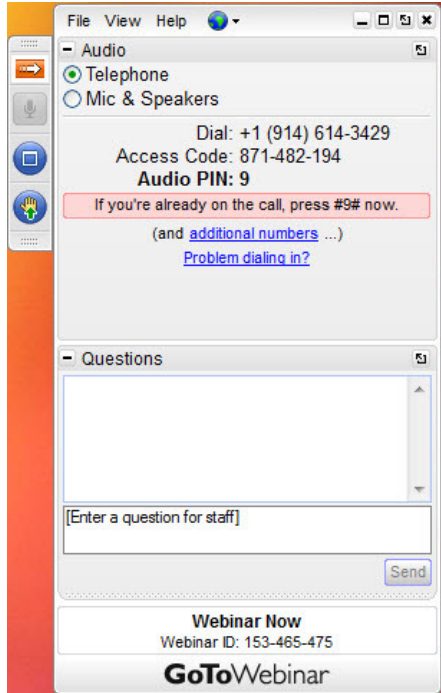
- 6** Live SAM Demonstration

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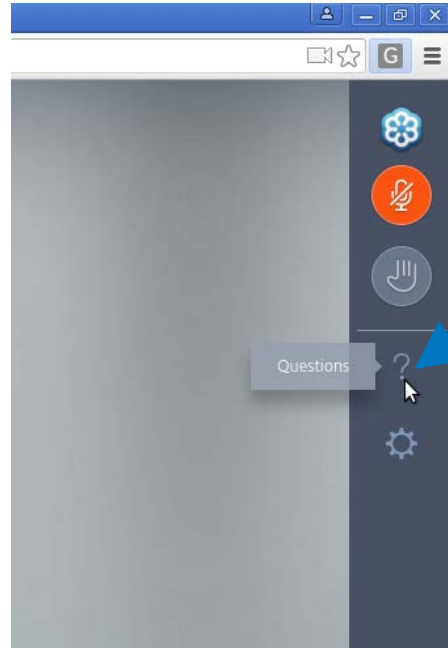
- 7** Q&A

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# Questions and Answers



Desktop application



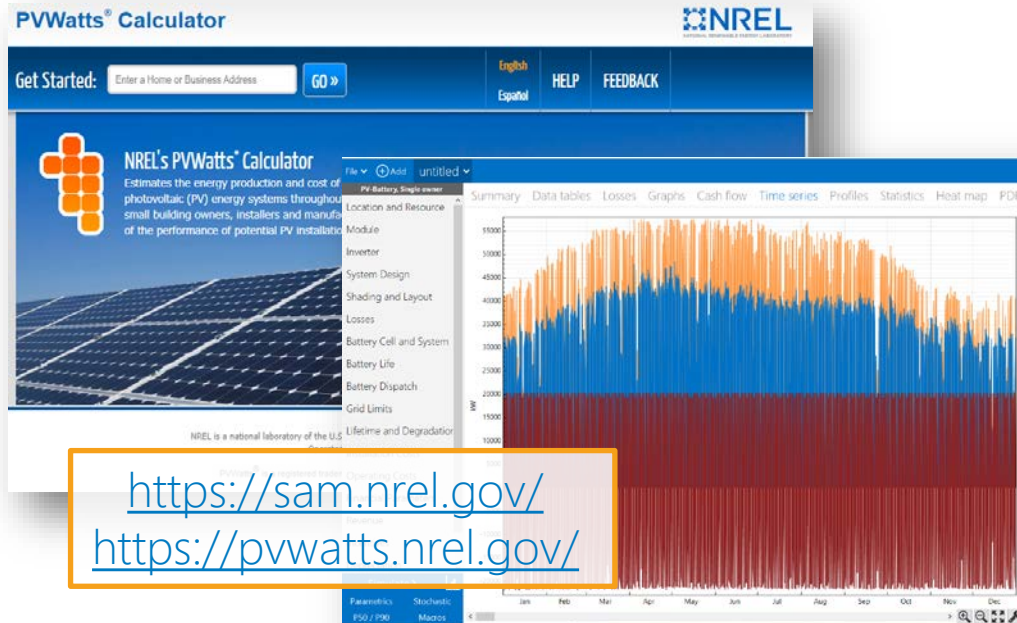
Instant Join Viewer

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

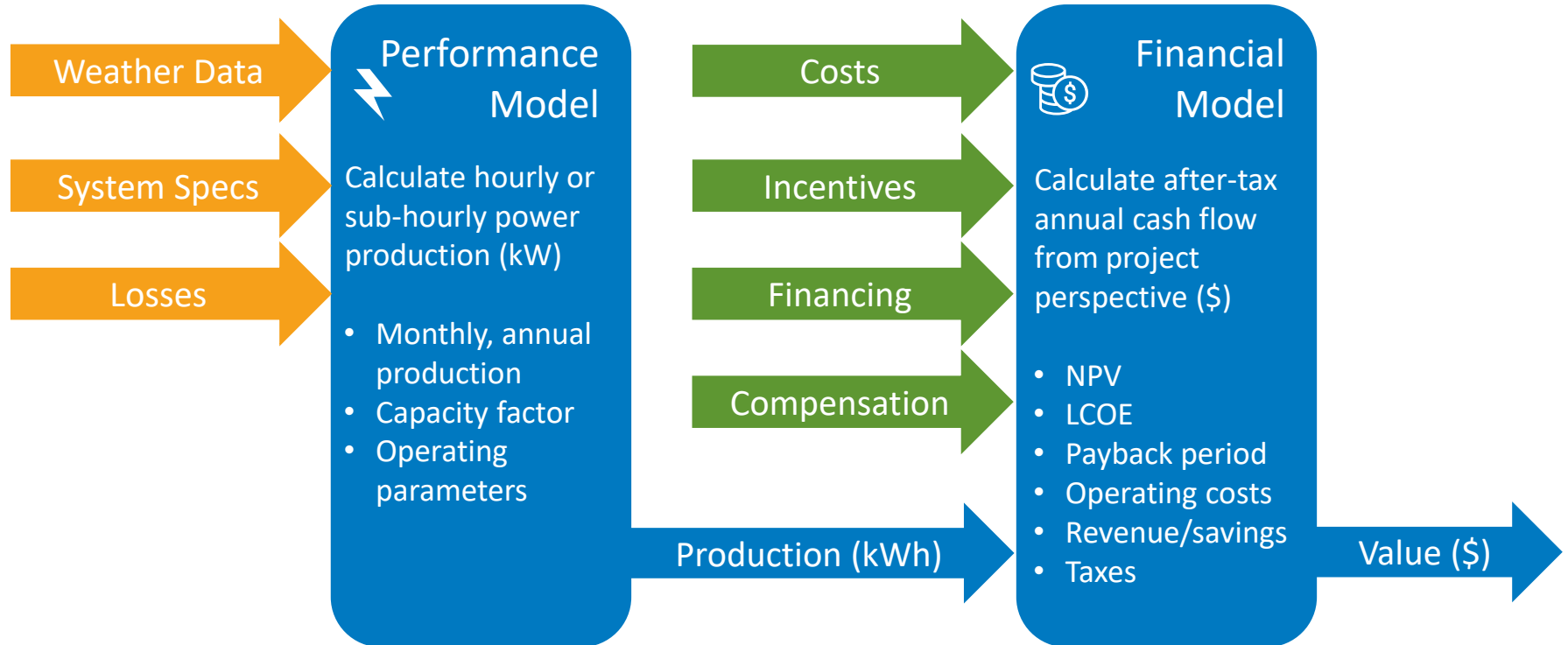
Free software that enable detailed performance and financial analysis for renewable energy systems



<https://sam.nrel.gov/>  
<https://pvwatts.nrel.gov/>

- ✓ 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

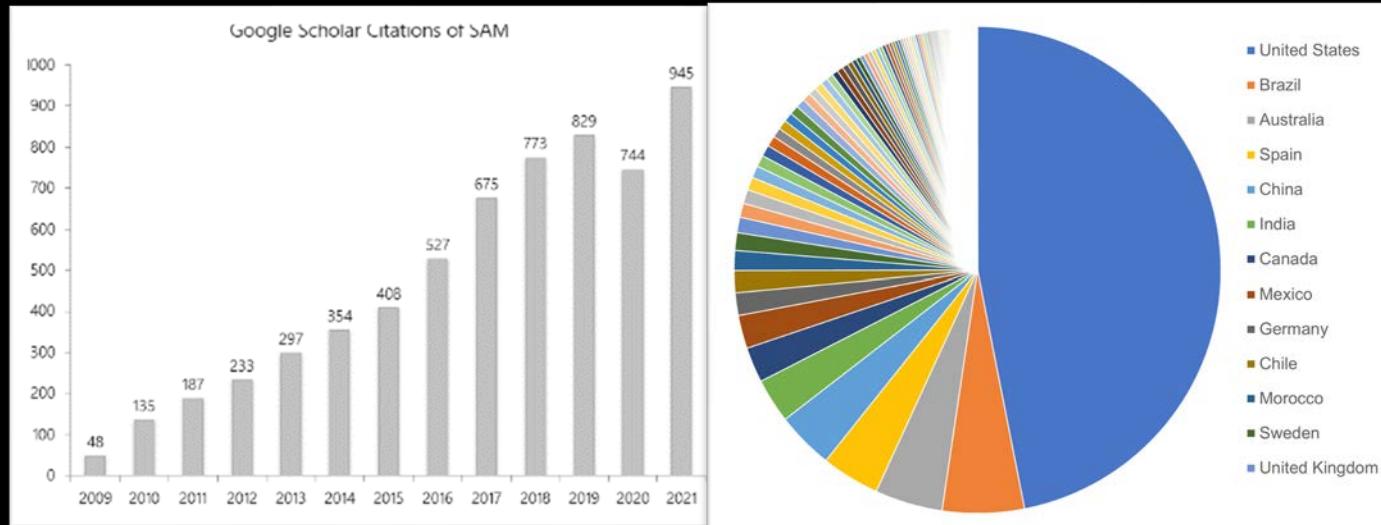
## Some Applications

- 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

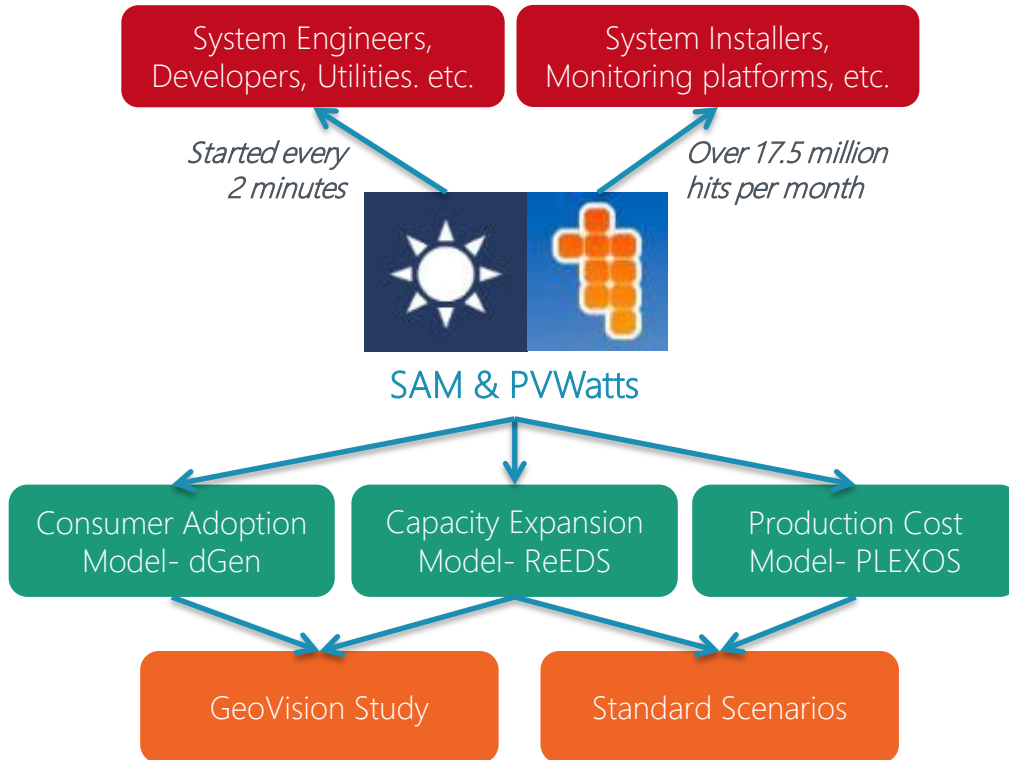




# Who Uses SAM? Why?

- **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

```
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:

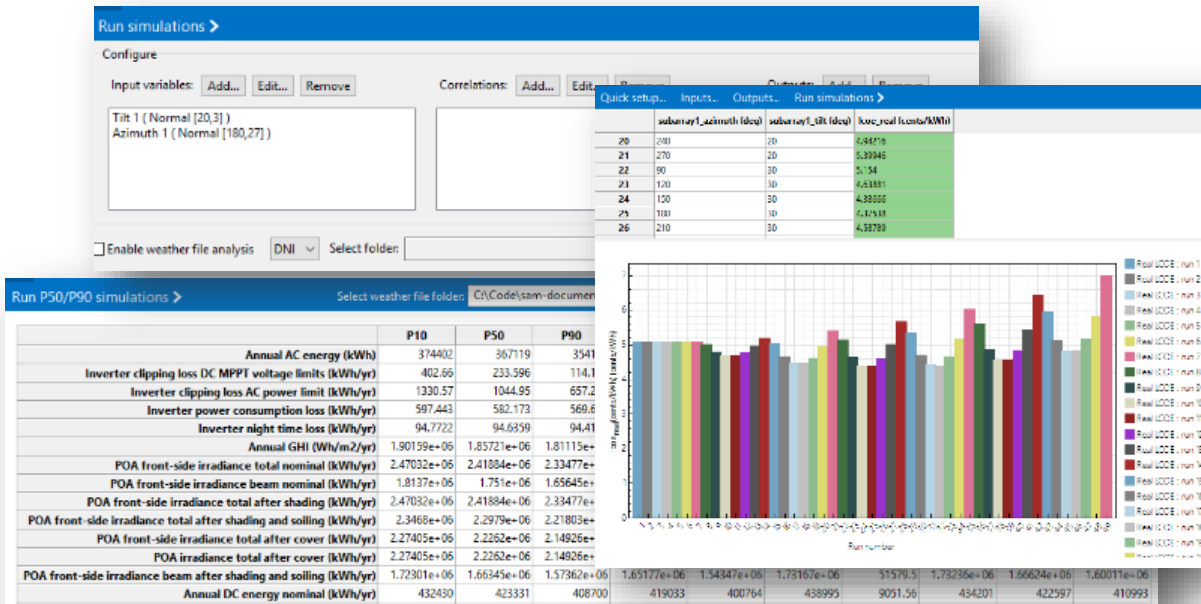
**Instructions:**

- 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

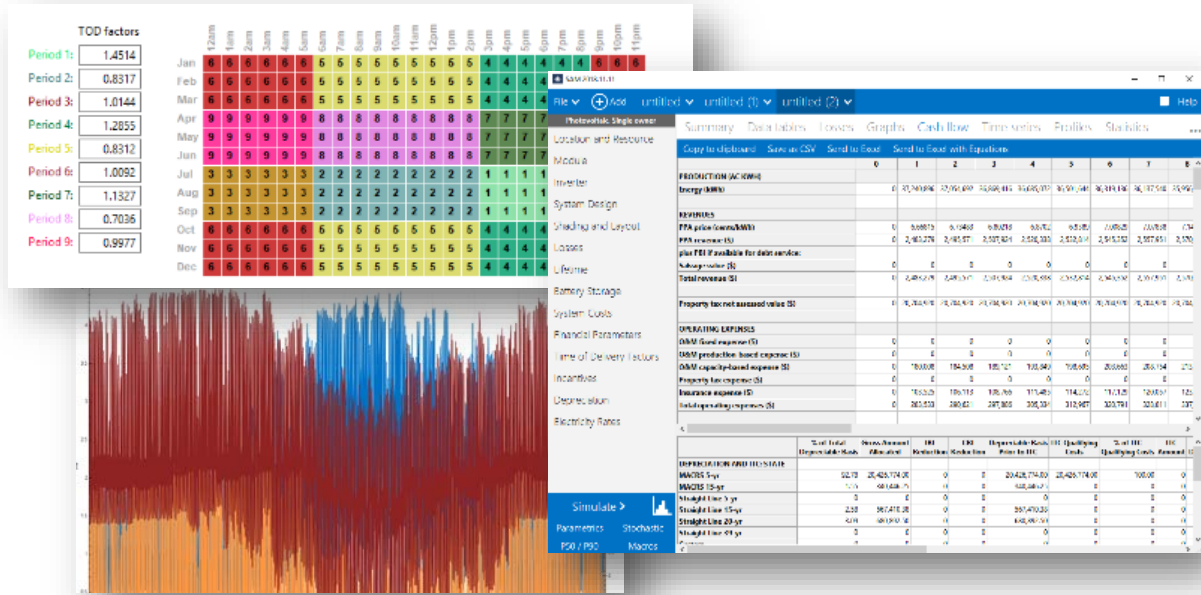
# Advanced Analysis Features

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



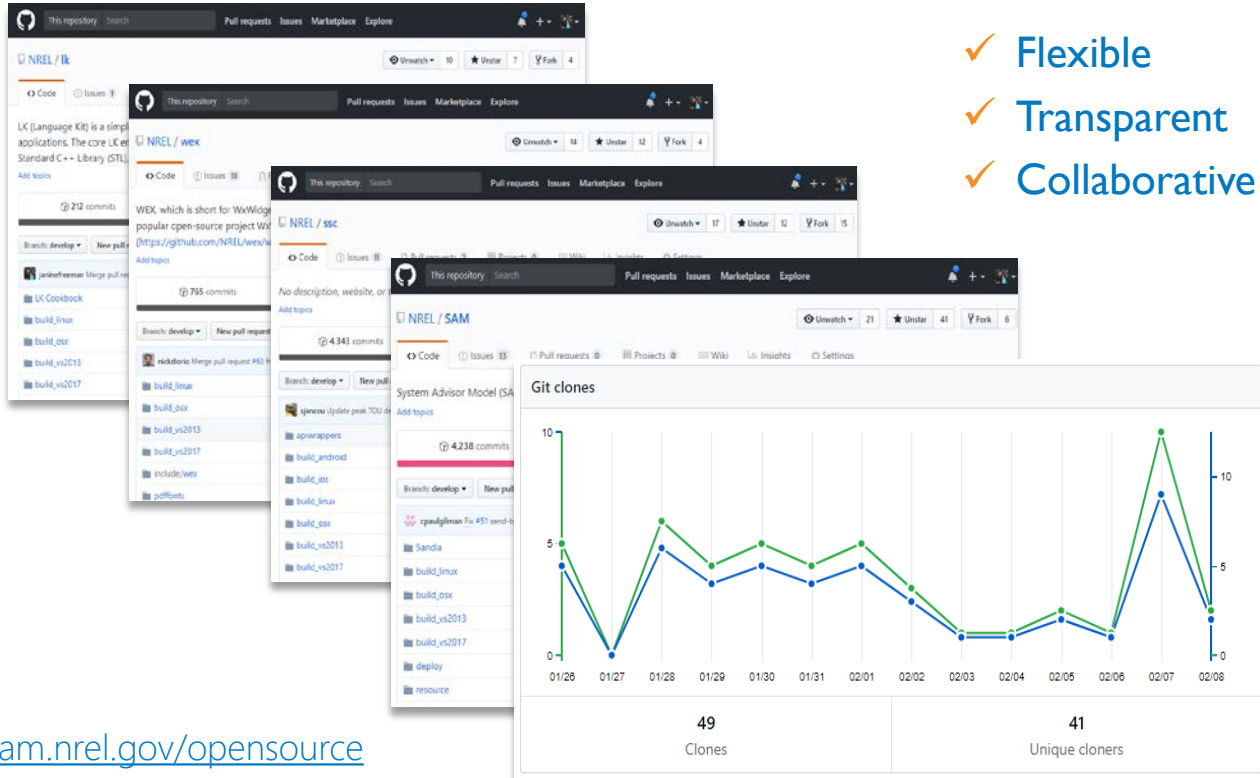
# Detailed Cash Flow Financial Models

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

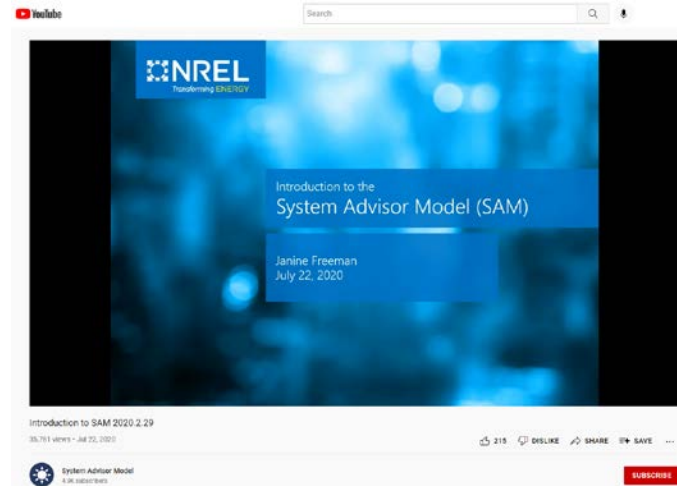
- ✓ Flexible
- ✓ Transparent
- ✓ Collaborative



<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 dropdowns 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**

**Binary**

**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
<b>Power Sales</b>	25.0
<b>Economic</b>	
<b>Permitting</b>	
<b>Exploration</b>	
<b>Drilling</b>	\$18,556,985
<b>Field Gathering System &amp; Pumping</b>	\$23,294,639
<b>Reservoir Performance</b>	\$7,075,195
<b>Operating &amp; Maintenance</b>	5.33
<b>Power Plant</b>	\$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

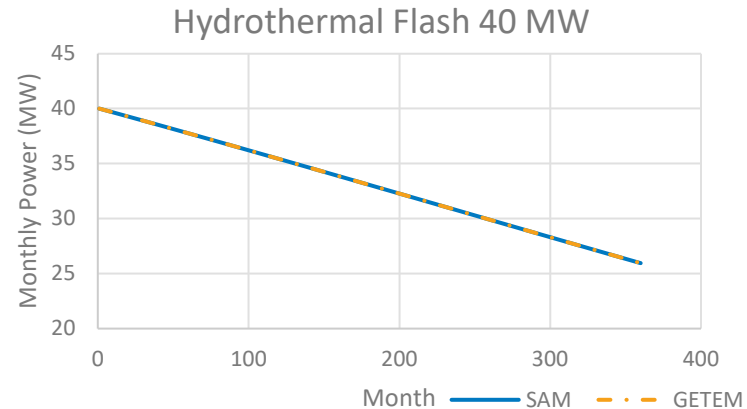
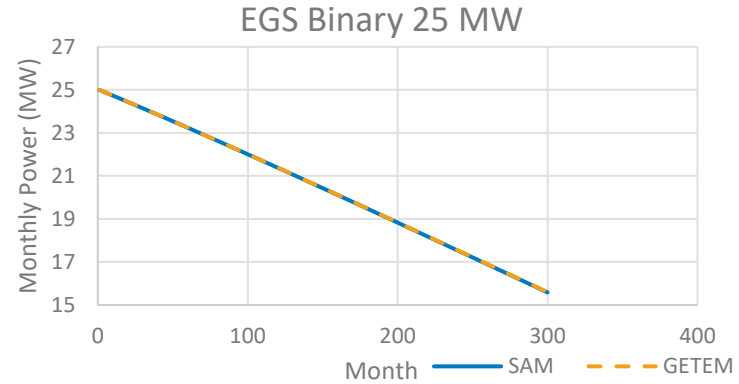
The default conversion system is based on the resourc elect to change the conversion system, the type select Default and the Revised Scenarios - if blank the default that Binary not be used above 200C and Flash not below

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.

overnight costs  
overnight costs  
production wells required per year  
overnight costs

# 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](#)

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**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  m  
 Fracture Length  m  
 Fracture Aperture  m  
 Number of Fractures   
 Fracture Width  m  
 Fracture Angle  deg from horizontal  
 Rock Density  kg/m<sup>3</sup>  
 Rock Specific Heat  J/kg-°C  
 Rock Thermal Conductivity  W/m-K  
 Subsurface Water Loss  % 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: Plant Efficiency  %  
 Flash: Subtype

Enter Plant Design Temperature (EGS only):  °C

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

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

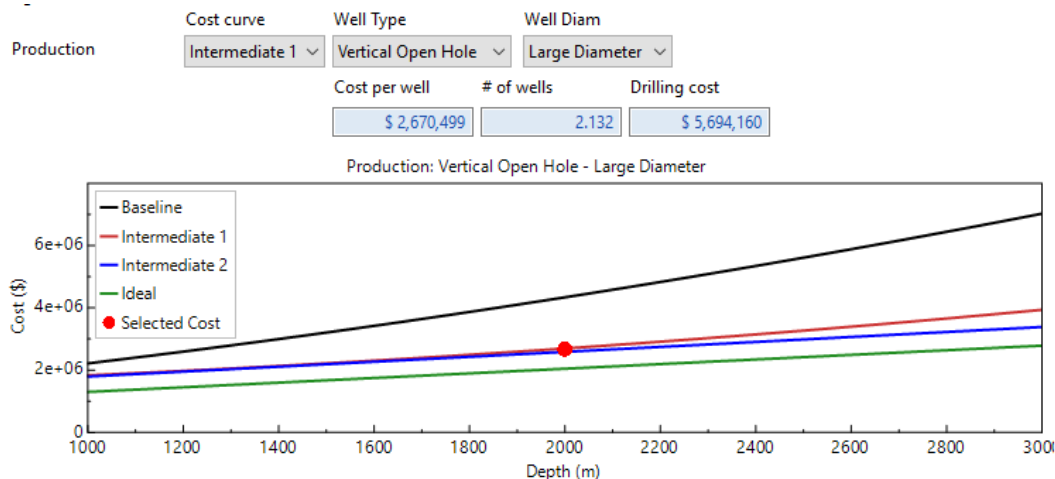
Ambient Pressure:  psi

### 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			

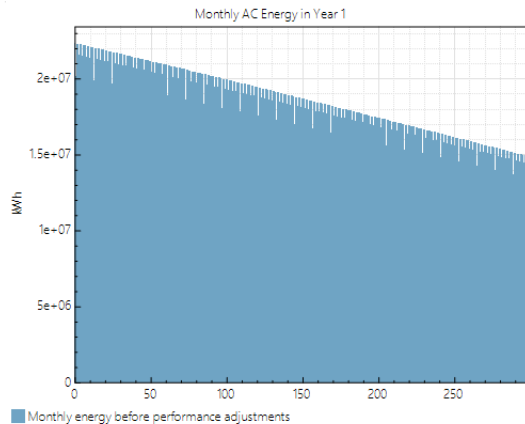
# GETEM SAM – Costs

- 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>)

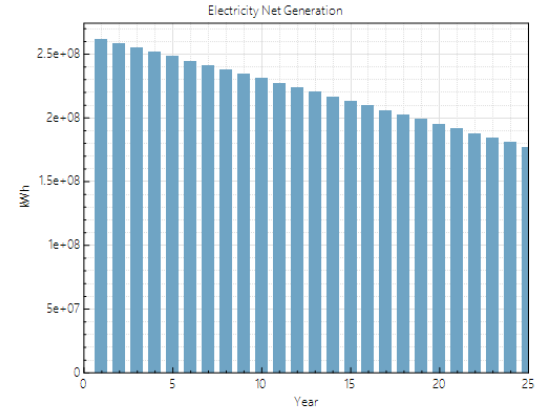


# GETEM SAM – Energy Outputs

- 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

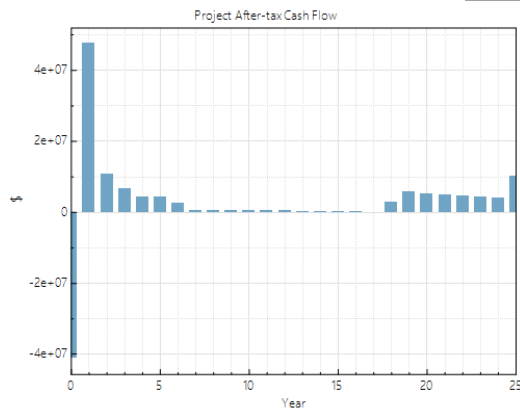


# GETEM SAM – Financial Outputs

- 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
<b>OPERATING EXPENSES</b>								
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
<b>Total operating expenses (\$)</b>	<b>0</b>	<b>7,714,234</b>	<b>7,875,582</b>	<b>8,040,963</b>	<b>8,210,479</b>	<b>8,384,234</b>	<b>8,562,331</b>	<b>8,744,882</b>
<b>EBITDA (\$)</b>	<b>0</b>	<b>13,189,235</b>	<b>12,970,898</b>	<b>12,742,768</b>	<b>12,504,747</b>	<b>12,256,733</b>	<b>11,998,622</b>	<b>11,730,310</b>
<b>OPERATING ACTIVITIES</b>								
<b>EBITDA (\$)</b>	<b>0</b>	<b>13,189,235</b>	<b>12,970,898</b>	<b>12,742,768</b>	<b>12,504,747</b>	<b>12,256,733</b>	<b>11,998,622</b>	<b>11,730,310</b>
Interest earned on reserves (\$)	0	111,624	111,582	111,519	111,434	111,328	111,200	111,051
<b>plus PBI if not available for debt service:</b>								
<b>Federal PBI income (\$)</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>



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 effect.

# Live SAM Demo

[www.nrel.gov](http://www.nrel.gov)

*Photo from iStock-627281636*

 **NREL**  
Transforming ENERGY

**45**<sup>Th</sup>  
anniversary



# Thank you! Questions?

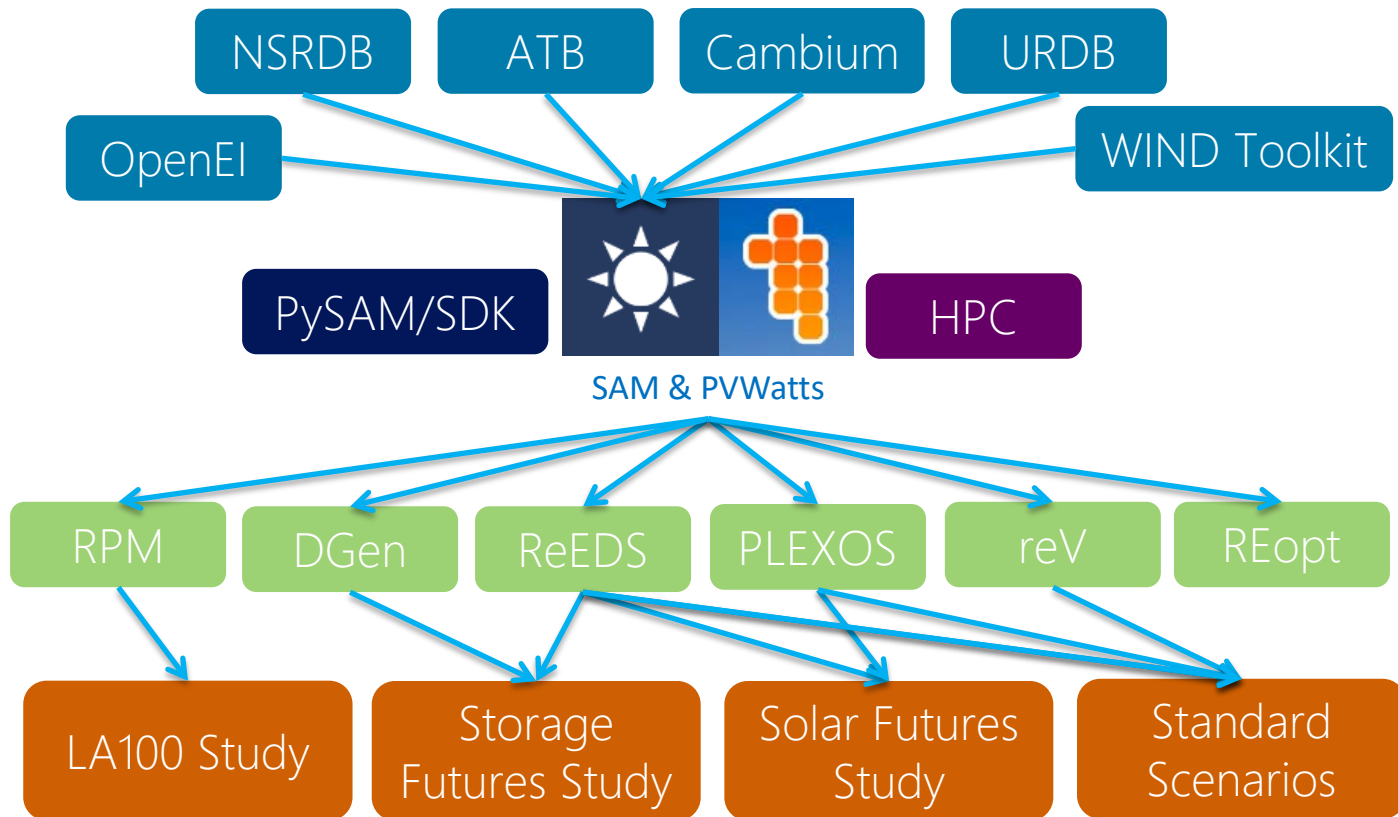
Janine (Freeman) Keith – project lead, photovoltaic and wind models  
Nate Blair – emeritus lead, financials, costs, systems  
Darice Guittet – software development, battery models  
Brian Mirlletz – software development, costs, battery models  
Matt Prilliman – photovoltaic, geothermal, and marine energy 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 training session is free. These 30-minute online sessions are held in 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

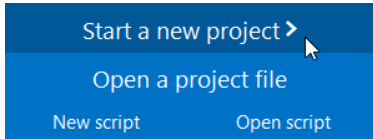
C:\Users\gaobo\Desktop\Temp\...

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

File Add untitled Help

Photovoltaic, No financial

Location and Resource

Module

Inverter

System Design

Shading and Snow

Losses

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

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 m<sup>2</sup>

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)	<input type="checkbox"/> Enable	<input type="checkbox"/> Enable
	2	<input type="checkbox"/> Enable	<input type="checkbox"/> Enable	<input type="checkbox"/> Enable
		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	20
	Azimuth (deg) 180	180	180	180
	Ground coverage ratio (GCR) 0.3	0.3	0.3	0.3
	Tracker rotation limit (deg) 45	45	45	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 m<sup>2</sup>

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.

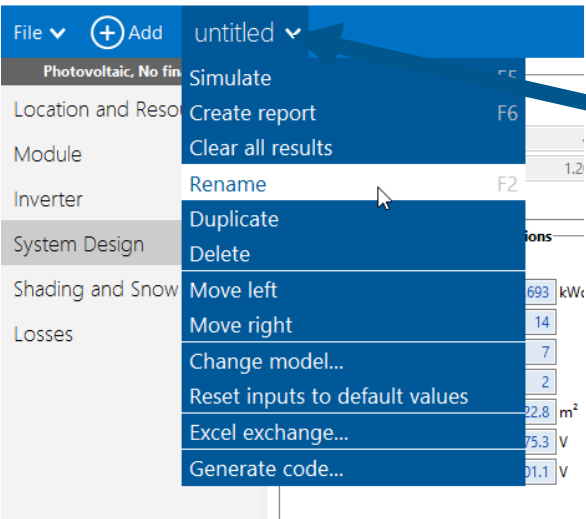
2, 3, and 4. To model a system with up to four subarrays specify a number of strings and other properties.

	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.

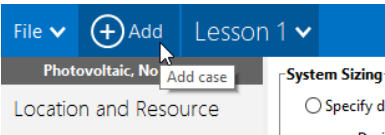
**Callout 2:** Blue inputs are values that you cannot change on this input page. They either come from other pages, or are calculated by SAM. For example, the module Nameplate capacity is a value that comes from the Module page. SAM calculated Number of modules by multiplying Modules per string by Strings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

**Bottom Bar:** Simulate > Parametrics Stochastic P50 / P90 Macros

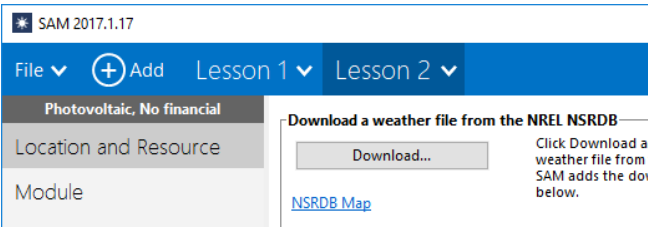


The Case menu lists commands for the current case. Click v to see the menu.

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.



Download a weather file from the NREL NSRDB —  
 Click Download a weather file from SAM adds the download below.  
[NSRDB Map](#)



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

Summary Data tables Losses Graphs Time series Profiles Statistics Heat map PDF / CDF ...

Metric	Value
Annual energy (year 1)	8,714 kWh
Capacity factor (year 1)	21.2%
Energy yield (year 1)	1,857 kWh/kW
Performance ratio (year 1)	0.79

Use these tabs to view results in different formats.

Monthly Energy Production

Month	Energy Production (kWh)
Jan	~500
Feb	~600
Mar	~700
Apr	~700
May	~700
Jun	~700
Jul	~700
Aug	~700
Sep	~700
Oct	~700
Nov	~550
Dec	~450

After you run a simulation, use the Results page to view results.

Energy Loss

Loss Category	Loss (%)
POA shading loss	~0.2
POA soiling loss	~4.8
DC module modeled loss	~9.2
DC inverter MPPT clipping loss	~0.1
DC mismatch loss	~0.1
DC diodes and connections loss	~0.1
DC wiring loss	~0.1
DC tracking loss	~0.1
DC nameplate loss	~0.1
DC power optimizer loss	~0.1
DC performance adjustment loss	~0.1
AC inverter power clipping loss	~0.1
AC inverter power consumption loss	~0.1
AC inverter night tare loss	~0.1
AC inverter efficiency loss	~0.1

Simulate >

Parametrics Stochastic

P50 / P90 Macros

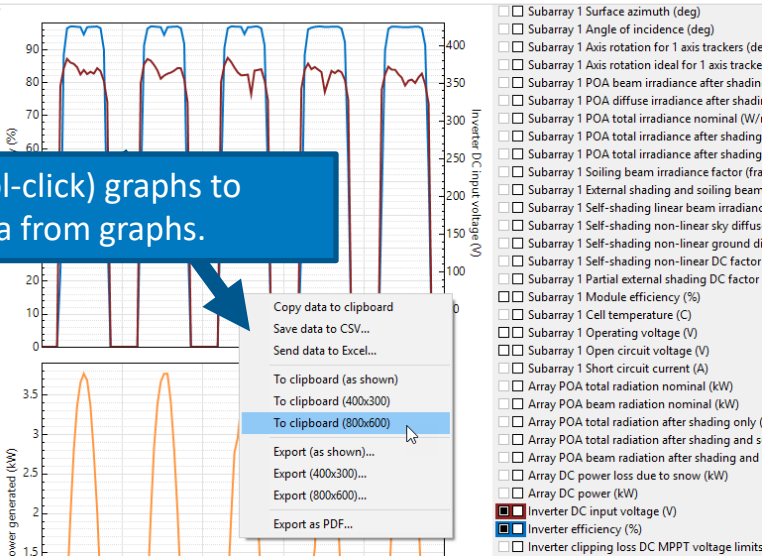
Q sys

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.

- 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/m<sup>2</sup>)
- 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 irradiance
- Subarray 1 Self-shading non-linear ground diffuse irradiance
- 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

The screenshot shows the SAM 2017.1.17 software interface. The top navigation bar includes 'File', '+ Add', 'Lesson 1', 'Lesson 2', and 'Help'. The left sidebar lists various system components: 'Photovoltaic, No financial', 'Location and Resource', 'Module', 'Inverter', 'System Design', 'Shading and Snow', and 'Losses'. The main content area is titled 'Irradiance Losses' and contains a table for 'Subarray 1' with columns for 'Monthly soiling loss' and 'Average annual soiling loss'. A yellow icon in the sidebar indicates a note for this page. A callout box explains that this icon indicates a note. Another callout box explains how to remove a note by deleting all text in the note box. A third callout box shows a note in the 'Notes' section: 'Don't forget to change losses if we change from an central inverters to microinverters.' The bottom of the interface shows 'Simulate' and 'Curtailment and Availability' sections.

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 subarray. See the Soiling and Snow page.

Subarray 1

	1	2	3	4
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"/>

DC wiring (%)

Tracking error (%)

Nameplate (%)

DC power optimizer loss (%)

Total DC power loss (%)

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

Notes

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

**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.**

Source:

The image shows the SAM 2017.1.17 software interface. The main window has a blue header with 'File', 'Add', 'Lesson 1', 'Lesson 2', and 'Help'. A blue callout box with an arrow pointing to the 'Help' button contains the text: 'Click Help, or press the F1 key to display help.' The left sidebar shows a tree view with categories like 'Photovoltaic, No financial', 'Location and Resource', 'Module', 'Inverter', 'System Design', 'Shading and Snow', and 'Losses'. The 'Module' category is selected, and a 'System Advisor Model Help' window is open over it. This help window has a blue header with 'Module' and a list of navigation links: 'Back', 'Home', 'Web site', 'Forum', 'Email support', 'Release notes', 'Scripting reference', 'About', and 'Close'. The main content of the help window explains the 'Module' page, stating that it allows users to choose a model for photovoltaic performance. It lists five models: 'CEC Performance Model with Module Database' (selected), 'Simple Efficiency Module Model', 'CEC Performance Model with User Entered Specifications', 'Sandia PV Array Performance Model with Module Database', and 'IEC61853 Single Diode Model'. Below the list, it says 'You can choose from five different module performance models:' and lists the 'Simple Efficiency Module Model' as the least accurate. At the bottom of the help window, there are input fields for 'Heat transfer dimensions', 'Mounting structure orientation', 'Module width', 'Columns of modules in array', and 'Temperature behind the module'. The background software interface shows a table with columns for 'Name', 'I\_m', 'V\_m', 'I\_sc\_ref', and 'V\_oc\_ref', with one row for 'SunPower SPR-X20-327-BLK'.

File Add Lesson 1 Lesson 2 Help

Photovoltaic, No financial CEC Performance Model with Module Database

Location and Resource Search for: Name

Name	I <sub>m</sub>	V <sub>m</sub>	I <sub>sc_ref</sub>	V <sub>oc_ref</sub>		
SunPower SPR-X20-327-BLK	5.71	57.3	1.631	96	6.09	67.6

System Advisor Model Help

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

## Module

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

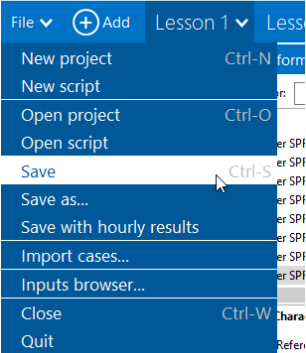
You can choose from five different module performance models:

- [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

Heat transfer dimensions Module Dimensions Columns of modules in array 10

Mounting structure orientation Structures do not impede flow underneath module Temperature behind the module 20 °C

Module width 1 m



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.

**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**

**Save as...**

**Save with hourly results**

**Import cases...**

**Inputs browser...**

**Close**

**Quit**

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

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