

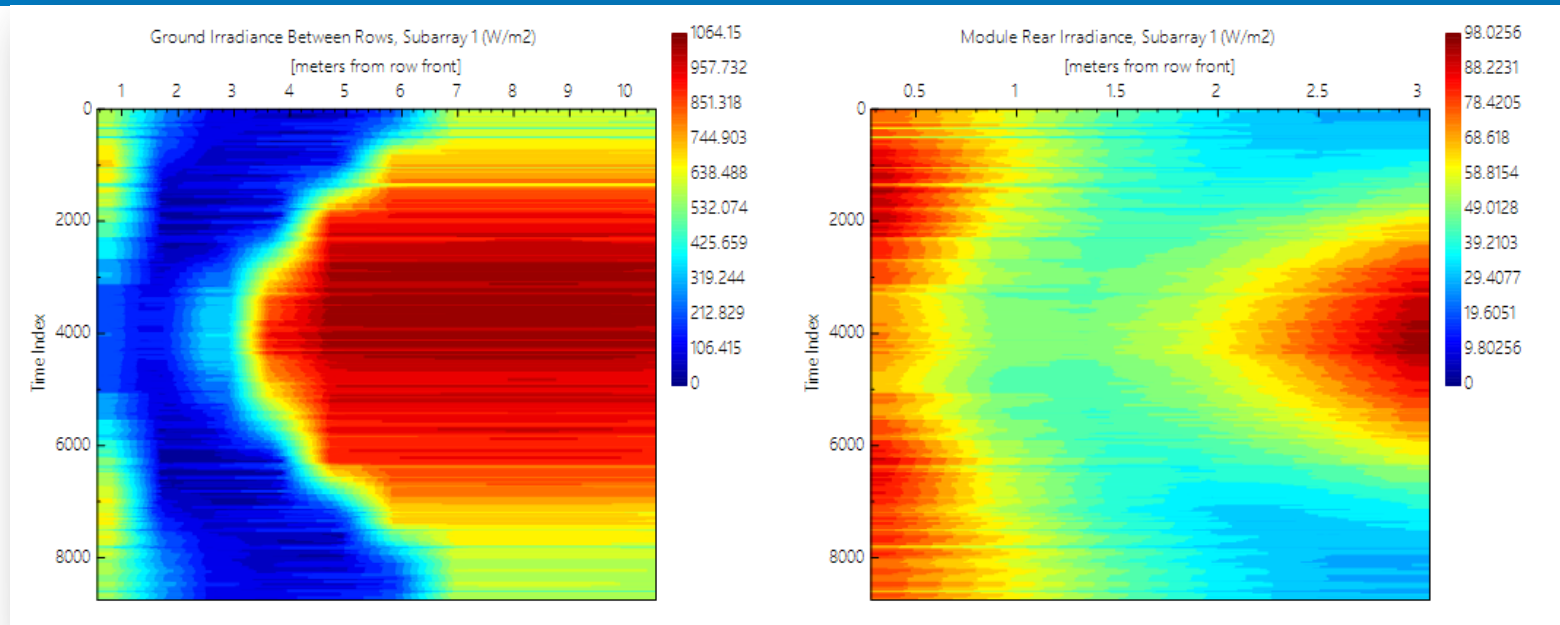


Recent and Planned Improvements to the System Advisor Model (SAM)

Nate Blair
2023 PV Performance Modeling Workshop
May 2023

Photo by Dennis Schroeder, NREL 55200

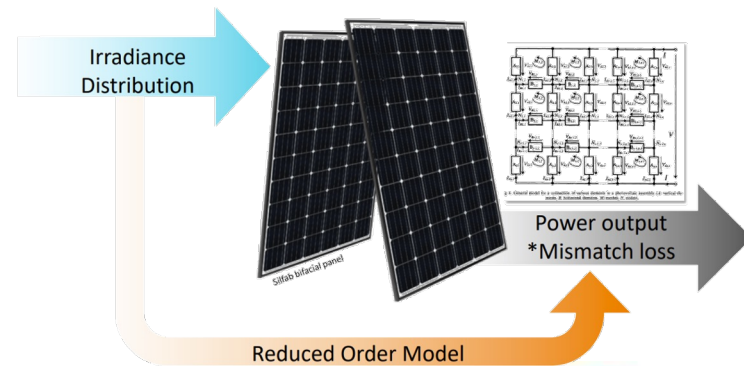
Spatial Albedo and Ground Irradiance Calcs



- SAM allows entry of monthly spatial albedo values by row
- Values incorporated into ground irradiance and rear side irradiance.
- Upcoming talk at PVSC on it's use with agrivoltaics: Ovaite, Boyd et al "Validating view-factor and spatial albedo models for Bifacial and AgriPV modeling"

Bifacial Model Improvements

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





NREL's PVWatts[®] 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
- API speed increase coming soon

- Now uses same module, thermal, & inverter models as detailed PV model
- Bifacials, snow, wind stow, monthly soiling
- Expanded global weather data availability

PySAM Improvements

- PySAM updated with the newest utility rate calculations
Don't forget: check out the workshop tomorrow!



- Organized into individual functions
- Fully customizable in Python
- Focused primarily on PV models
- Implemented in Python
- May be better suited for PV research applications

Both!

- Robust implementations of PV modeling algorithms
- End-to-end PV model with limited model choices available in each tool
 - ModelChain in pvlib
 - pvsamv1 in PySAM
- Open-source
- Example scripts to help you get started
- Available via pip install
- Shared module and inverter libraries
 - PySAM for module coefficients
 - pvlib for inverter coefficients
- Great for use in your own Python project!

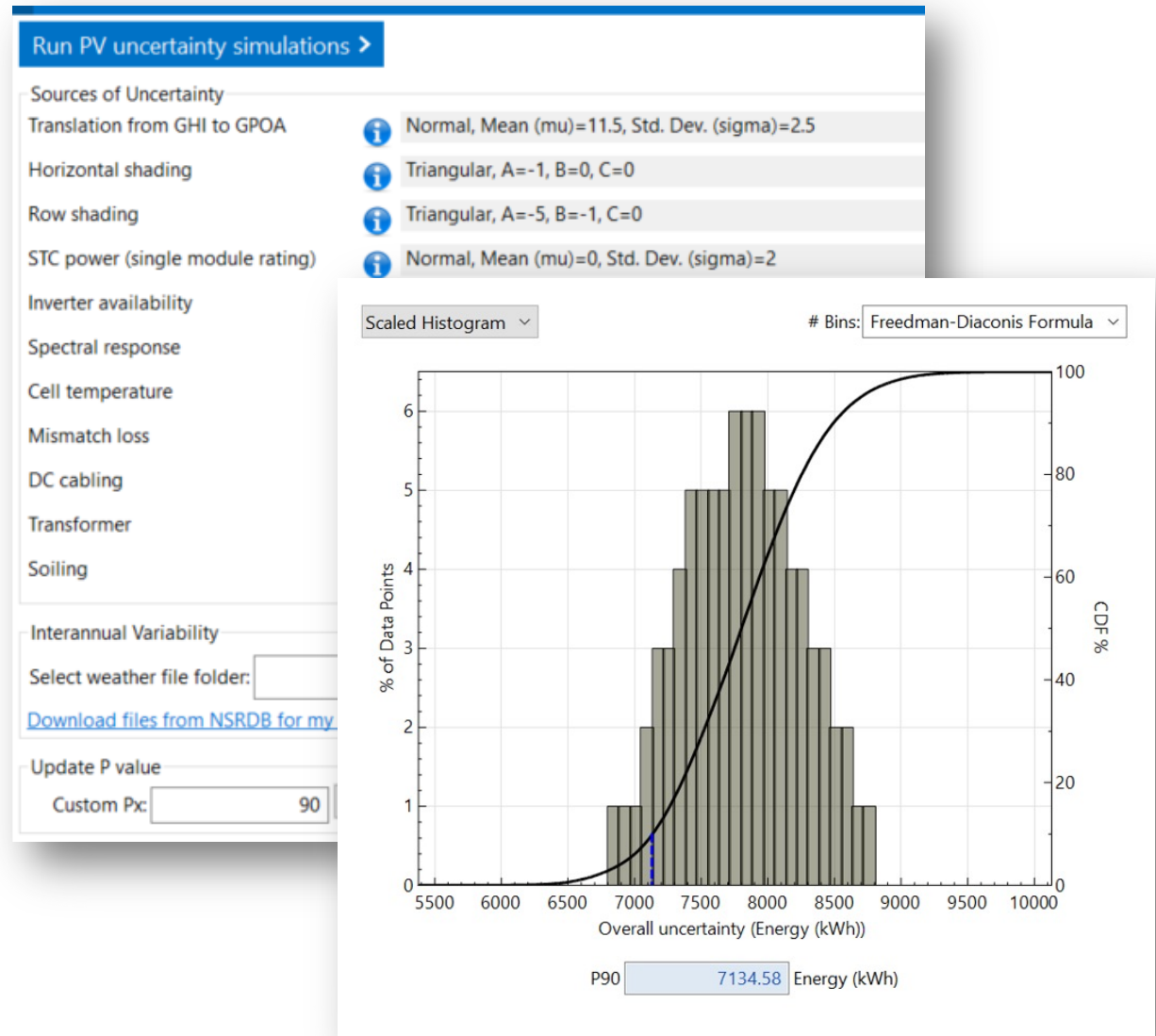


- Primarily organized into functions for complete resource-to-energy system simulation
 - Some sub-functions available (module, inverter, irradiance)
- Minimal coding required to perform a PV simulation
- Export system setups to/from the SAM desktop tool
- Implemented in C++ and accessed as a Python package
- Includes financial models
- May be better suited for batch analysis or PVsyst-type simulations

PV Uncertainty Model- in Collaboration with Sandia

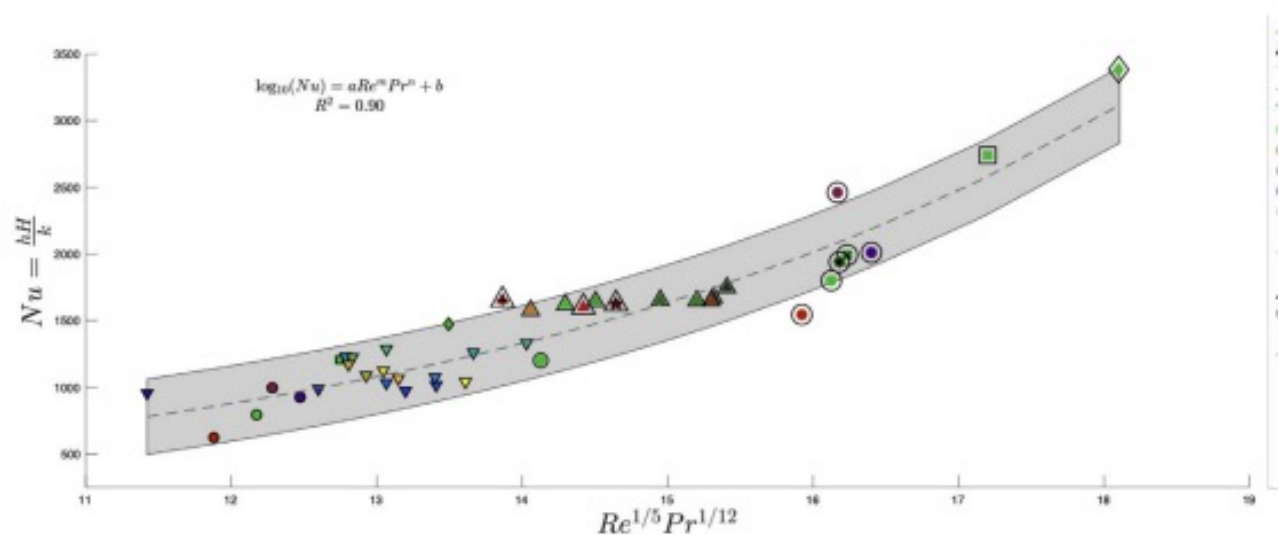
Implemented functionality to combine specifying multiple weather years (interannual uncertainty) with annual uncertainty factors for calculation of joint probability of exceedance (P90 etc.)

Check out Matt Prilliman's poster!



Input Your Own Module Temp (SDK only)

- ✓ Input array of module temperatures rather than modeled values
- ✓ Good for custom thermal models
- ✓ Stanislawski et. al convective heat transfer correlation also in SDK



Sarah E. Smith, Brooke J. Stanislawski, Byron Kasey Eng, Naseem Ali, Timothy J Silverman, Marc Calaf, Raúl Bayoán Cal; Viewing convection as a solar farm phenomenon broadens modern power predictions for solar photovoltaics. *Journal of Renewable and Sustainable Energy* 1 November 2022; 14 (6): 063502. <https://doi.org/10.1063/5.0105649>

Battery Technology Models



Image credit: <https://www.teslarati.com/tesla-powerwall-demand-after-australian-blackouts/>

- ✓ DC or AC coupled PV + Battery
- ✓ Standalone Electric Battery
- ✓ Standalone Electric Thermal Energy Storage
- ✓ NEW: Pumped Thermal Energy Storage

Financial Model Updates

- **ITC over multiple years – relevant particularly for low income / low tax entities**
- **Analyze tradeoffs between taking ITC and PTC for a solar (or any) project**

Edit Data Table by Column (Single)	
	%/year
1	5
2	5
3	5
4	5
5	5
6	5
7	0
8	0
9	0
10	0
11	0

Coming Soon!

Hybrid Simulations (PV+Wind+Battery)

- Develop Graphical User Interface (GUI) inputs:
 - The GUI will use existing technology pages for each component with the existing cost page for each component
 - Implement new shared O&M costs page and shared costs inputs page
 - Create or adapt a single combined financial model with usual financial model inputs
- Include the following technology configurations:
 - Wind+PVWatts+Battery
 - Wind+PVWatts+Fuel Cell+Battery
 - Wind+Detailed PV+Battery
 - Generic System+Wind+PVWatts+Fuel Cell+Battery
- No changes to SAM Simulation Core (SSC) except input/output naming



Dispatch for Instantaneous Carbon Zero

Develop instantaneous Net Zero Dispatch for AC-connected batteries

Attributes to include:

- Implement a new dispatch algorithm
- Make available this dispatch option in BTM financial models
- Implement additional outputs to determine percentage of load unmet by a system
- Develop a preset parametric template for sizing the battery or Parametric/macro setup for sizing battery



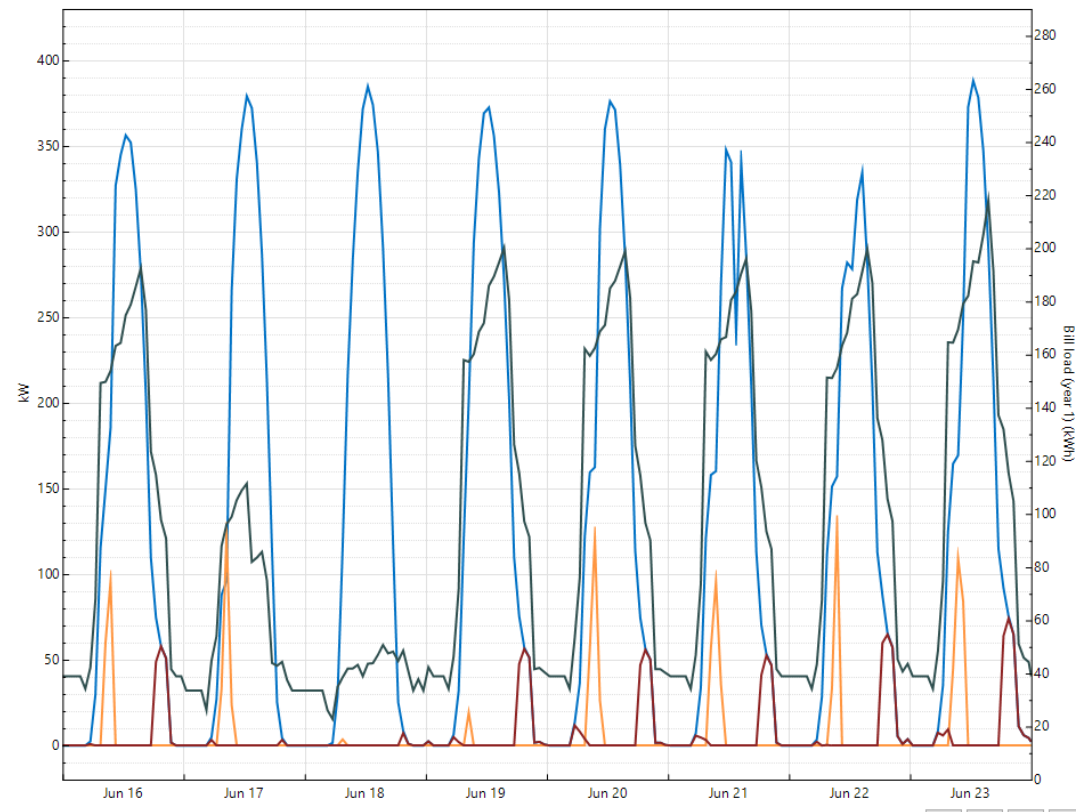
Sub-hourly Clipping Correction



- ✓ Southern Co. methodology presented at previous PVPMC
- ✓ In SAM, an input matrix of clipping is applied to an hourly timeseries simulation. The new feature will include a default clipping matrix and a way to modify that matrix
- ✓ Include NREL methodology (Andy Walker et al) as an alternative method

PV + Battery + Load + Utility Rate Visualization

- Many SAM users focused on behind the meter hybrid systems
- Examining the hourly interplay between PV, battery, load and utility rate structure is difficult
- Plan to create views of utility rates by hour
- Standardized graphics will speed analysis.



Future Directions

Directions We Hope to Pursue

- Tracker model improvements
 - Wind stow, hardware limitations, diffuse light capture
- Agrivoltaics
 - Proper accounting for crop revenue, thermal impacts of crops
- Battery thermal management modeling
- Off-MPPT module temperature impacts during curtailment/clipping
- Building-integrated PV
- PV/CSP hybrids
- Continued growth and support of key DOE analyses

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 Mirletz – 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

Non-PV Updates

Marine Energy

technology models for wave and tidal power

- Now available with batteries!

Geothermal Energy

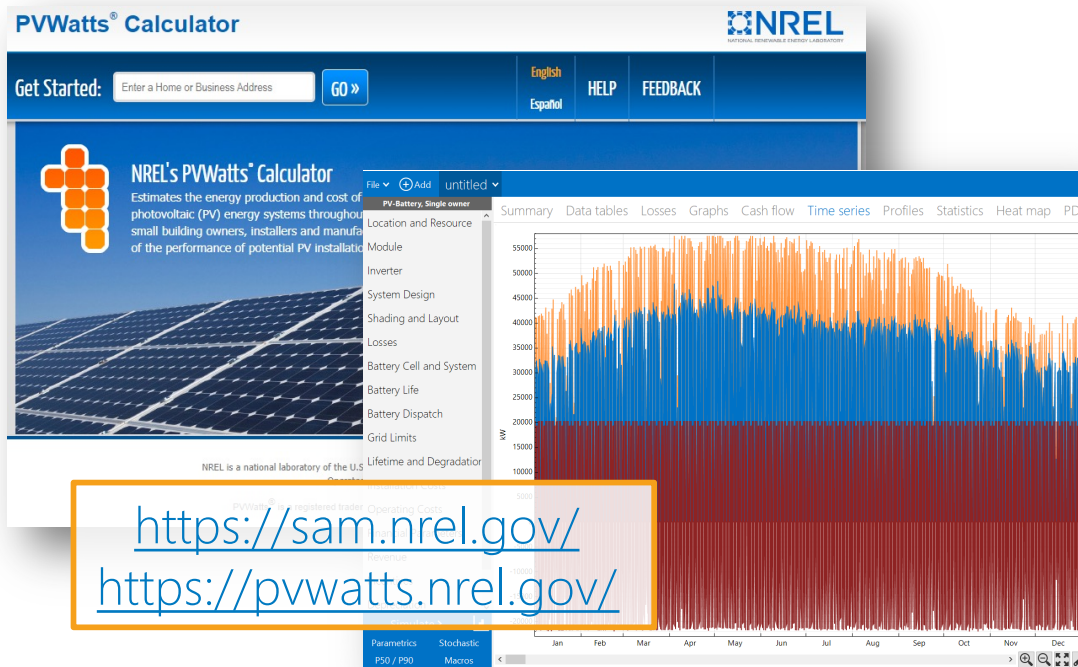
- New investment in models provide updates and re-validated against GETEM (Spreadsheet tool)



Image credit: <https://www.nytimes.com/2012/10/02/business/energy-environment/marine-energy-projects-pick-up-momentum.html>

System Advisor Model (SAM) & PVWatts

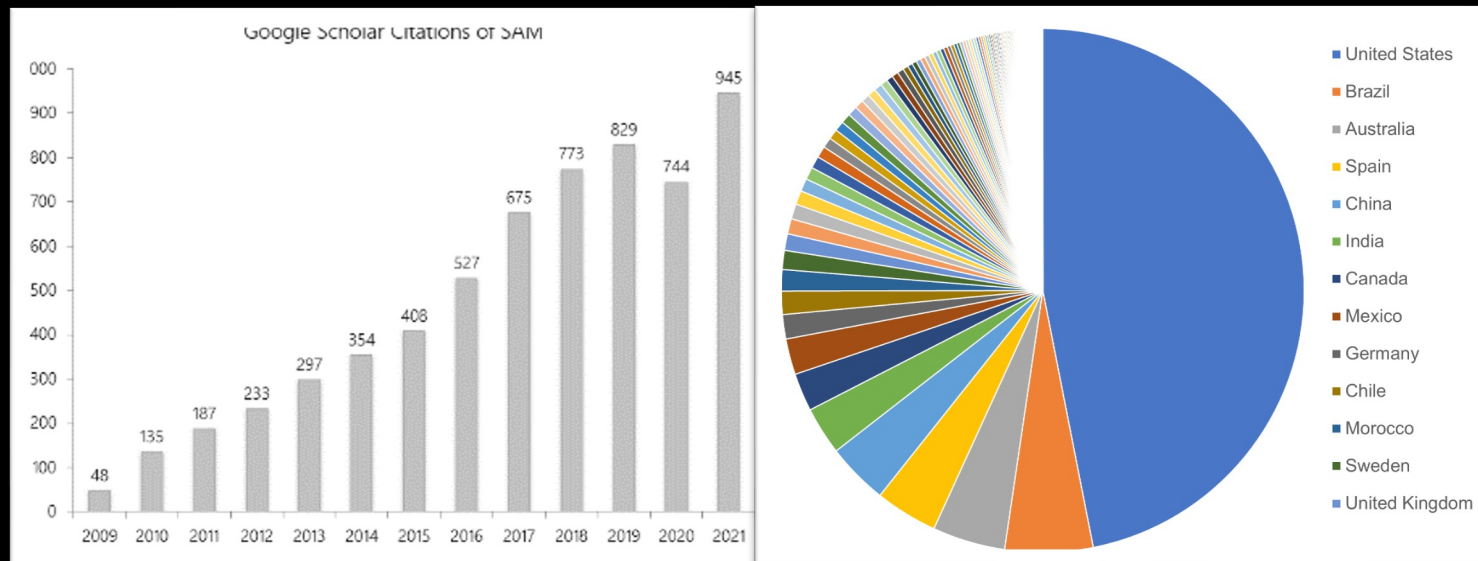
Free software that enable detailed performance and financial analysis for renewable energy systems



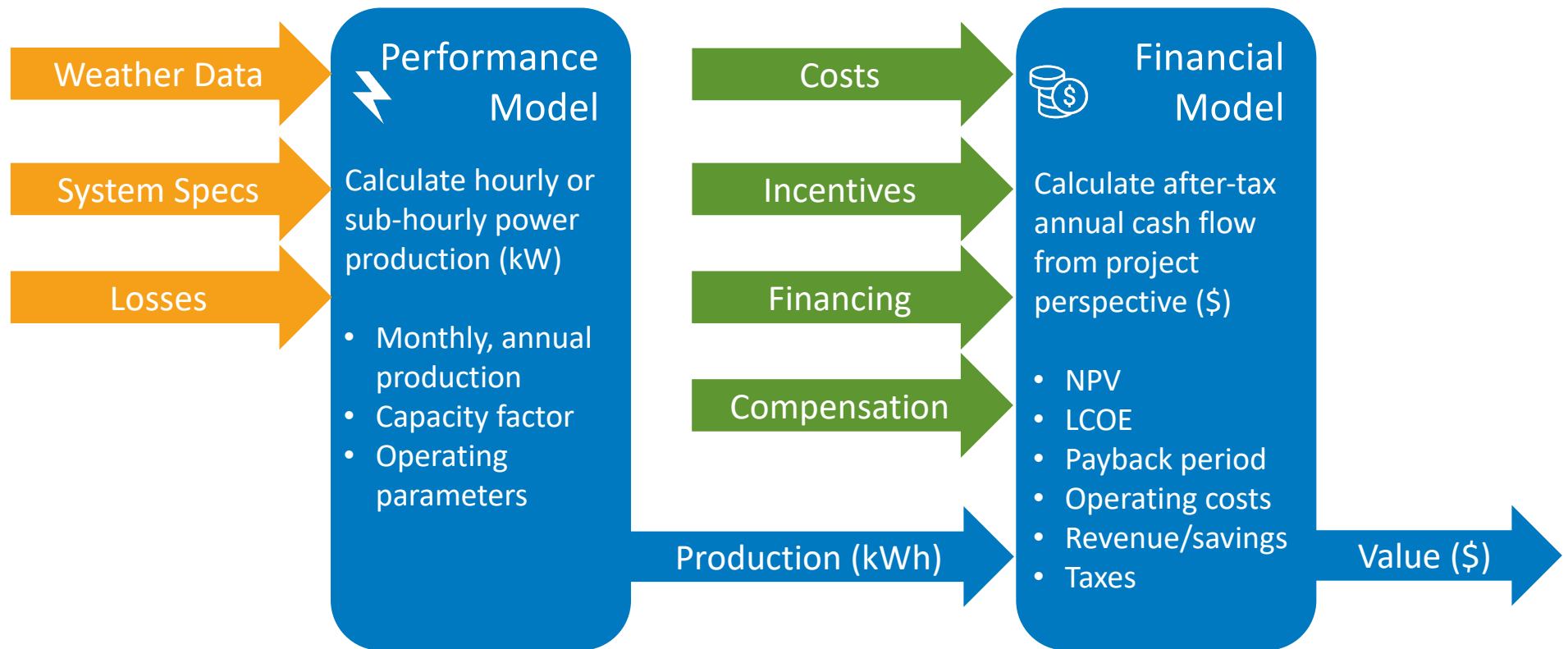
- ✓ Desktop application
- ✓ PVWatts web tool & API
- ✓ Software development kit
- ✓ PySAM Python package
- ✓ Open source code
- ✓ Extensive documentation
- ✓ User support

SAM Users

SAM is started **once every 1.4 minutes**
PVWatts receives over **17.5 million hits per month**
Over **169,000** users in 190+ countries
120+ webinars with **over 280,000 views**
Users include Sunrun, Enphase, AEP, Southern Company, EPRI, & more



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