

# Recent and Planned Improvements to the System Advisor Model (SAM)

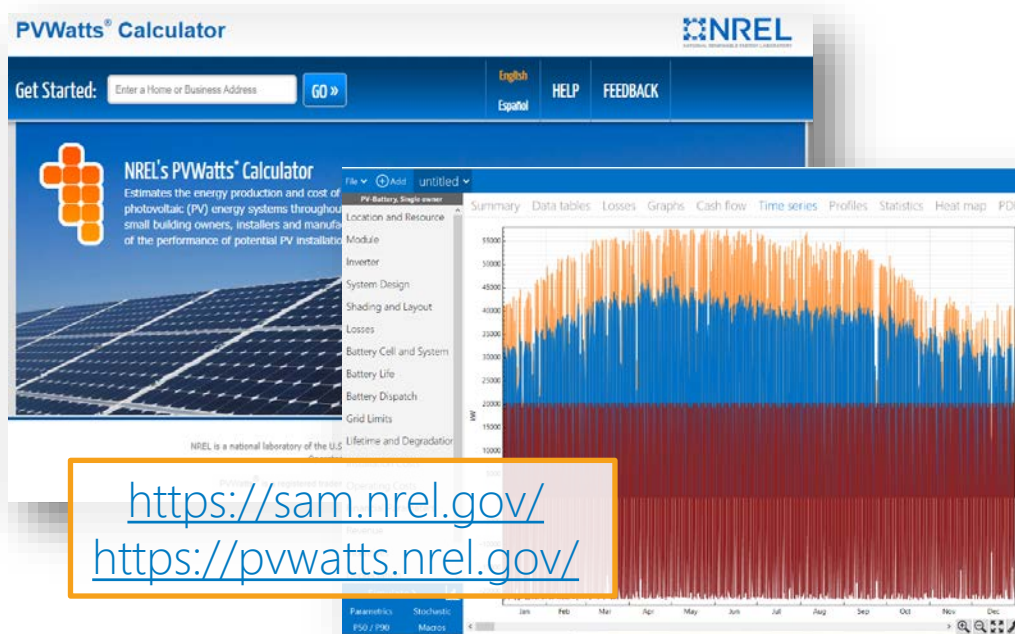
Brian Mirletz

2023 European PV Performance Modeling  
Workshop

November 2023

# System Advisor Model (SAM) & PVWatts

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

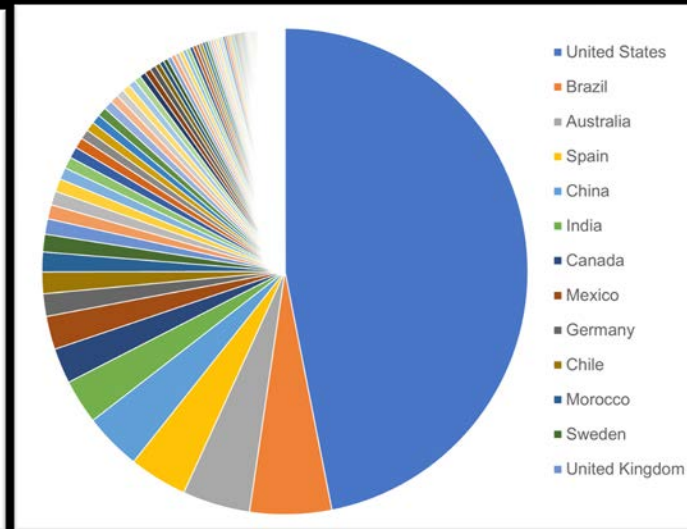
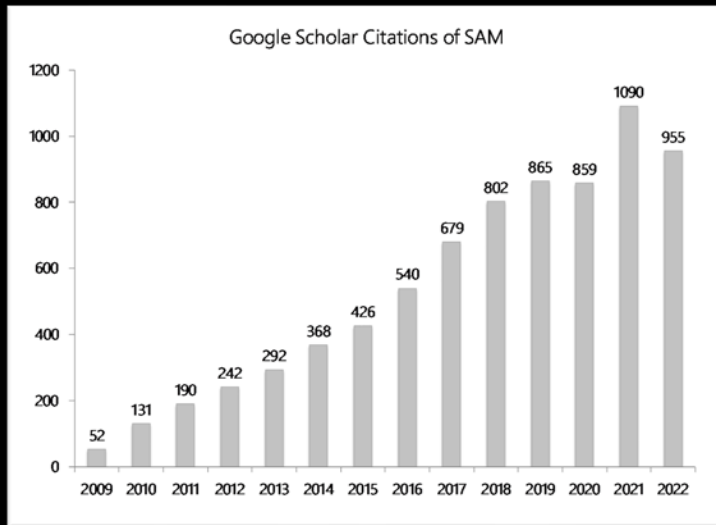


- ✓ Desktop application
- ✓ PVWatts web tool & API
- ✓ Software development kit
- ✓ PySAM Python package
- ✓ Open source code
- ✓ Extensive documentation
- ✓ User support

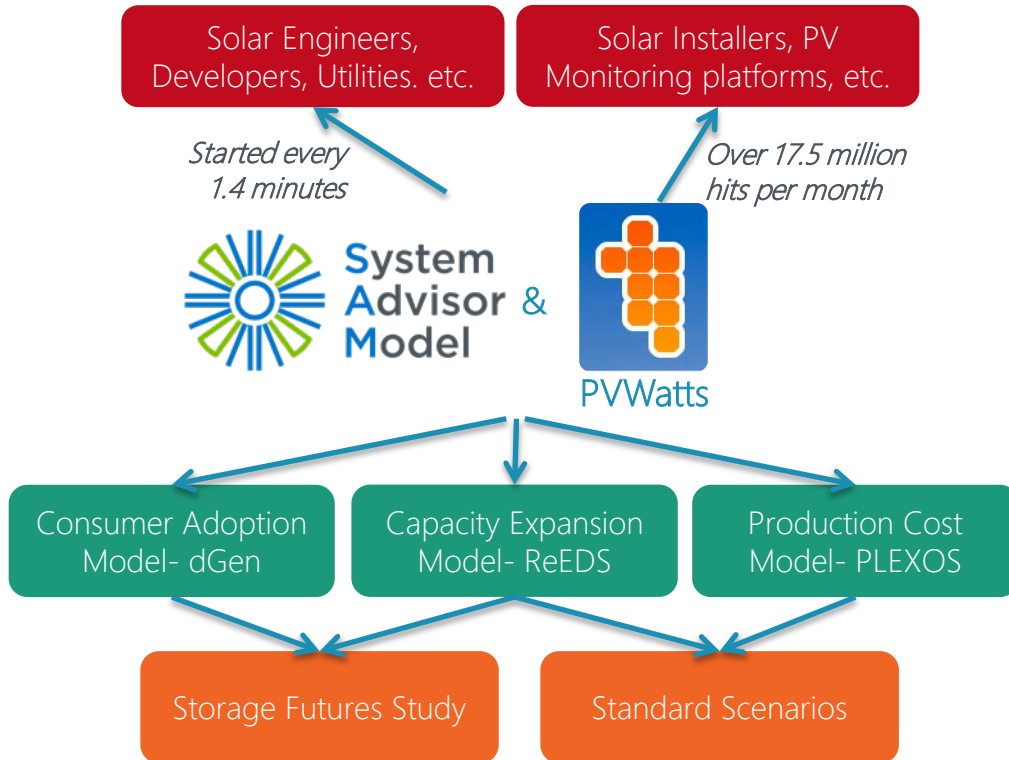
# SAM Users

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



# How SAM Fits in at NREL and Externally

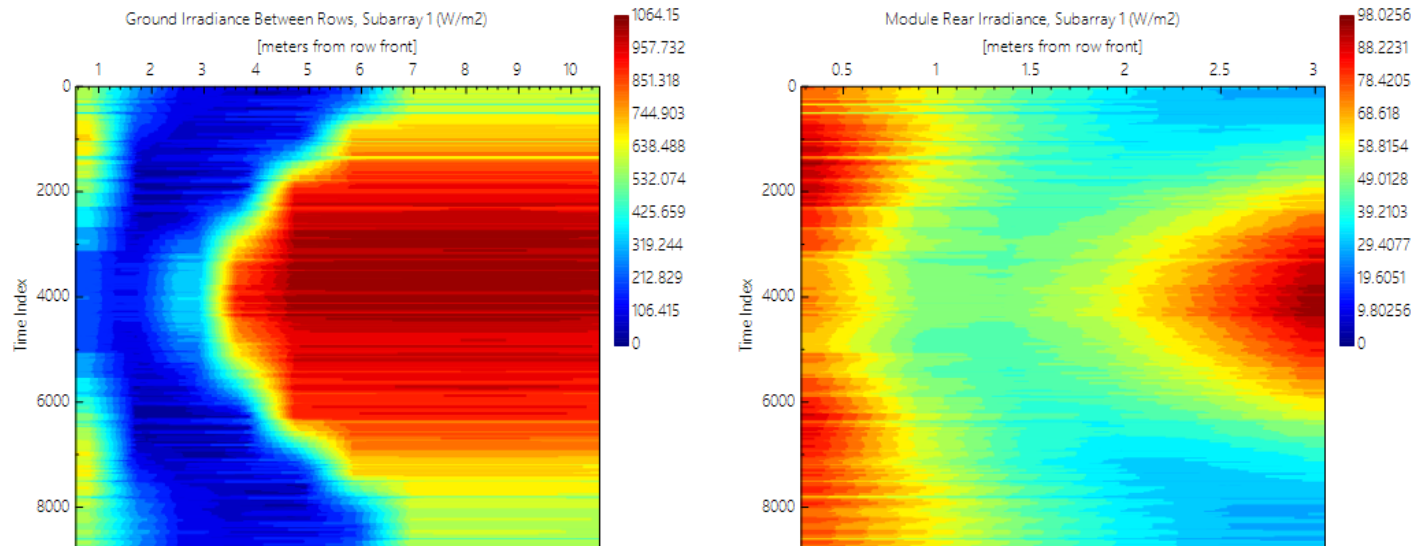


- ✓ Grid integration studies
- ✓ Renewable energy futures
- ✓ LCOE of breakthrough technologies
- ✓ Policy and utility rate design
- ✓ Technical potential studies
- ✓ Commercial applications (e.g. Southern Company, AEP, Sunrun)

Available in 2022.11.21

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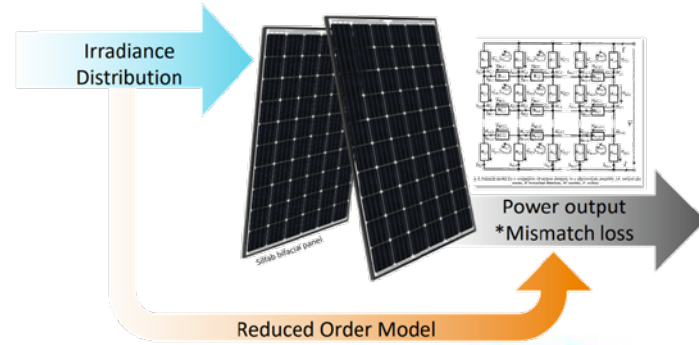
# Spatial Albedo and Ground Irradiance Calcs



- SAM allows entry of monthly spatial albedo values by row
- Values incorporated into ground irradiance and rear side irradiance.
- Talk at 2023 PVSC on its use with agrivoltaics:

# Bifacial Model Improvements

- Bifacial electrical mismatch
- Shading from racking structures
- Bifacial rear soiling
- Edge effects







## NREL's PVWatts<sup>®</sup> Calculator

Estimates 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.



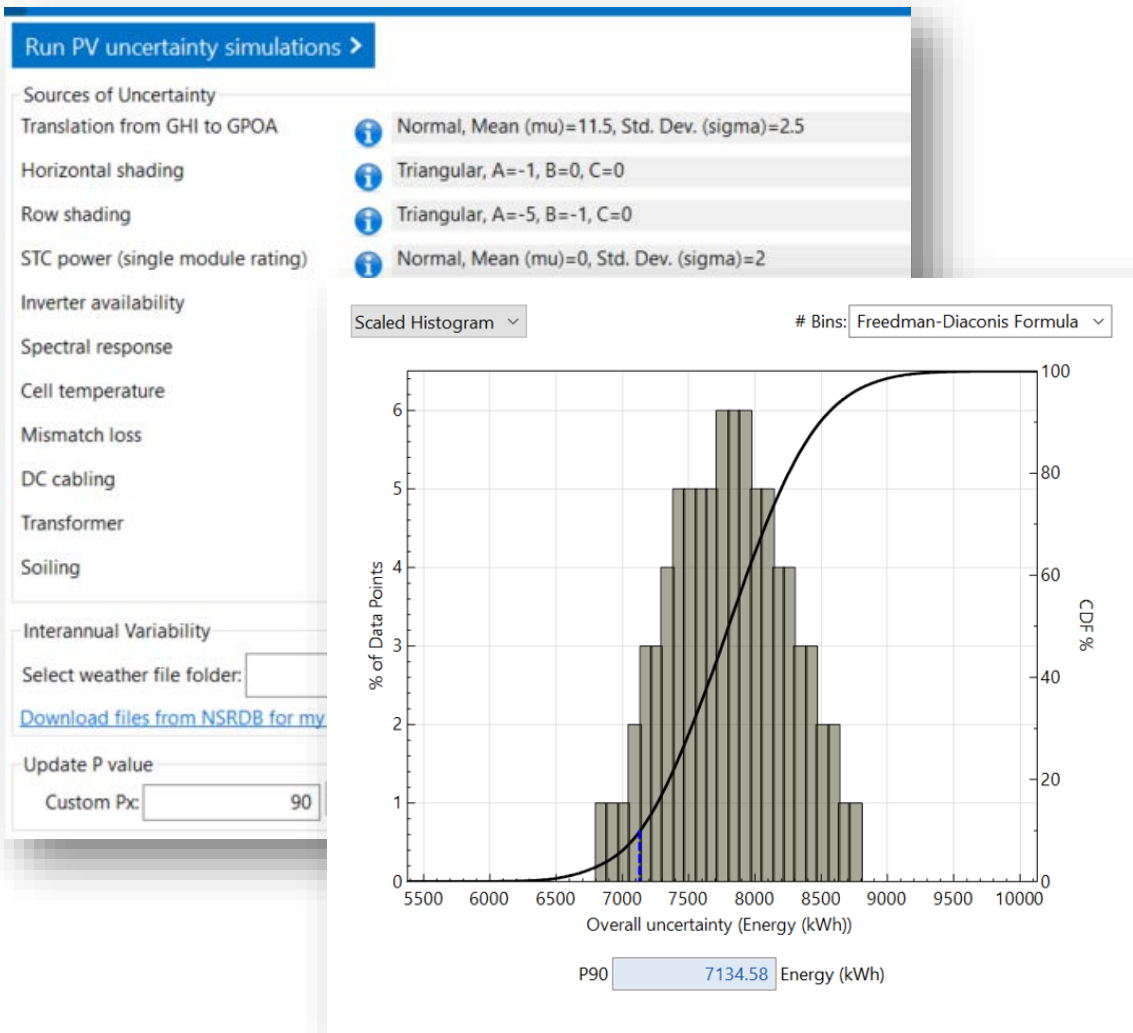
## PVWattsV8

- Available in the SAM desktop application, PySAM, the PVWatts website, and as an API
- Now uses same module, thermal, & inverter models as detailed PV model
- Bifacials, snow, wind stow, monthly soiling
- TMY Weather Data available for Ukraine, full Africa and Europe data coming in 2024



# PV Uncertainty Model- in Collaboration with Sandia

Implemented functionality to combine specifying multiple weather years (interannual uncertainty) with annual uncertainty factors for calculation of joint probability of exceedance (P90 etc.)



# Features coming in the next release Available now in a public Beta version

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## SAM Downloads

The current version of SAM is SAM 2022.11.21 Revision 3, SSC 280. Use the Download buttons below to download the current version for Windows, Mac, or Linux.

SAM 2023.10.31 Beta is available for testing!

<https://sam.nrel.gov/download.html>

# Hybrid Simulations (PV+Wind+Battery)

- Includes the following technology configurations:
  - Wind + PVWatts + Battery
  - Wind + PVWatts + Fuel Cell + Battery
  - Wind + Detailed PV + Battery
  - Generic System + Wind + PVWatts + Fuel Cell + Battery

SAM (Open Source) 2023.10.6

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

▼ Hybrid	▼ Power Purchase Agreement
PVWatts Wind Battery Hybrid	Single Owner
PVWatts Wind Fuel Cell Battery Hybrid	▼ Distributed
Photovoltaic Wind Battery Hybrid	Third Party - Host / Developer
Generic PVWatts Wi...ll Battery Hybrid	
Wind	
Generic System	
> Photovoltaic	
Geothermal	
> Energy Storage	
> Concentrating Solar Power	
> Industrial Process Heat	
> Marine Energy	
Fuel Cell - PV - Battery	
Solar Water Heating	
Biomass Combustion	



Features co-funded by Southern Company and DOE SETO

# Dispatch for Self Consumption

## Behind-the-meter (BTM) Storage Dispatch Options

The storage dispatch options determine how and when the battery charges and discharges. Choose an option below and then set dispatch parameters as appropriate.

- Peak shaving
  - Input grid power targets
  - Input battery power targets
  - Manual dispatch
  - Retail rate dispatch
  - Self-consumption
- Battery can charge from grid
  - Battery can charge from system
  - Battery can charge from clipped system power
  - Battery can discharge to grid
  - Charge from system only when system output exceeds load
  - Discharge battery only when load exceeds system output

Battery is AC-connected. Charging from clipped power is only available for DC-connected batteries. See input under Power Converters on Battery Cell and System page. See input under Power Converters on Battery Cell and System page.

## Self-consumption

The self-consumption dispatch option tries to minimize power imported from or exported to the grid. This is also referred to as 24/7 carbon-free energy. There are no additional inputs required for this dispatch option.

Features co-funded by Southern Company and DOE SETO



- Self consumption is a new dispatch method for behind-the-meter systems, also called 24/7 carbon-free energy.
- Can be used for generation co-located with load or a PPA with transmission.
- Enables additional outputs with the number of steps when the electric load is fully met by the system.

ries Heat map Notices

Single Values X	
Battery number of timesteps electric load met by system (lifetime)	219000
Battery number of timesteps electric load met by system (year 1)	8760
Battery percent of timesteps electric load met by system (lifetime)	100
Battery percent of timesteps electric load met by system (year 1)	100

# Sub-hourly Clipping Correction

- ✓ Beta includes method 3.4 MW from Allen, Hobbs, and Bolen 2022
- ✓ Planning to include Walker method in the future as well

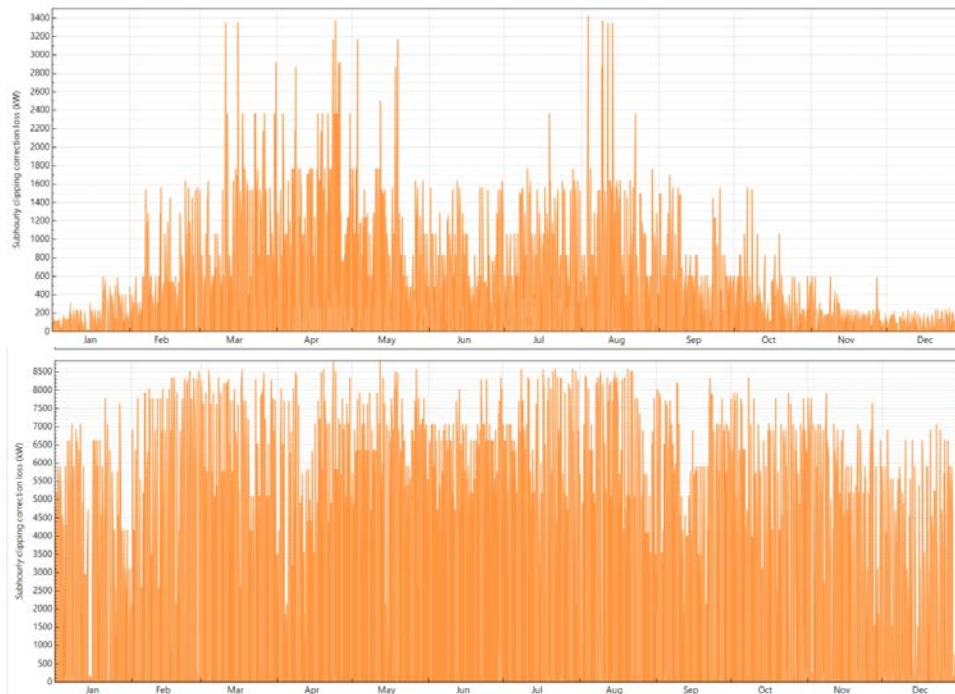


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8.5 MW

1.3 ILR

2.0 ILR

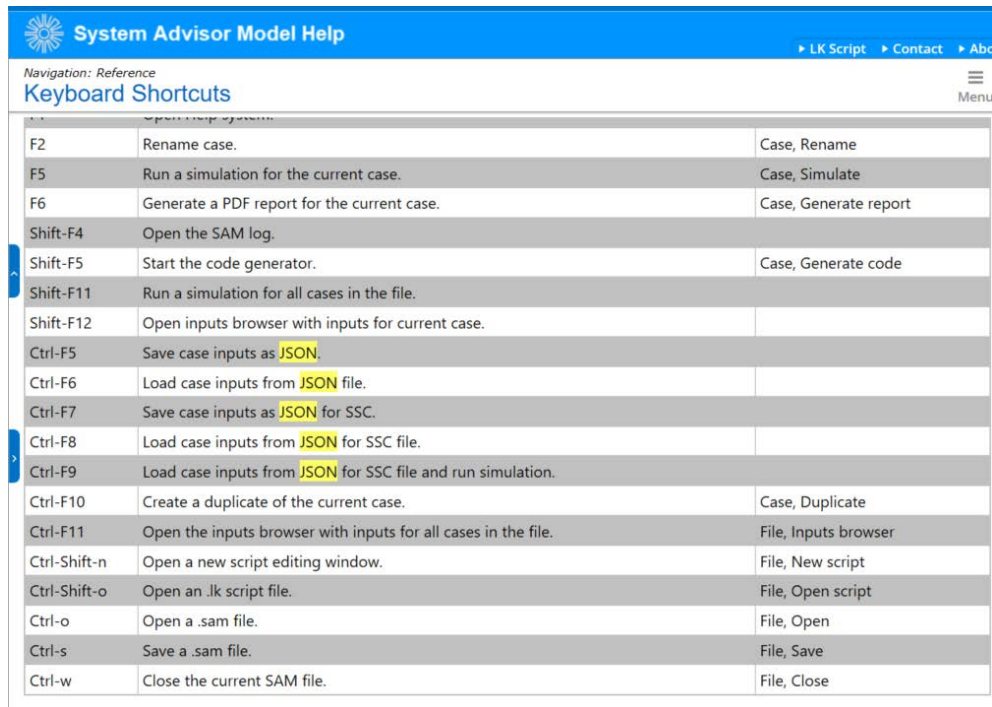


Allen, J. O., Hobbs, W. B., and Bolen, M., "Classification Method to Predict the Effect of Short-Term Inverter Saturation on PV Performance Modeling", PVPMC Workshop 2022, Salt Lake City, UT.

Walker, Andy, and Jal Desai. *Distribution Function Instead of Steady-State Assumption in Time-Series Simulation*. No. NREL/PO-7A40-83733. National Renewable Energy Lab.(NREL), Golden, CO (United States), 2022.

# Improved PySAM & JSON integration

- ✓ New keyboard shortcuts now support loading a case from JSON in addition to saving to JSON
- ✓ Useful for loading cases generated in PySAM or the SDK for a more detailed analysis or debugging



System Advisor Model Help		
Navigation: Reference		LK Script Contact Abo
Keyboard Shortcuts		Menu
F2	Rename case.	Case, Rename
F5	Run a simulation for the current case.	Case, Simulate
F6	Generate a PDF report for the current case.	Case, Generate report
Shift-F4	Open the SAM log.	
Shift-F5	Start the code generator.	Case, Generate code
Shift-F11	Run a simulation for all cases in the file.	
Shift-F12	Open inputs browser with inputs for current case.	
Ctrl-F5	Save case inputs as JSON.	
Ctrl-F6	Load case inputs from JSON file.	
Ctrl-F7	Save case inputs as JSON for SSC.	
Ctrl-F8	Load case inputs from JSON for SSC file.	
Ctrl-F9	Load case inputs from JSON for SSC file and run simulation.	
Ctrl-F10	Create a duplicate of the current case.	Case, Duplicate
Ctrl-F11	Open the inputs browser with inputs for all cases in the file.	File, Inputs browser
Ctrl-Shift-n	Open a new script editing window.	File, New script
Ctrl-Shift-o	Open an .lk script file.	File, Open script
Ctrl-o	Open a .sam file.	File, Open
Ctrl-s	Save a .sam file.	File, Save
Ctrl-w	Close the current SAM file.	File, Close



# Features for Digital Twins

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# Features for Digital Twin Development

- Available in PySAM/SDK
  - Detailed PV and PVWatts support sub-annual simulations
  - User-specified timeseries for measured module temperature input
  - (coming soon) User-specified timeseries tracker angle input
- Available in GUI as well
  - User-specified POA irradiance input

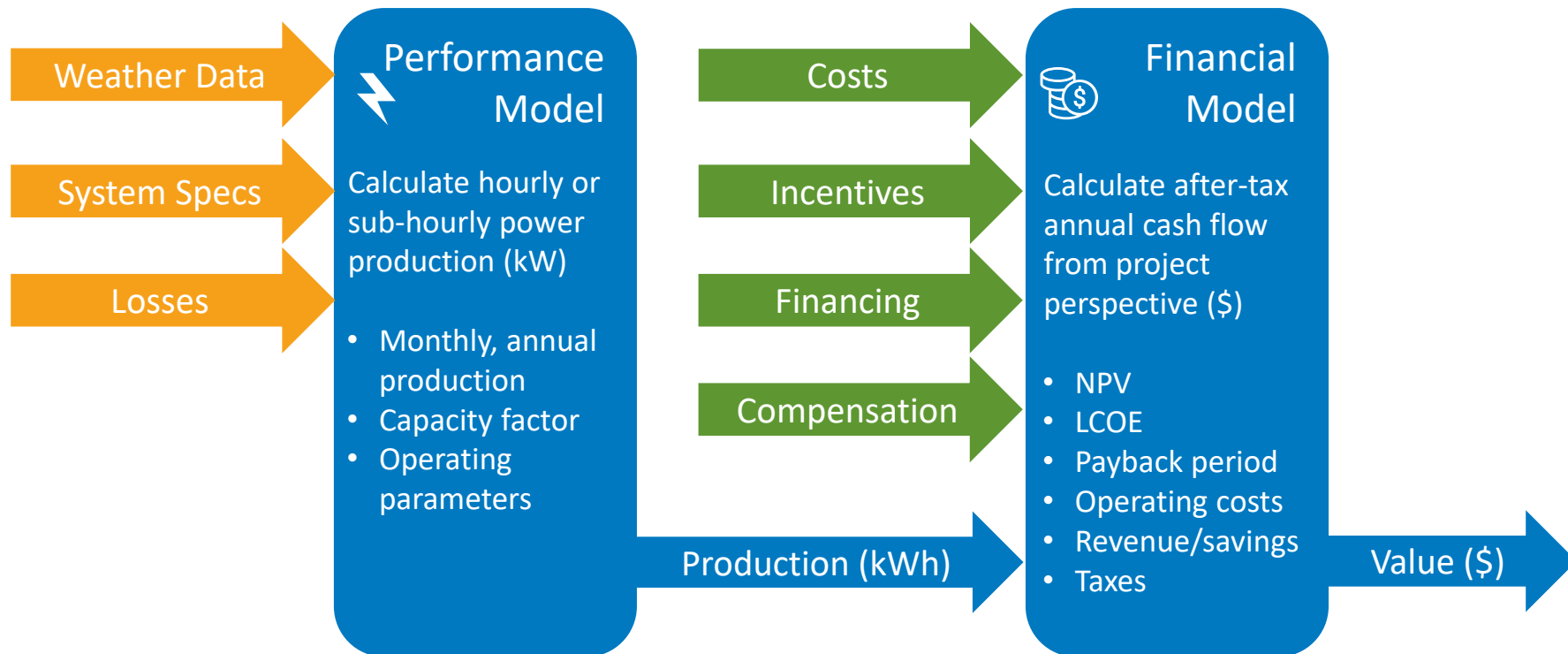
Public beta for testing:  
<https://sam.nrel.gov/download.html>

# Thank you! Questions?

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Paul Gilman – user support and documentation (subcontractor)  
Ty Neises – concentrating solar power models  
Matt Boyd – concentrating solar power models

# Model Structure





## Technologies

- Photovoltaic
- Energy storage
  - Electric battery
  - Electric thermal
  - Pumped thermal
- 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

## 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**