

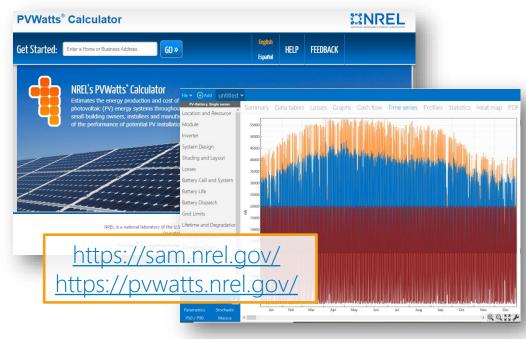
Recent and Planned Improvements to the System Advisor Model (SAM)

Janine (Freeman) Keith 2022 PV Performance Modeling Workshop August 23, 2022

Photo by Dennis Schroeder, NREL 55200

System Advisor Model (SAM) & PVWatts

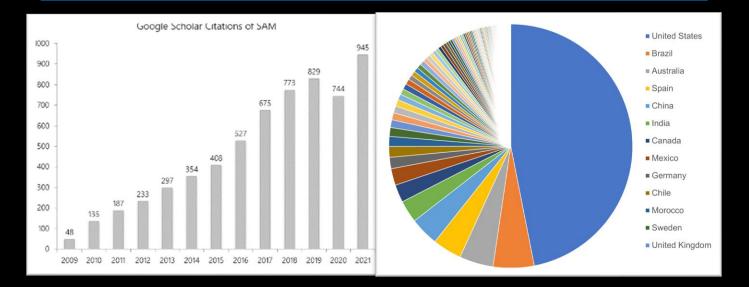
Free software that enable detailed performance and financial analysis for renewable energy systems



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

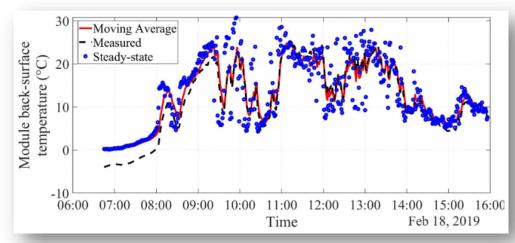
SAM Users

SAM is started once every 2 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

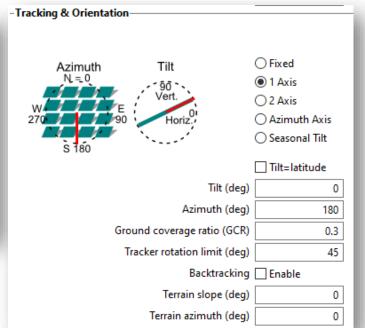


Detailed PV Model Improvements

Transient Module Thermal Model for subhourly simulations

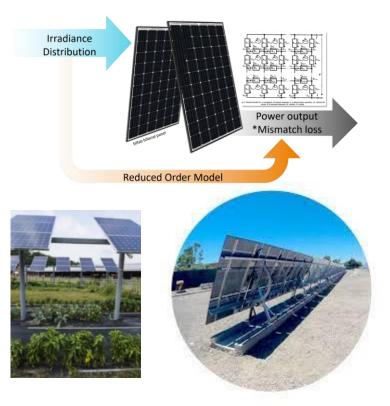


M. Prilliman, J. S. Stein, D. Riley and G. Tamizhmani, "Transient Weighted Moving-Average Model of Photovoltaic Module Back-Surface Temperature," in IEEE Journal of Photovoltaics, vol. 10, no. 4, pp. 1053-1060, July 2020, doi: 10.1109/JPHOTOV.2020.2992351. Improved backtracking algorithm with simple terrain slope input



Upcoming: Bifacial Model Improvements

- Bifacial electrical mismatch
- Shading from racking structures
- Multi-albedo ground surface
- Edge effects





PVWattsV8

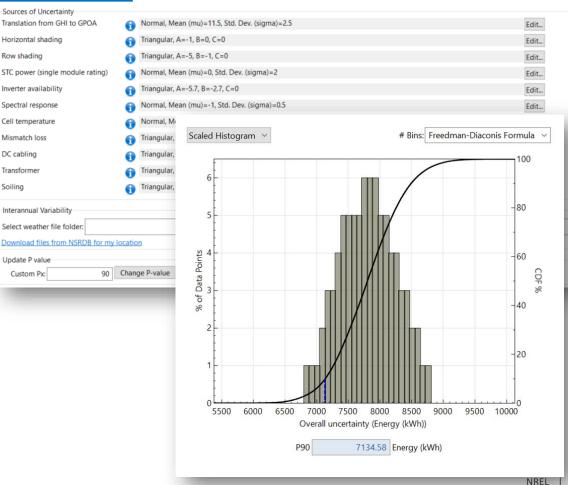
- Available now in the SAM desktop application/PySAM
- Coming soon to the PVWatts API and website

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

Coming this fall: PV Uncertainty Model

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

Run PV uncertainty simulations >



New Battery Technology Models

Standalone Electric Battery



Image credit: https://www.teslarati.com/teslapowerwall-demand-after-australian-blackouts/

Standalone Electric Thermal Energy Storage

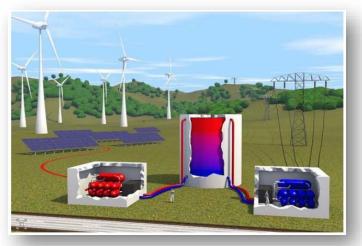
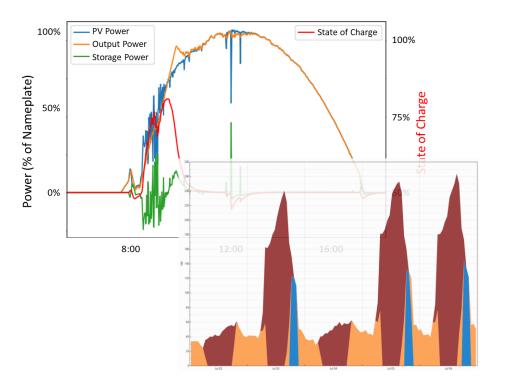


Image credit: https://physicsworld.com/a/how-tostore-electrical-energy-as-heat/ https://www.nrel.gov/docs/fy22osti/82989.pdf

New Battery Dispatch Algorithms

- Utility-scale PV smoothing dispatch algorithm
 - Thank you EPRI and Southern Company!
- Behind-the-meter dispatch to respond to prices
 - Previously responded to energy peaks that might not always coincide with highest cost
- Optimal battery sizing and dispatch profile using NREL's REopt tool



Grid and Resiliency Capabilities



Image credit: https://www.constructionweekonline.com/projects-tenders/260365gcc-egypt-jordan-ink-mou-to-work-on-interconnected-arab-power-grid

- Specify grid outages and use the battery to cover only critical loads
- Calculate **resiliency** metrics

• Specify **interconnection** limits and grid curtailment

More Battery Model Features

• Levelized Cost of Storage (LCOS)

- Improved battery degradation modeling for Li-ion NMC/graphite
 and LMO/LTO technologies
 - Forthcoming report on **battery model validation**

Check out Brian Mirletz's poster for more battery info!

New Financial Models

- Community solar
- Merchant plant
 - Access to NREL's CAMBIUM dataset for market price proxies



Image credit: https://www.vox.com/2016/3/24/11297054/shared-solar

New Technology Models



Image credit: https://www.mmc.gov/priority-topics/offshoreenergy-development-and-marine-mammals/renewableenergy-development-and-marine-mammals/

> Marine Energy technology models for wave and tidal power

PV+Battery+Fuel Cell

model within SAM with funding from Southern Company



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

NREL | 13

Special Shoutouts

 "New" SAM team members! (Find them and say hi!)
 Open source code contributors
 PySAM contributors

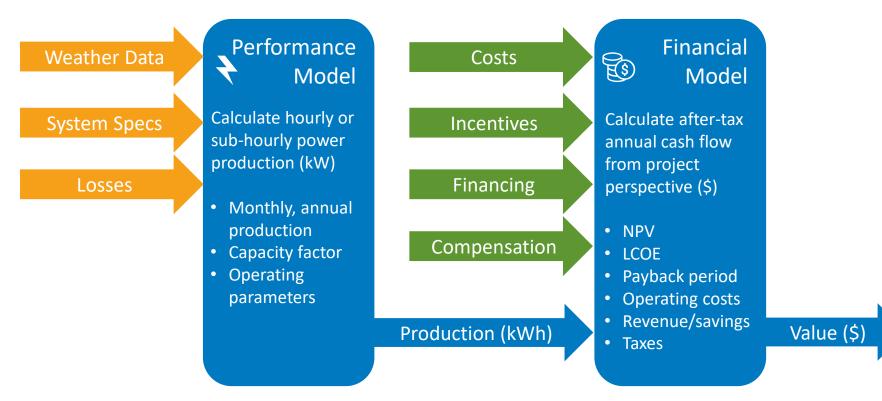




Thank you! Questions?

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

Model Structure





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

Technol

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

Models

Financial

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

Advanced Analysis Features

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

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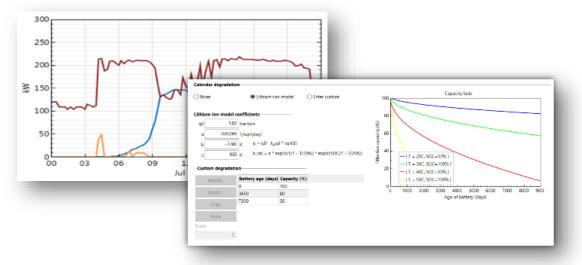
Detailed Cash Flow Financial Models

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

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Detailed Battery Model

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



- ✓ Currently integrated with PV, "Generic System" model, Standalone battery model
- \checkmark Available on DC or AC side of PV system
- \checkmark Multiple automated dispatch strategies for different markets
- ✓ Behind-the-meter or front-of-the-meter operation

Open Source Code

This repository Search	Pull requests	Issues Marketplace Explore	© Unwatch ▼ 10 ★ Unstar 7	♣ + • ○○ 7 ○ ¥ Fork 4			\checkmark	Flexible
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Extensive Help Documentation

- Website <u>http://sam.nrel.gov</u>
 - Support Forum Ask your question!
 - General info/ online help file / contact info
- YouTube Channel
 - <u>https://www.youtube.com/user/SAMDemoVideos</u>
 - 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



Other Resources Online

The following information resources about SAM are available.

- <u>News</u>
- <u>Webinars</u> (mostly on the SAM YouTube channel)
- <u>Weather Data</u> (Description of various weather data sources)
- <u>Sample Files</u> (particularly scripting language examples)
- Financial Model Documentation
- <u>Performance Model Documentation</u> (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)
- <u>Source Code</u> (linkages to Open Source code on GitHub)

A Partial Web of NREL Data & Tools

