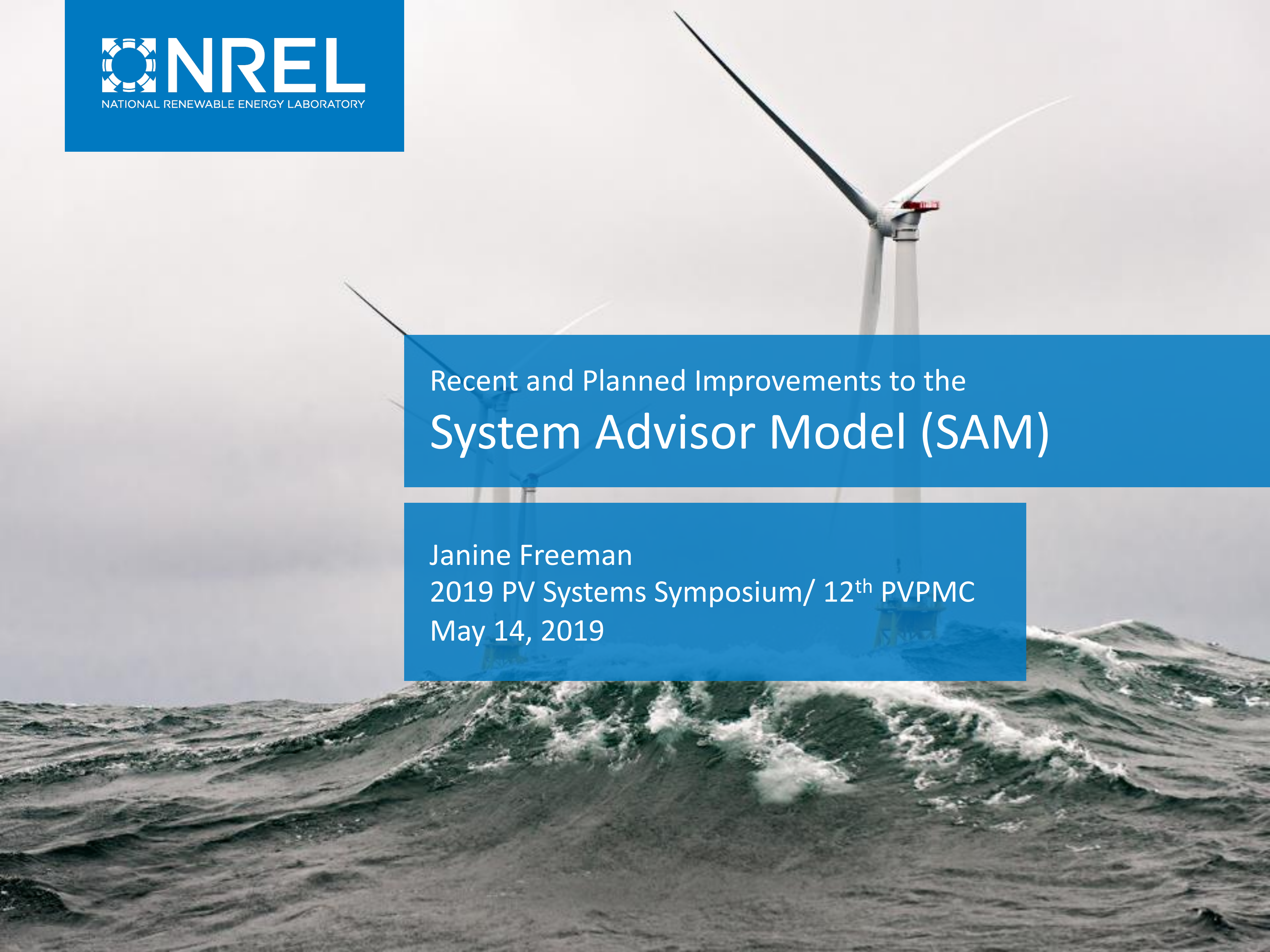


NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Recent and Planned Improvements to the

System Advisor Model (SAM)

Janine Freeman

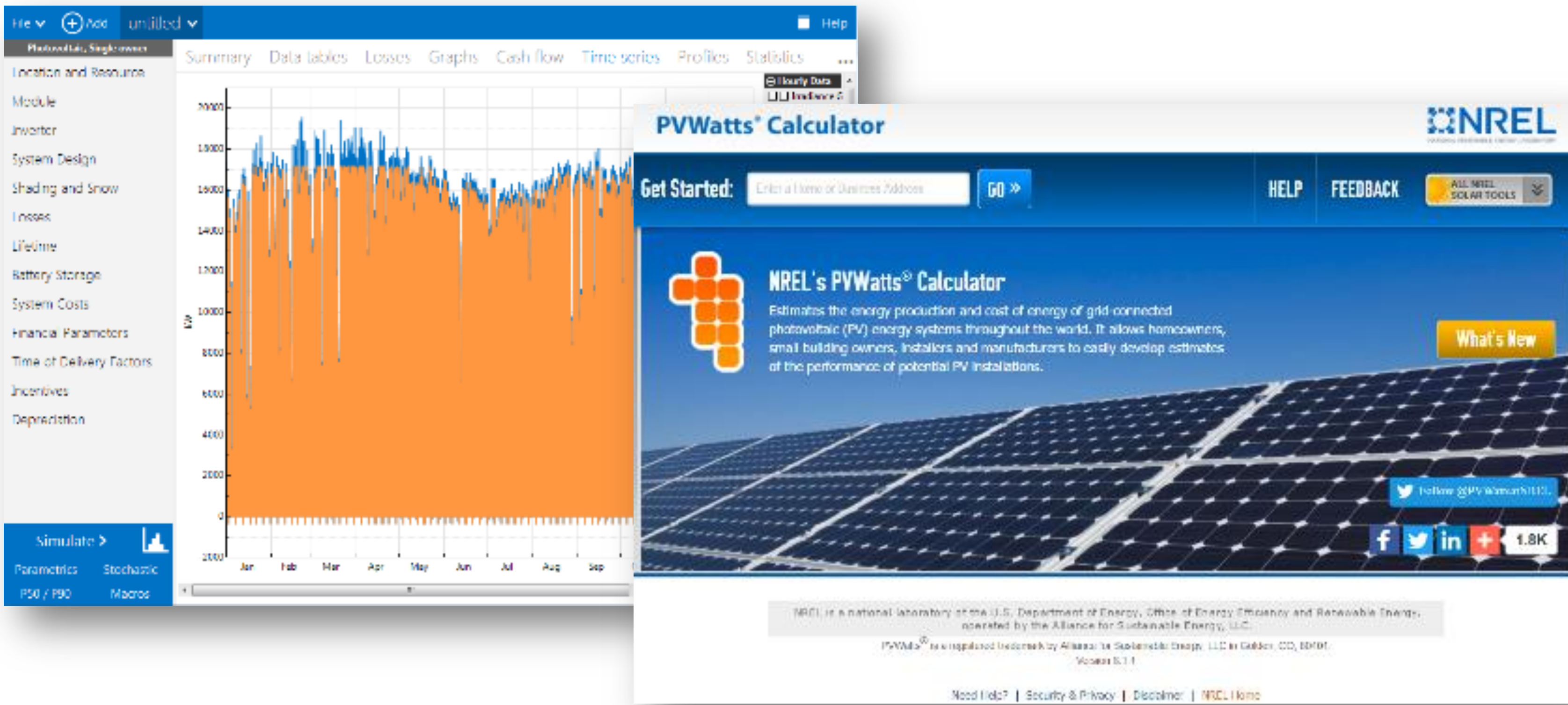
2019 PV Systems Symposium/ 12th PVPMC

May 14, 2019

System Advisor Model (SAM) & PVWatts

System Advisor Model

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



http://sam.nrel.gov/download
https://pvwatts.nrel.gov

Multiple ways to access SAM models

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

SAM Users

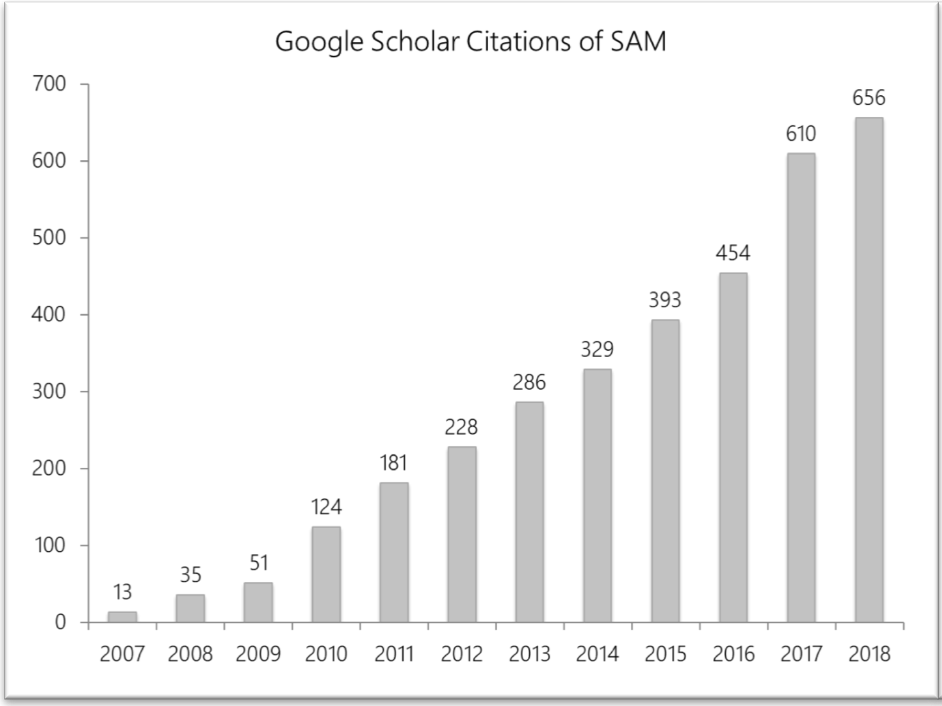
SAM is started **once every 2 minutes**

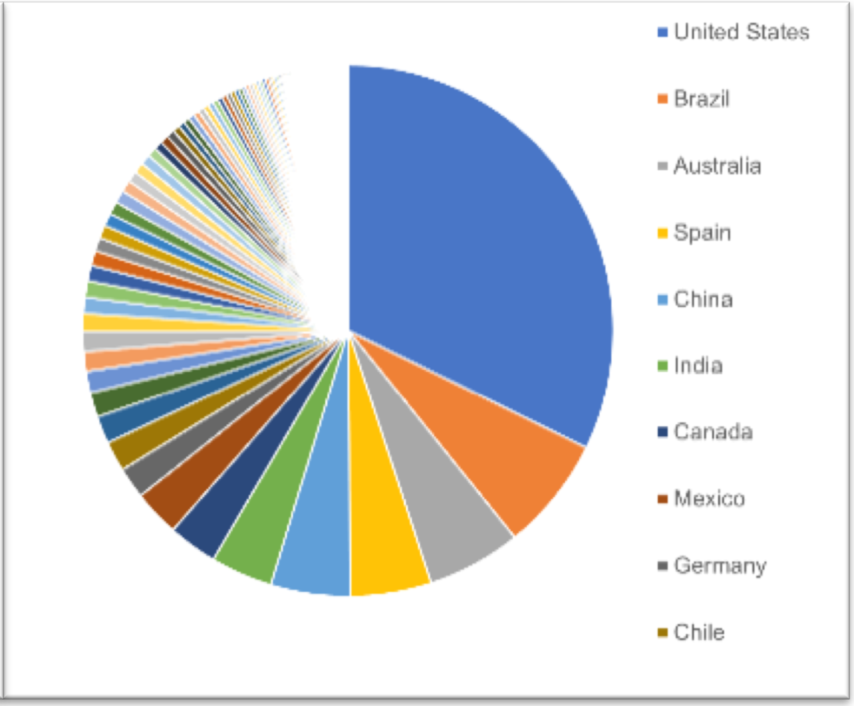
PVWatts receives over **2 million hits per month**

Over **100,000** users in 190+ countries

90+ webinars with **over 100,000 views**

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





Recent Highlights

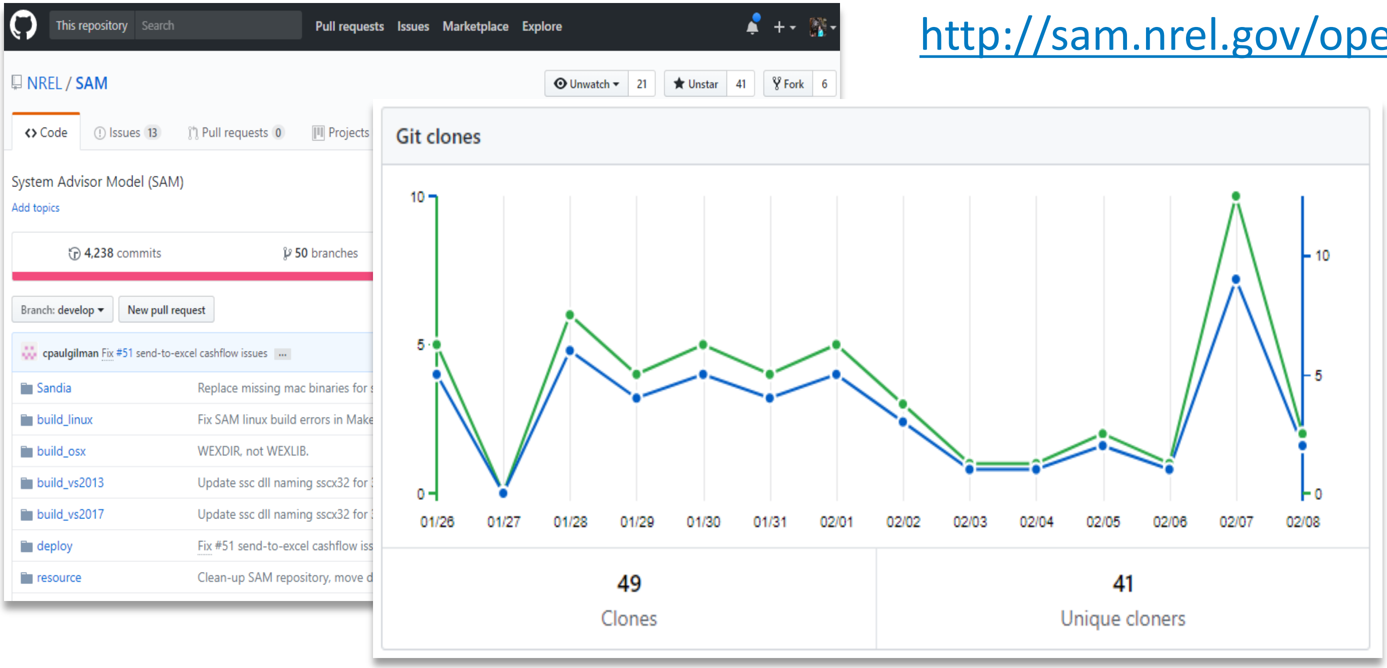
Open Source Code Contributions

Mermoud-Lejeune module and inverter models added to SDK (Timo Richert, PVYield)

New condenser & cooling system for CSP power towers (Ana Dyreson, University of Wisconsin, Madison)

Bug fixes and new outputs (Casey Zak, Cypress Creek Renewables)

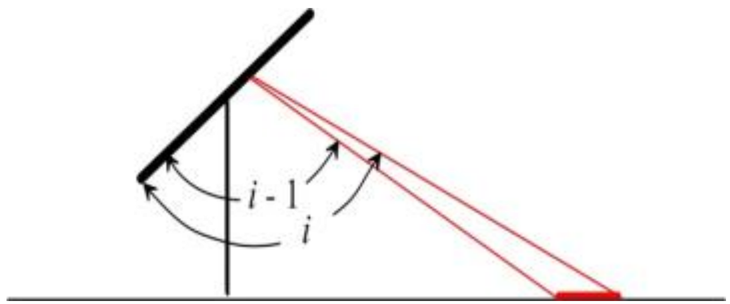
Join us for the SAM Developer's Conference this summer!



http://sam.nrel.gov/opensource

PV Bifacial Module Model

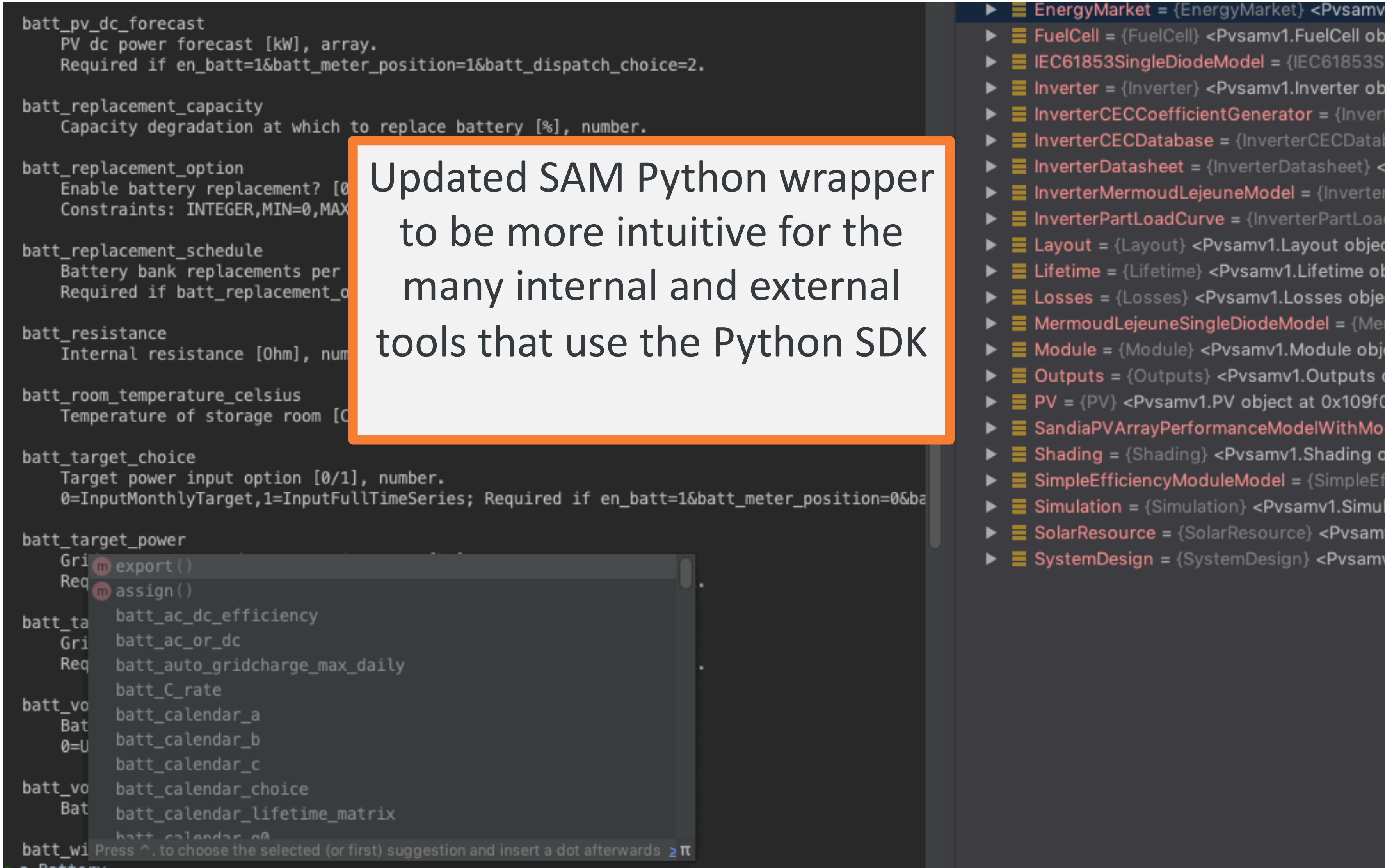
Implemented bifacial model developed by Marion, Deline, et al into main workflow of SAM



"A Practical Irradiance Model for Bifacial PV Modules", Marion et al, 44th IEEE PVSC, June 2017

Improved Python Wrapper

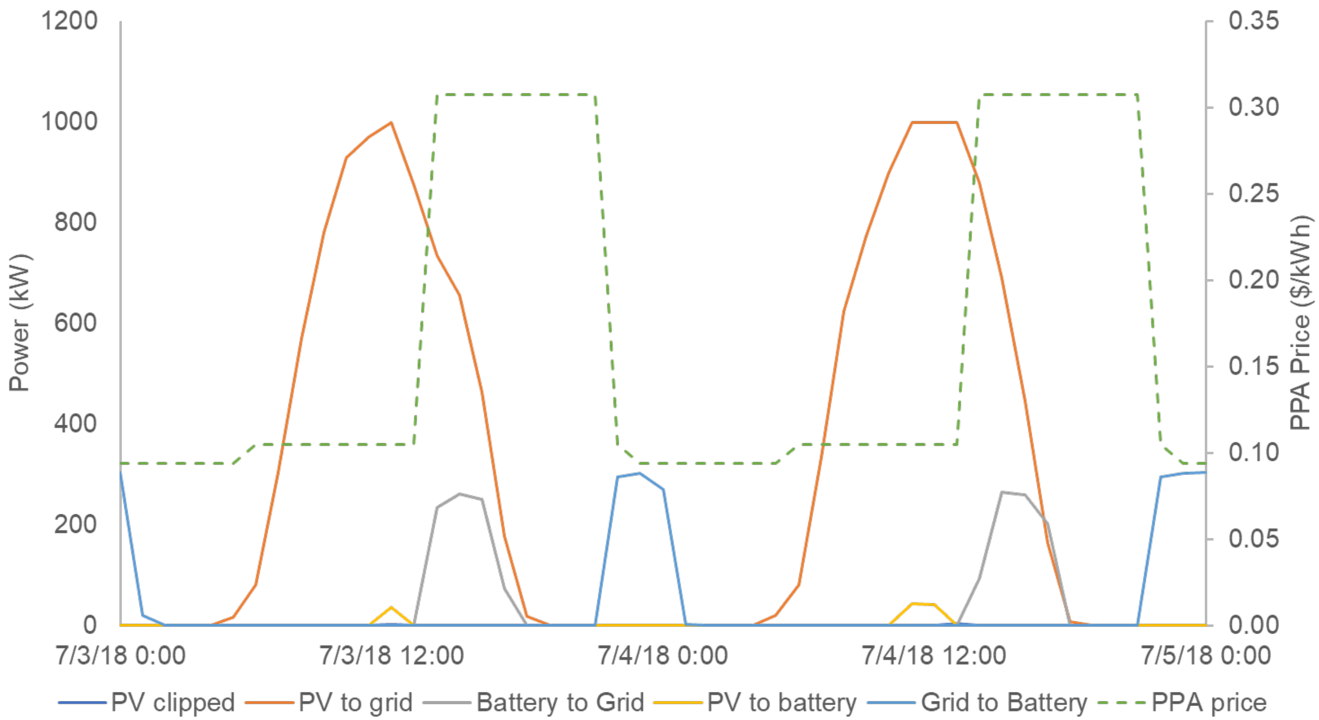
System Advisor Model



Updated SAM Python wrapper to be more intuitive for the many internal and external tools that use the Python SDK

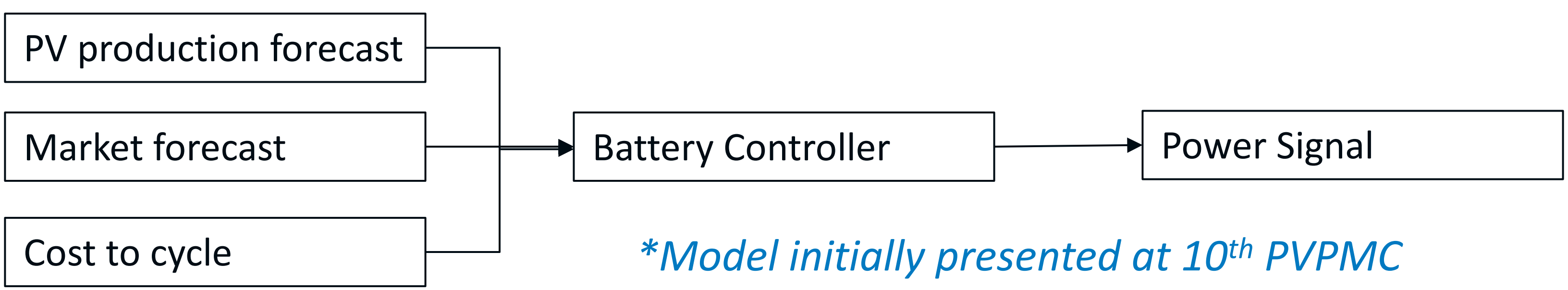
Battery Model Improvements

Fixed issues in the economic dispatch model for front-of-meter systems



Issues addressed:

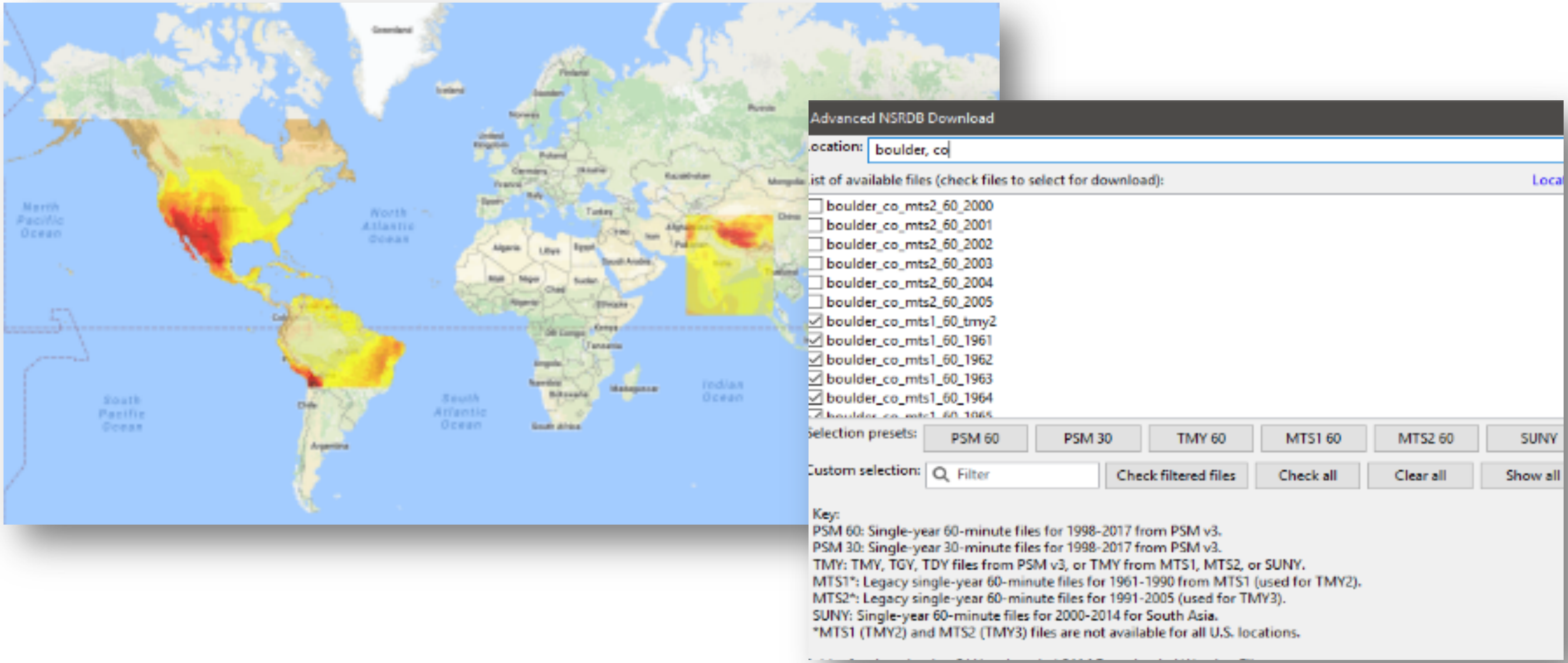
- Consider efficiencies when generating dispatch
- Consider forecast low value period for charging



**Model initially presented at 10^{th} PVPMC*

Improved Weather Data Access

System Advisor Model

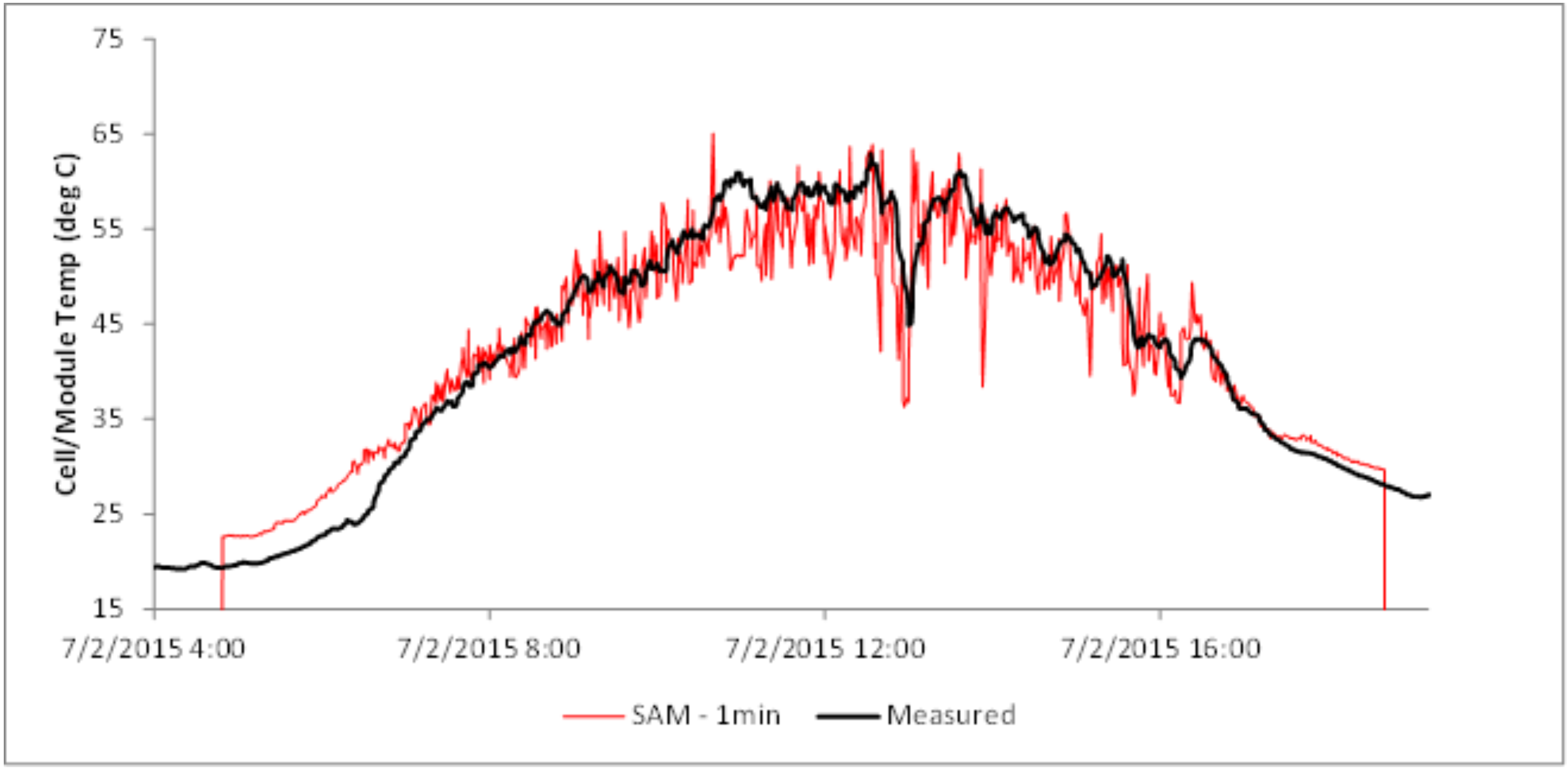


- Download all available data NREL NSRDB data automatically
- Advanced Download capability: easily download multiple years, 30-minute or 60-minute data, multiple locations
- *Coming soon: 5-minute data for Puerto Rico & surrounding areas*

Coming Soon

Transient Module Thermal Model

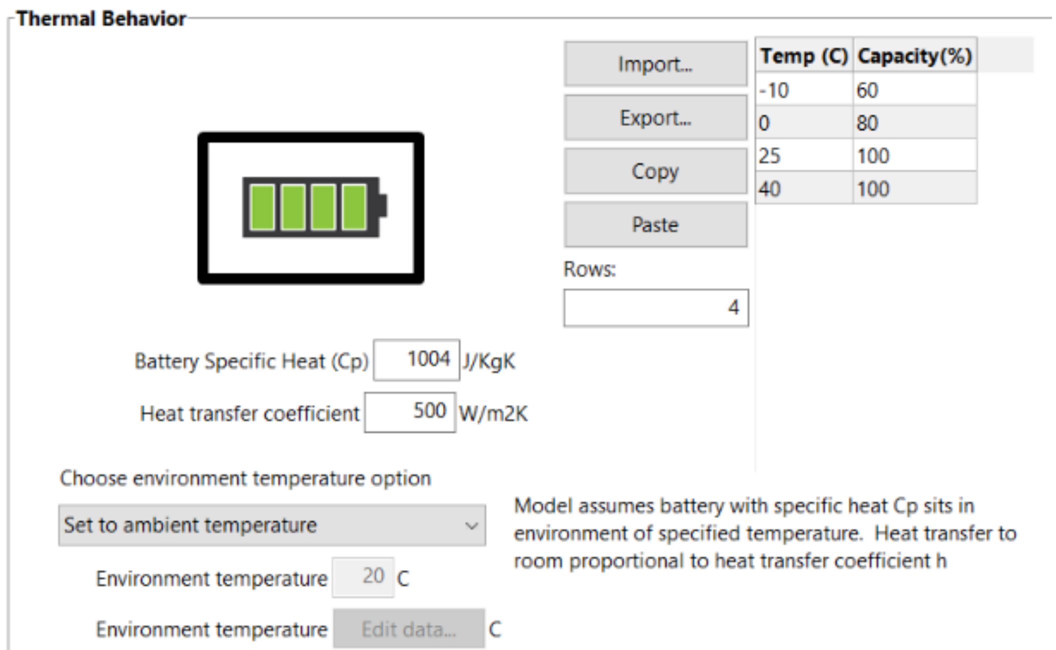
- Implement moving average transient thermal model being developed by Sandia/ASU, similar to investigations performed by Southern Company with measured data (below)
- Doesn’t require many extra inputs

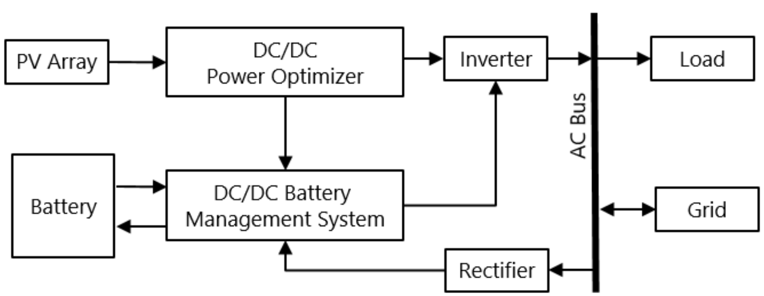


Battery Model Improvements

Battery temperature governs available capacity, affects degradation

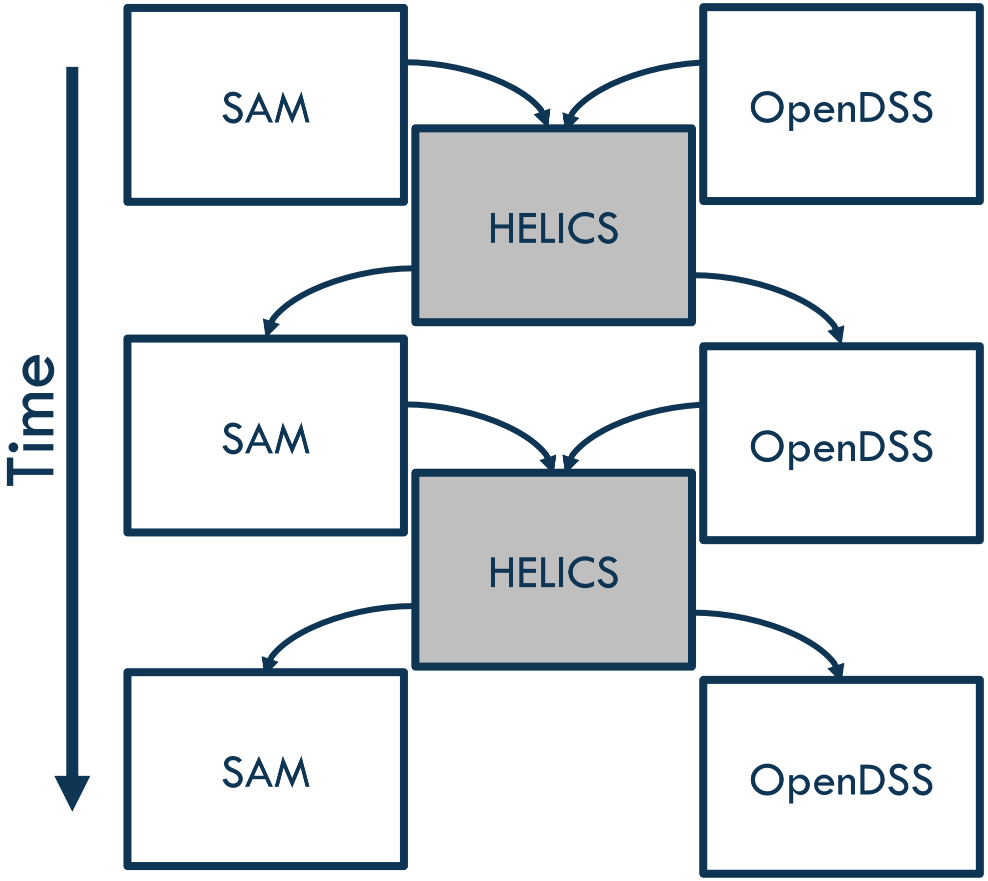
- Expanded options for battery environment temperature
- Can now model battery with ambient temperature from weather file or input time series





Adding more complex solar + storage layout options, including connecting a battery to a specific inverter input on the DC side

Single Timestep Modeling for Co-Simulation



- Co-simulation: multiple models exchanging data as they advance through time
- Allows linking detailed PV+Battery models with large-scale distribution feeder or grid-level simulations
- Requires that PV and Battery models run at a single timestep

System Sizing and Resiliency Analysis

Image source

Add **resiliency analysis** and metrics, and optimal sizing for resiliency for the PV+Battery models, leveraging the NREL REopt tool

Capacity Markets & Ancillary Services

Enable financial models to allow participation in **capacity markets** and allow systems to respond to external price or grid signals and receive compensation for **ancillary services** provided

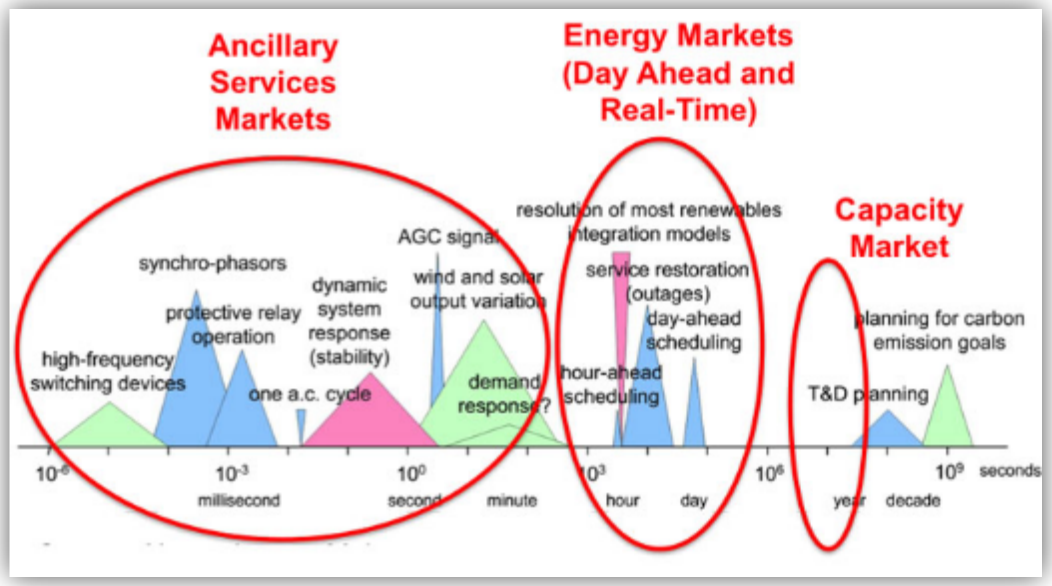
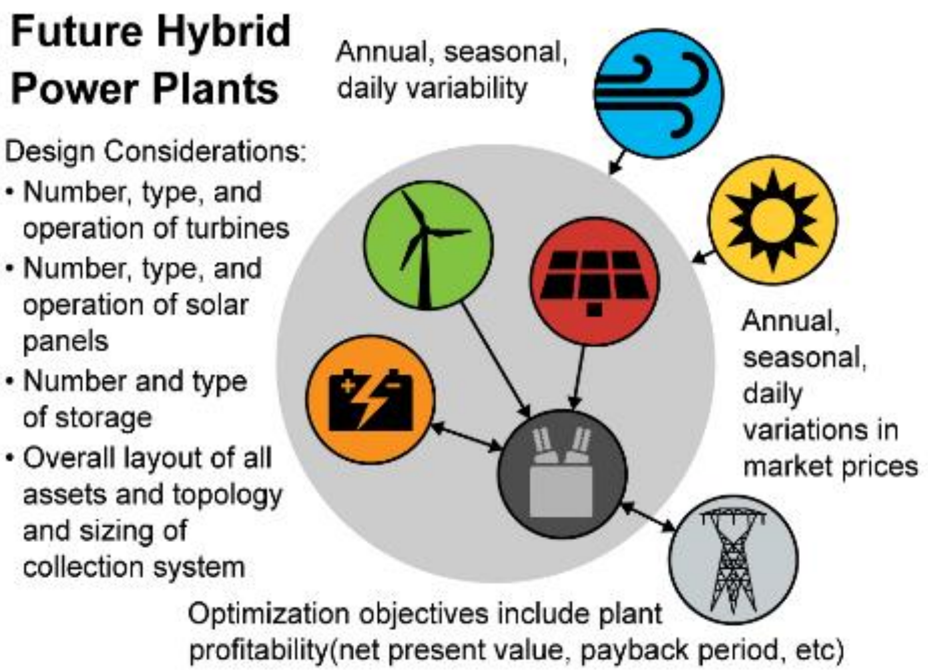


Image source

Hybrid System Modeling

System Advisor Model



Adding capability in SAM to model detailed **wind+solar+storage** systems, leveraging detailed wind system design & optimization of NREL WISDEM tool

PV + Agriculture

System Advisor Model

Simple calculations for available crop area based on PV system layout and including crop revenue in financial calculations

New Technologies

System Advisor Model

Image source

Implementing a **PV+Battery+Fuel Cell** model within SAM

New **Marine Hydrokinetic** technology model combining simple performance model and detailed cost model that can leverage SAM's existing advanced features

Image source

Probability of Exceedance Analysis

System Advisor Model

Add detailed **probability of exceedance analysis** framework to SAM wind model, discussing options to add a similar framework to the PV model

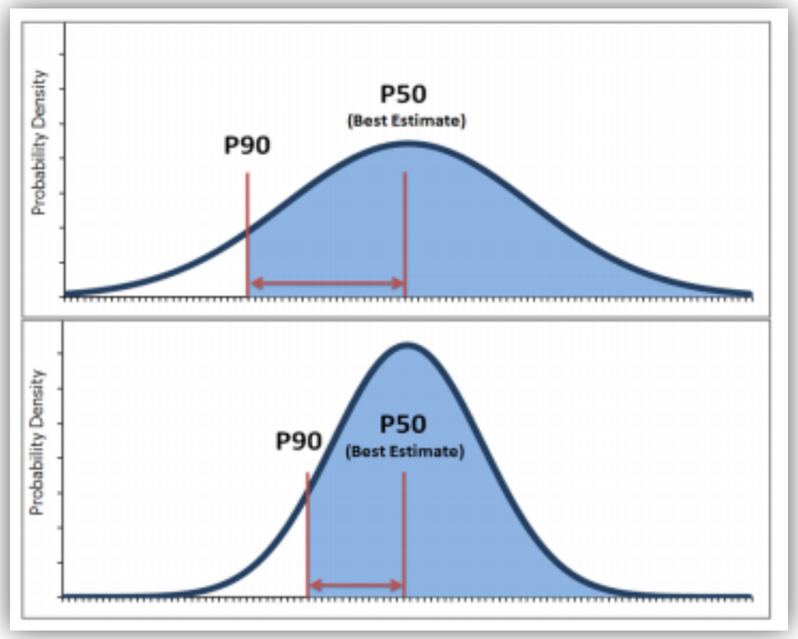


Image source

Project Ideas

Future Ideas (No funded agreement in place)

- **Crowd-sourced component database**
- Floating PV, BIPV, Transparent/shifted spectrum PV
- Using spectral data from the new spectral NSRDB
- Improved representation of non-linear battery behavior in linear optimization models
- PV+CSP+Battery+Thermal Storage systems

Thank you! Questions?

Janine Freeman - project lead, photovoltaic and wind models

Nick DiOrio - code architecture, battery storage models

Nate Blair - emeritus lead, financials, costs, systems

Darice Guittet – software development, photovoltaic models

Steve Janzou - programming, utility rate structures (subcontractor)

Paul Gilman - user support and documentation (subcontractor)

Ty Neises - concentrating solar power models

Mike Wagner - concentrating solar power models

Matt Boyd- concentrating solar power models

www.nrel.gov

http://sam.nrel.gov

NREL

NATIONAL RENEWABLE ENERGY LABORATORY

Backup Slides

Technologies

- Photovoltaics
  - Detailed & PVWatts
  - Battery Storage
  - *Coming soon: Fuel Cell*
- Wind
- Concentrating solar power
- Geothermal
- Biomass
- Solar water heating
- *Coming soon: MHK*

Financial

- Behind-the-meter
  - residential
  - commercial
  - third-party ownership
- Power purchase agreements
  - single owner
  - equity flips
  - sale-leaseback
- Host/Developer
- Simple LCOE calculator

Other Resources Online

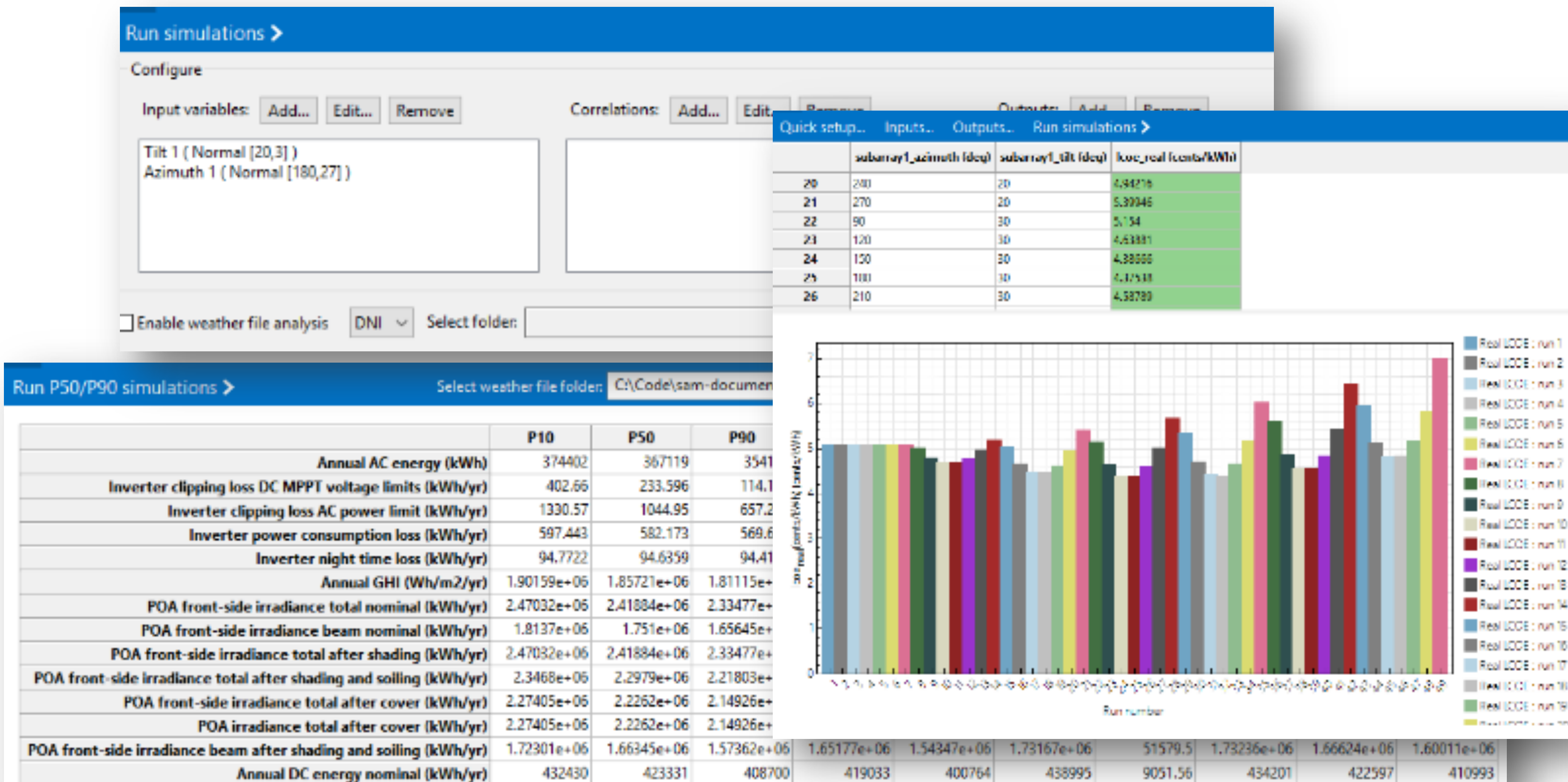
The following information resources about SAM are available.

- 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)

Advanced Analysis Features

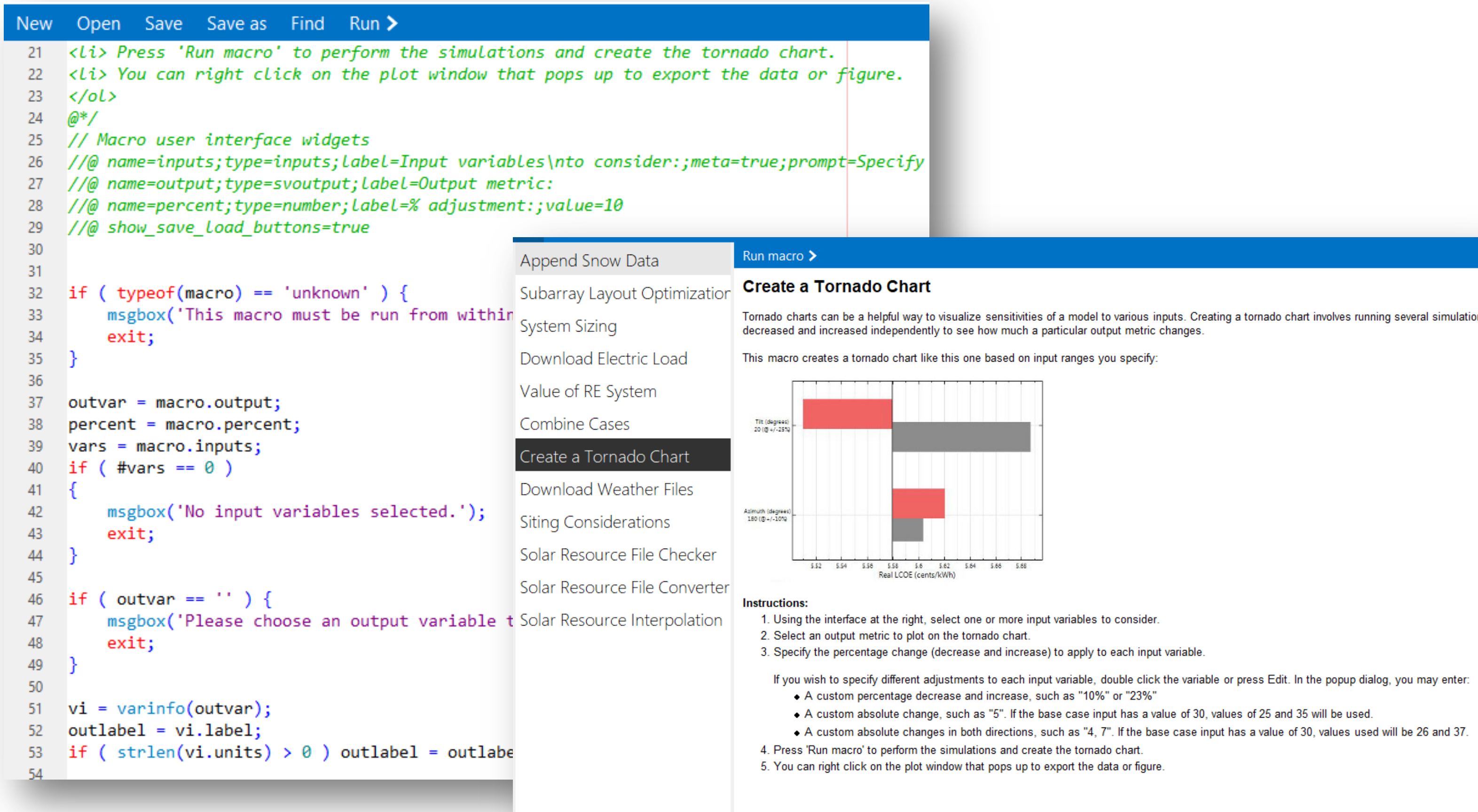
System Advisor Model

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



Built-in Scripting Language and Macros

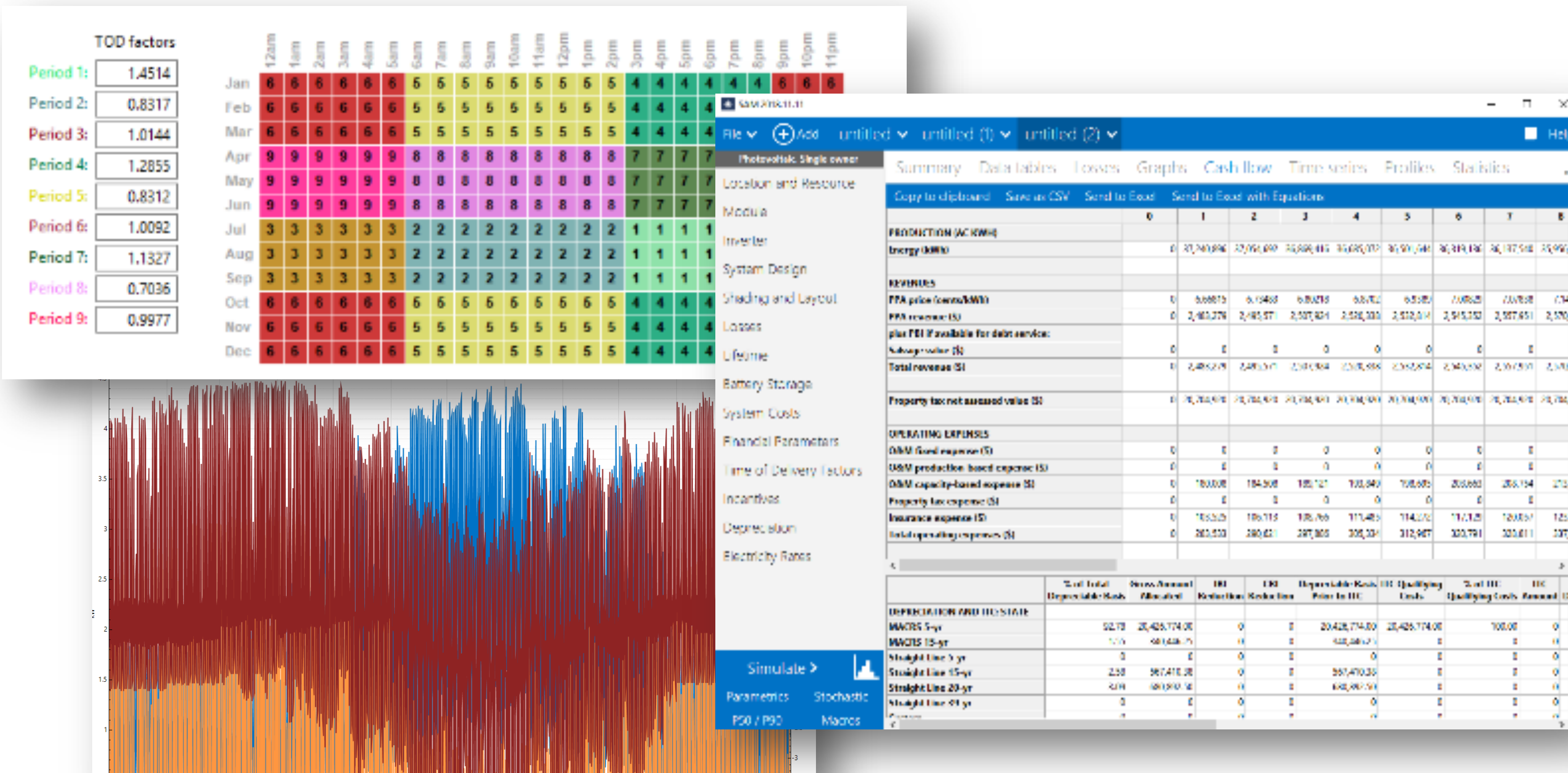
System Advisor Model



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

Detailed Cash Flow Financial Models

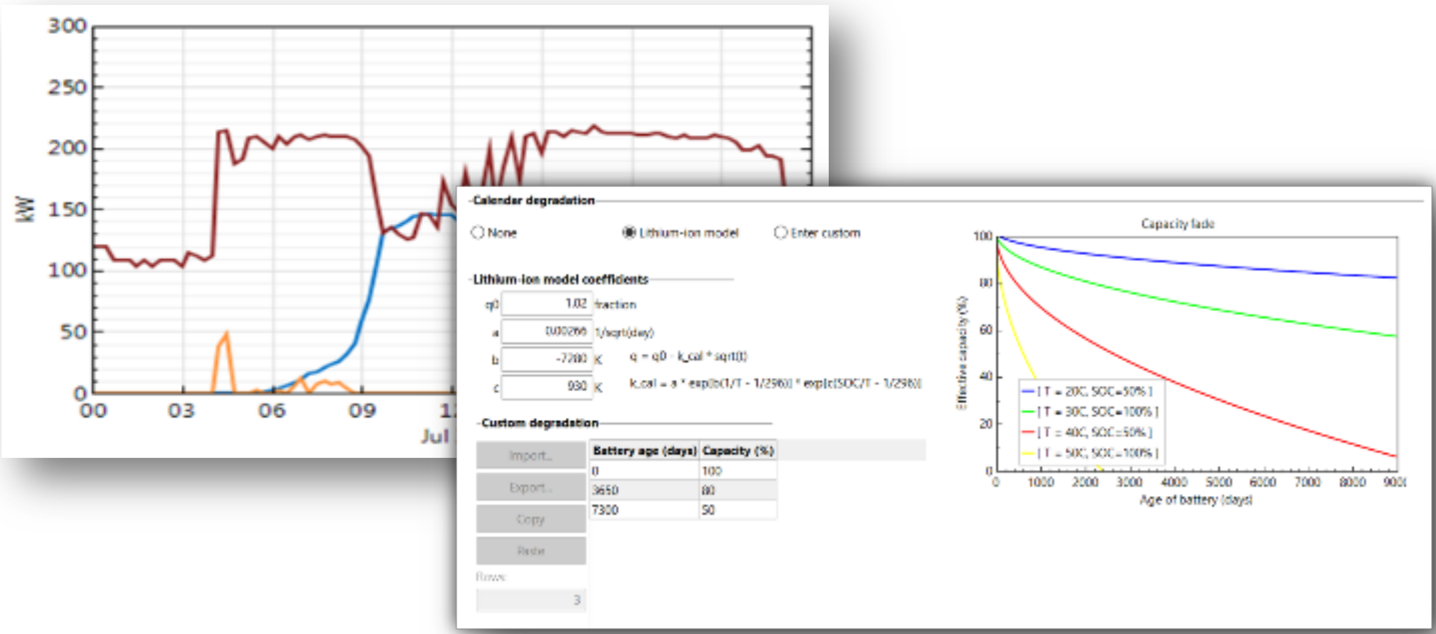
No other tool provides detailed, ***time-based*** financial modeling across multiple market sectors, including complex utility rates, combined with detailed performance modeling



Detailed Battery Model

System Advisor Model

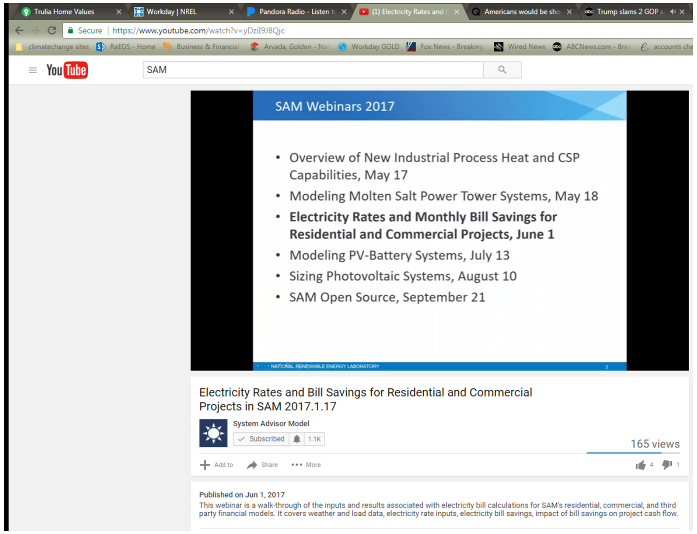
Only publicly available tool with detailed battery model that accounts for voltage characteristics, calendar and cycle degradation, etc



- ✓ Currently integrated with PV and “Generic System” model
- ✓ Available on DC or AC side of PV system
- ✓ Multiple automated dispatch strategies for different markets
- ✓ Behind-the-meter or front-of-the-meter operation

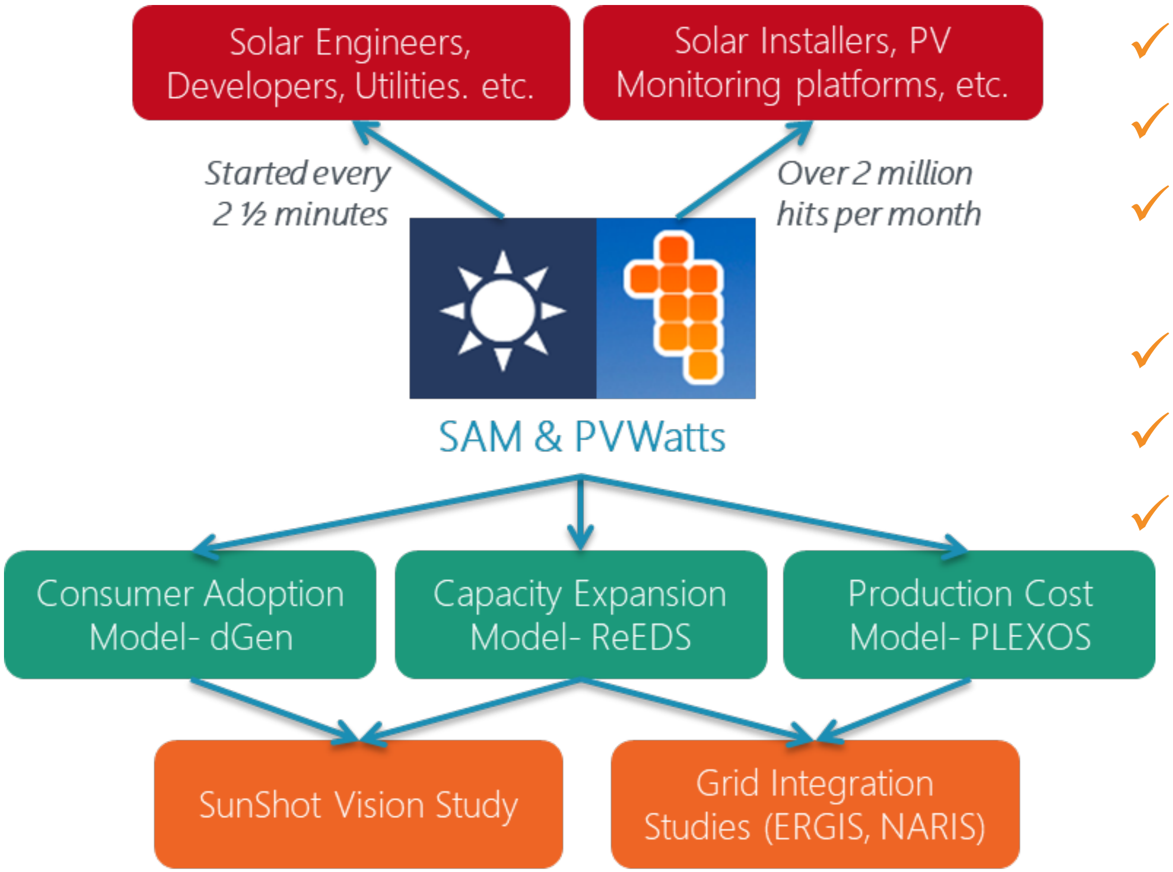
Extensive Help Documentation

- 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



How does SAM fit in at NREL and externally?

System Advisor Model



- ✓ 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)