# Successes, Lessons Learned, and Ongoing Challenges from the Open-Source Release of the System Advisor Model

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Photo by Dennis Schroeder, NREL 55200

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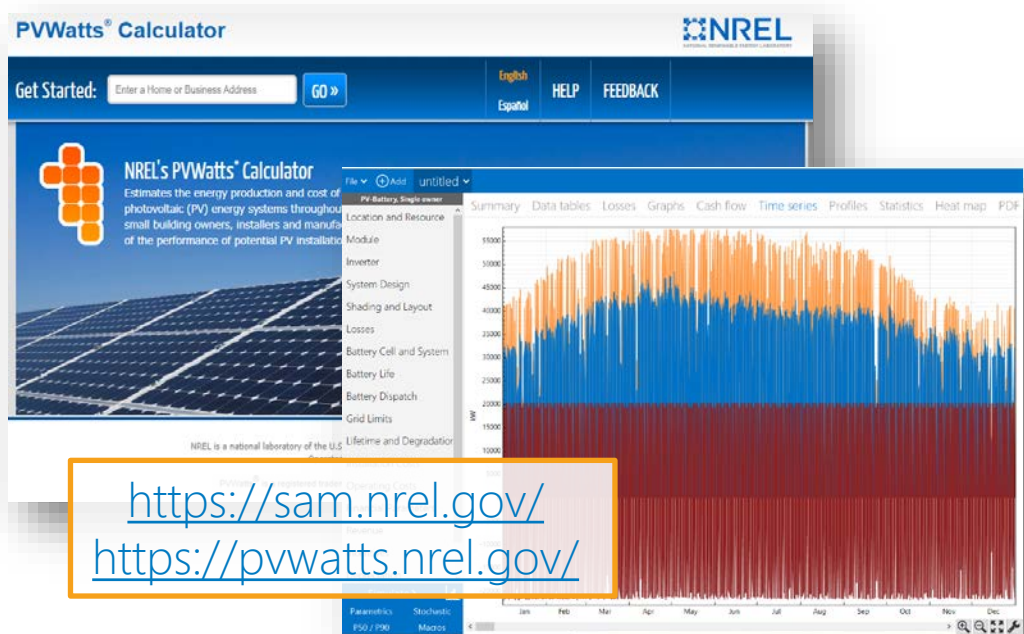
- ✓ Desktop application
- ✓ PVWatts web tool & API
- ✓ Software development kit
- ✓ PySAM Python package
- ✓ Open-source code
- ✓ Extensive documentation
- ✓ User support

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
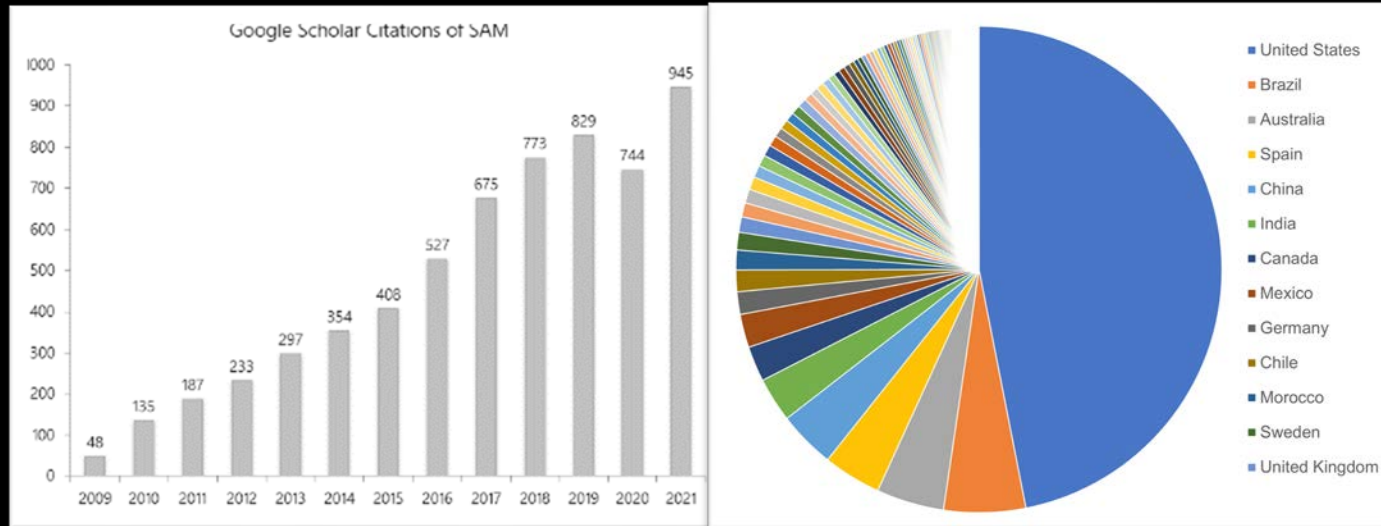Community solar
Simple LCOE calculator

SAM Users

SAM is started **once every 2 minutes**
PVWatts receives over **17.5 million hits per month**
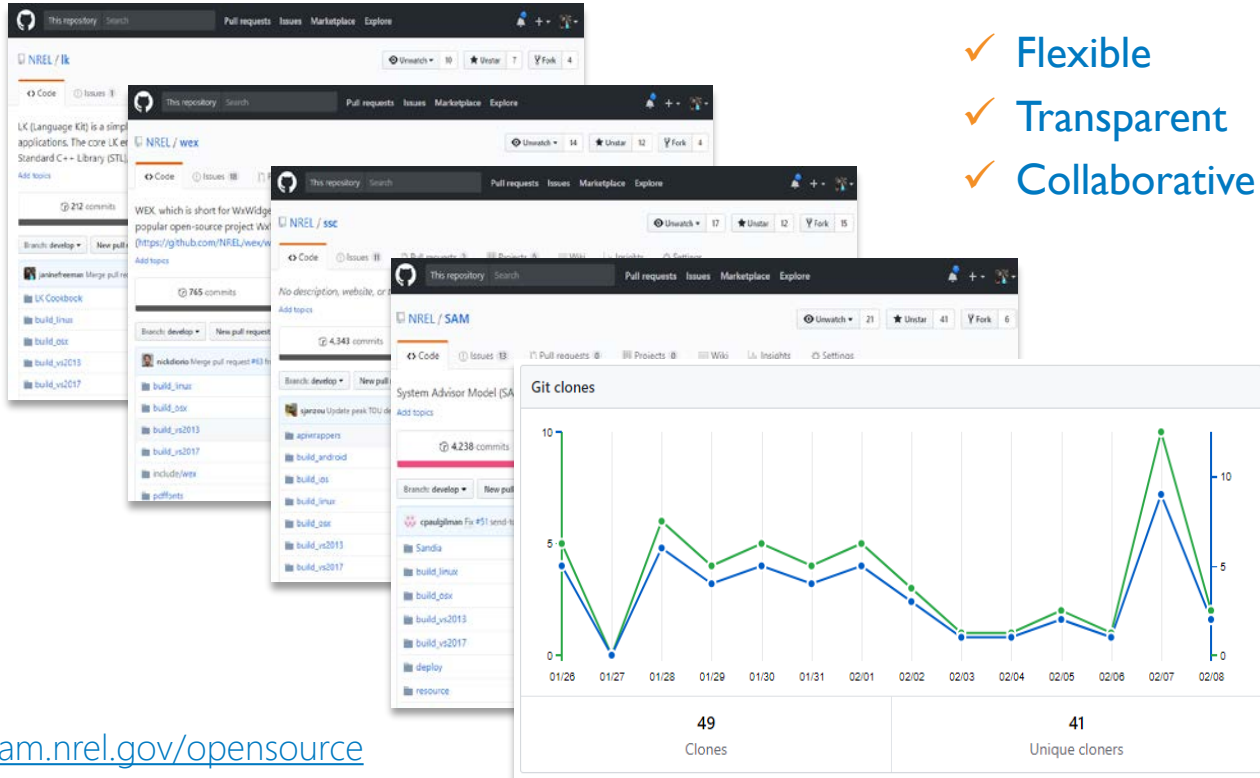Over **150,000** users in 190+ countries
120+ webinars with **over 280,000 views**
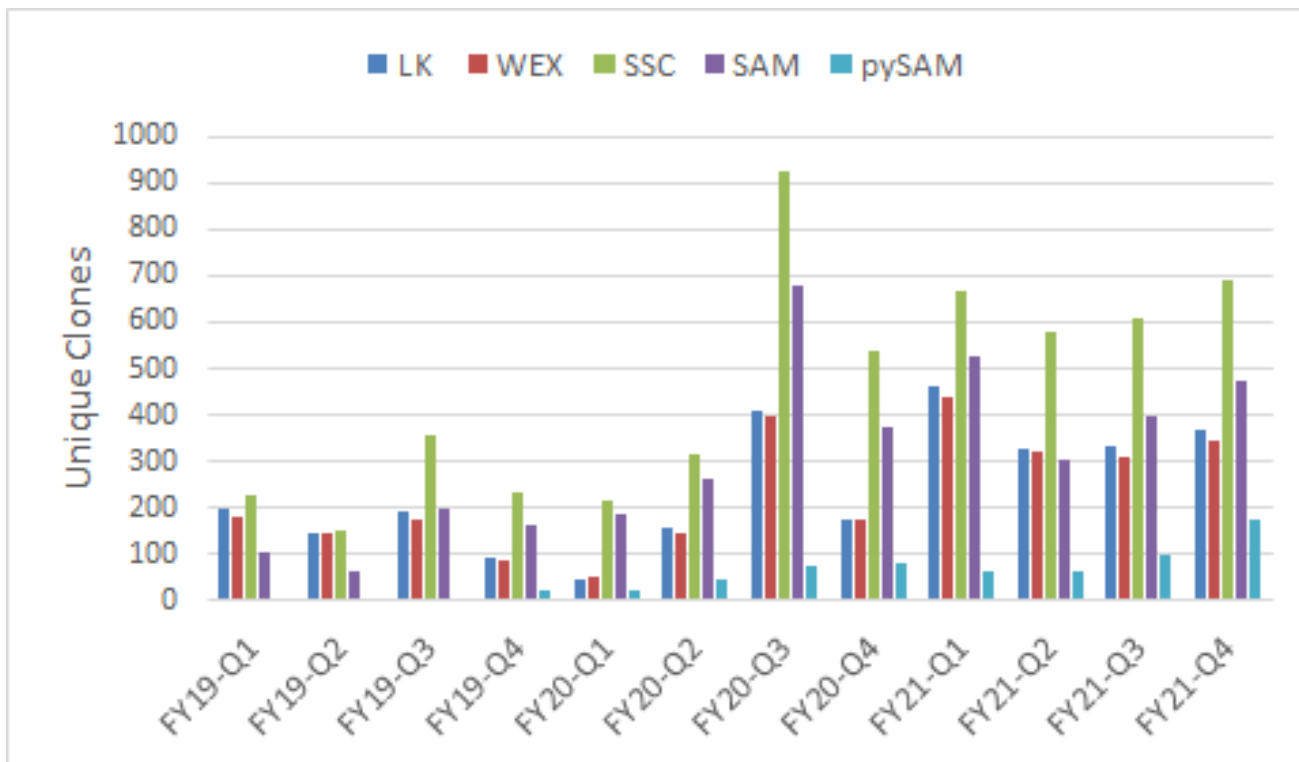Users include Sunrun, Enphase, AEP, Southern Company, EPRI, & more

Google Scholar Citations of SAM

Open-Source Code

- ✓ **Flexible**
- ✓ **Transparent**
- ✓ **Collaborative**

http://sam.nrel.gov/opensource

Open-Source Usage

History

Developed by

- Department of Energy
- National Renewable Energy Laboratory
- Sandia National Laboratories

Originally launched closed-source in 2004

- Model different renewable energy projects in a single platform
- Facilitate technology comparison by handling performance, costs and financing consistently across technologies

Motivation for Open-Source

Open-source Launch in 2017. Provides:

Transparency

- Look at the underlying code of models

Flexibility

- Can tweak models to represent a new or unusual configuration

Standards

- Provides standards for all models, including closed-source

Collaboration

- New technology models that might not yet have a commercial market
- Encourages collaboration amongst taxpayer funded projects

Licensing

Entity	2017-2019 License	Current License
Commercial Entities	MIT-type license with no sharing restrictions	BSD3-clause (no sharing restrictions)
Research and Non-profit Entities	GPLv3 like license with sharing required	BSD3-clause (no sharing restrictions)

Lesson learned: standard licenses make it easier for contributors

Open-Source Contributors

- Other NREL teams
- Sandia National Laboratories
- Cypress Creek Renewables
- Envision Digital
- OpenInvest
- Passivenous Consulting
- Southern Company

Types of Contributions

Report bugs directly to GitHub with line numbers

Fix compiler warnings

Adding additional PV sub-models

Publish NREL battery degradation models

Write no code

Write large modules
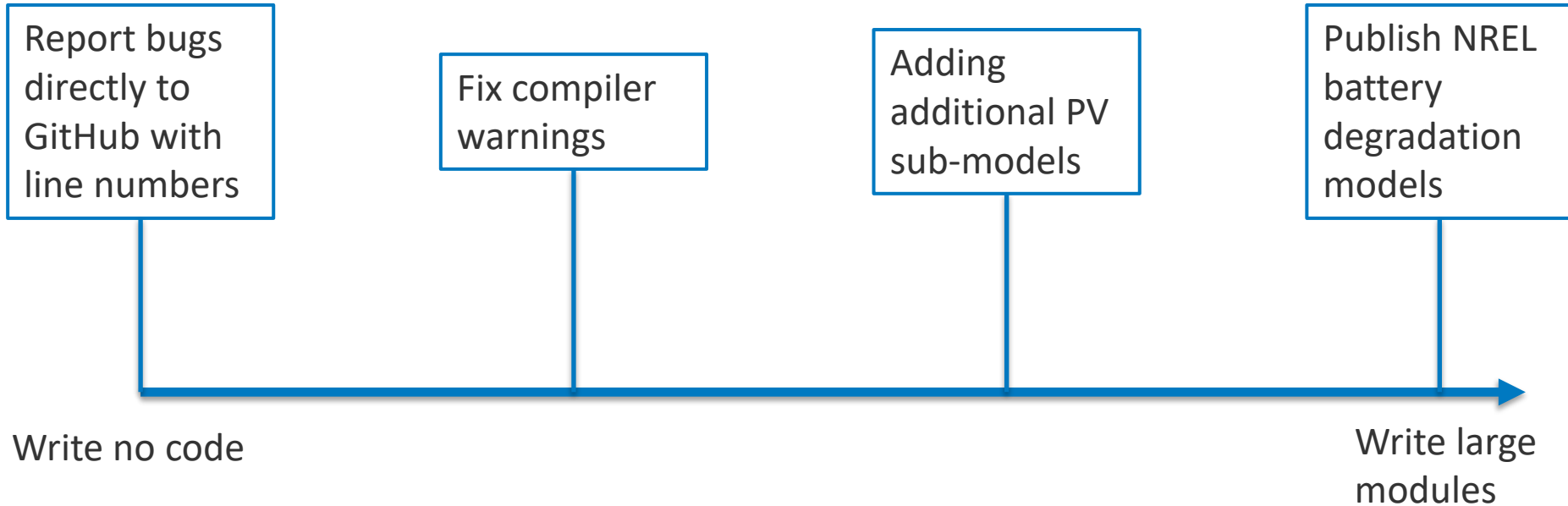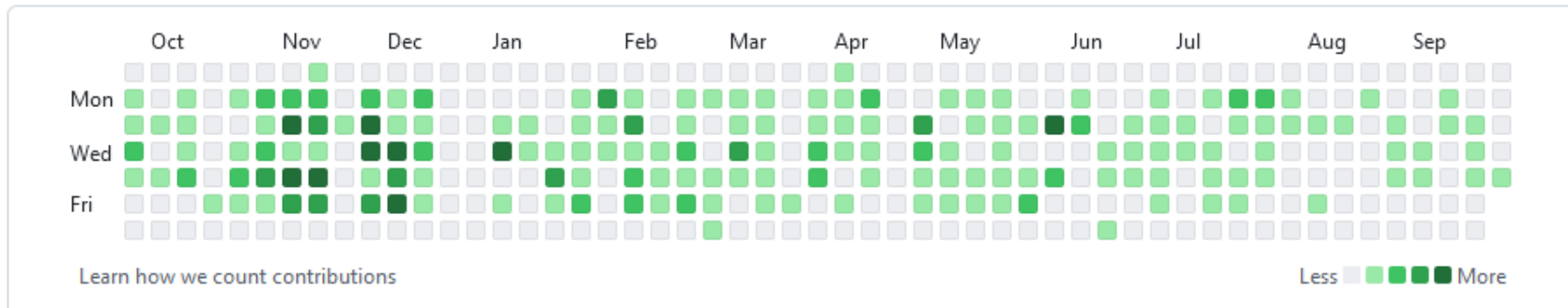
Large Successful Contributions

- Mermoud/Lejeune module model
  - Included unit tests, released as an SDK option
  - Received subsequent open-source contributions with extensions and fixes
- Slope-aware backtracking algorithm
  - Able to keep the original author aware of updates
- Chemistry specific battery degradation algorithms

Reasons to Contribute

- Prestige
  - Contributions are public
- Solving business needs
- Unofficial "stamp of approval"
  - Able to say changes are in the official NREL SAM repository

931 contributions in the last year

Contribution settings ▾

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep

Mon

Wed

Fri

Learn how we count contributions

Less ▢▢▢▢▢ More

Challenges

- Language choice
  - C++ is fast, but smaller pool of developers
- Desktop GUI increases user base, but adds another barrier to contributions
  - Core team has needed to develop GUI interfaces for some contributed features
- Keeping some code private (usage tracking, API keys) adds development overhead

Contributor Outreach

- Outreach is different when the primary interfaces is a GUI (vs code)
- Use in university courses provides opportunities to get programmers into renewable energy
- "Volunteer" contributors are rare
  - Contributors are usually affiliated with the energy field professionally
- How do we get companies to view using and contributing to open-source tools as an advantage?
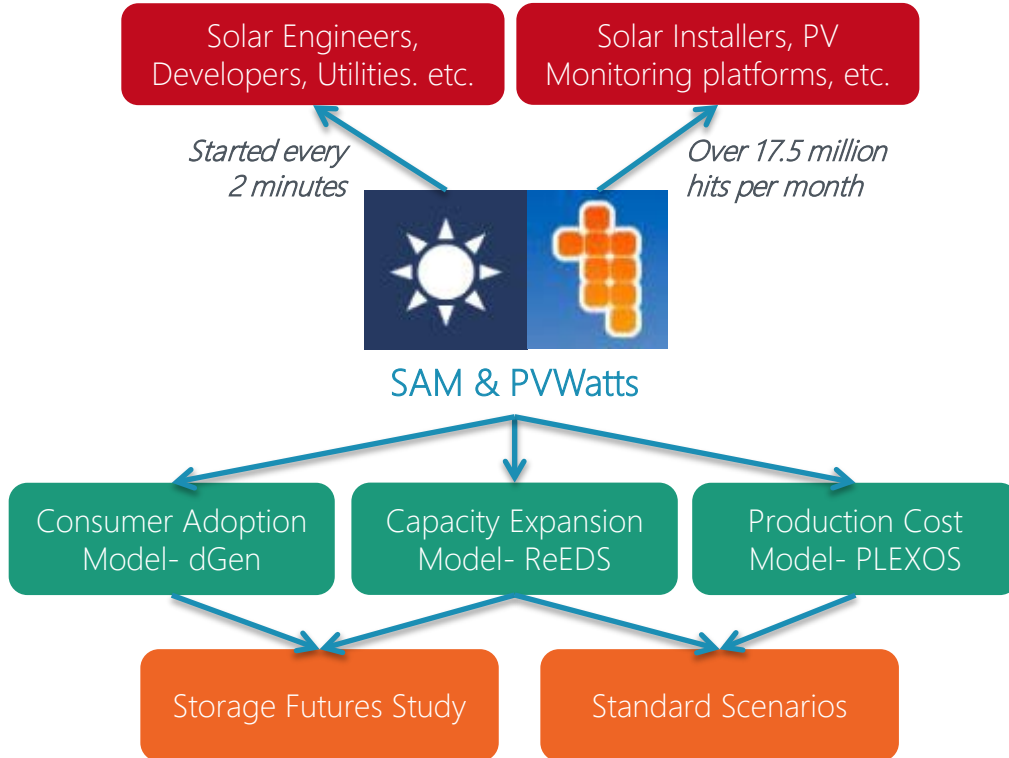
Thank you! Questions?

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

Photo from iStock-627281636

How SAM Fits in at NREL and Externally

Solar Engineers, Developers, Utilities. etc.

Solar Installers, PV Monitoring platforms, etc.

Started every 2 minutes

Over 17.5 million hits per month

SAM & PVWatts

Consumer Adoption Model- dGen

Capacity Expansion Model- ReEDS

Production Cost Model- PLEXOS

Storage Futures Study

Standard Scenarios

- ✓ 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)

Model Structure

Weather Data → Performance Model

System Specs → Performance Model

Losses → Performance Model

Performance Model

Calculate hourly or sub-hourly power production (kW)

- Monthly, annual production
- Capacity factor
- Operating parameters

Costs → Financial Model

Incentives → Financial Model

Financing → Financial Model

Compensation → Financial Model

Production (kWh) → Financial Model

Financial Model

Calculate after-tax annual cash flow from project perspective ($)

- NPV
- LCOE
- Payback period
- Operating costs
- Revenue/savings
- Taxes

→ Value ($)

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

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