

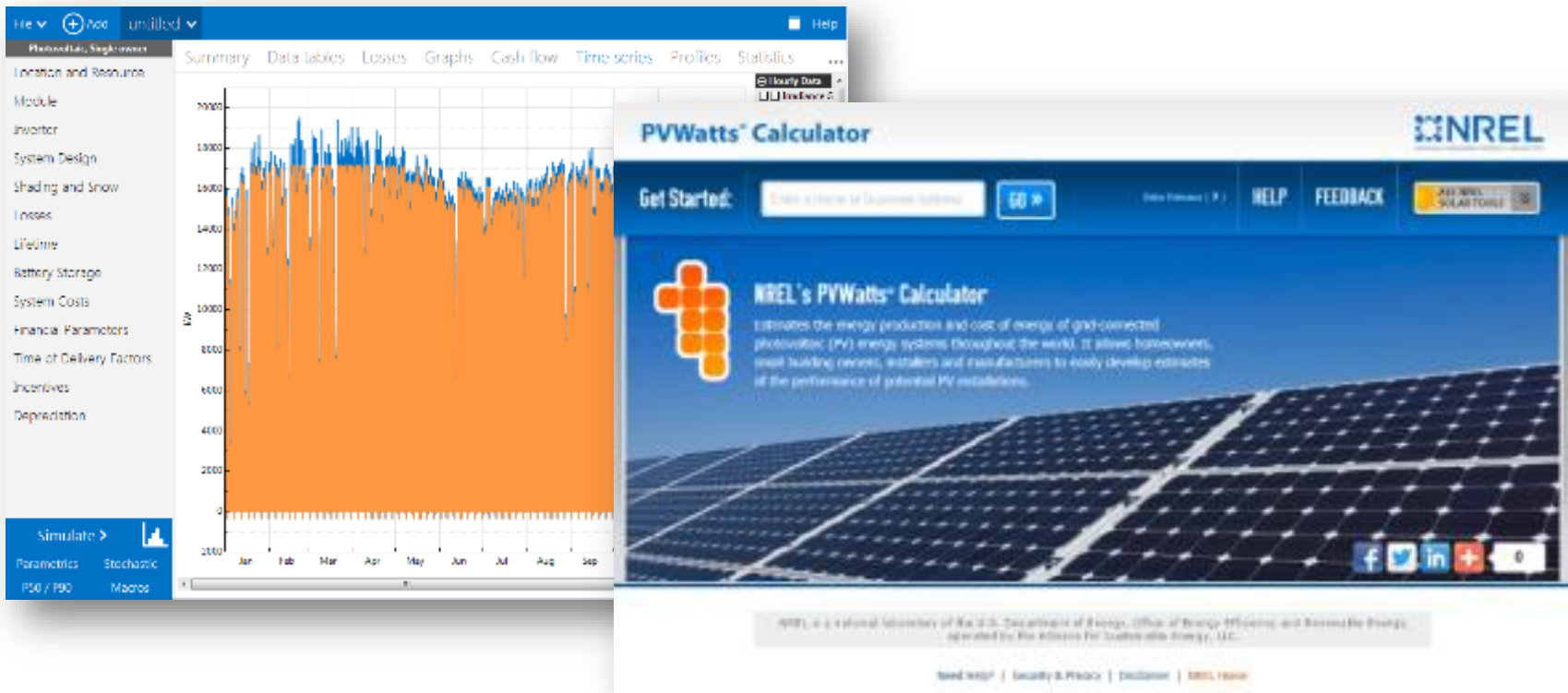


Recent and Planned Improvements to the  
**System Advisor Model (SAM)**

Janine Freeman  
2018 PV Systems Symposium/ 10<sup>th</sup> PVPMC  
May 1, 2018



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

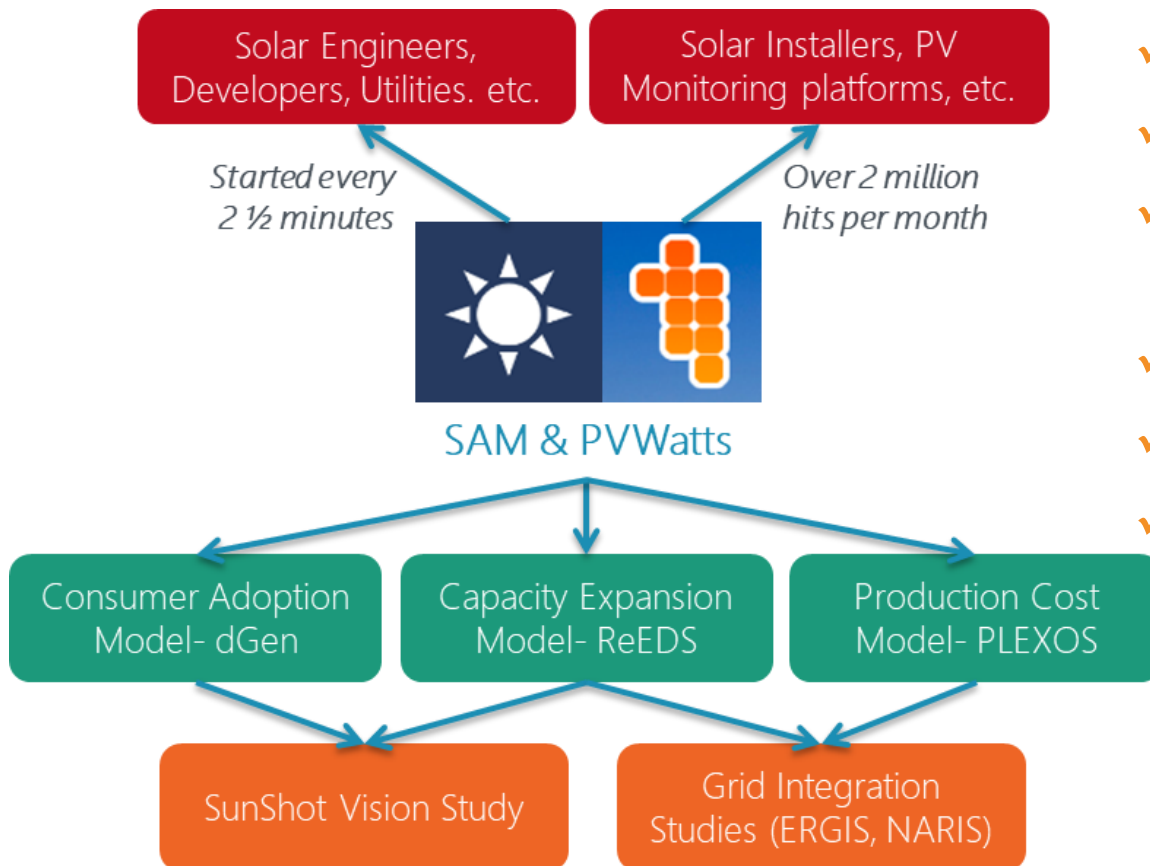


<http://sam.nrel.gov/download>

## How can you 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
  - PHP
  - C#
  - Java
  - VBA
  - *NEW: iOS / Android*
- Web Services API (PVWatts Only)
- *NEW: Open-source SAM code*

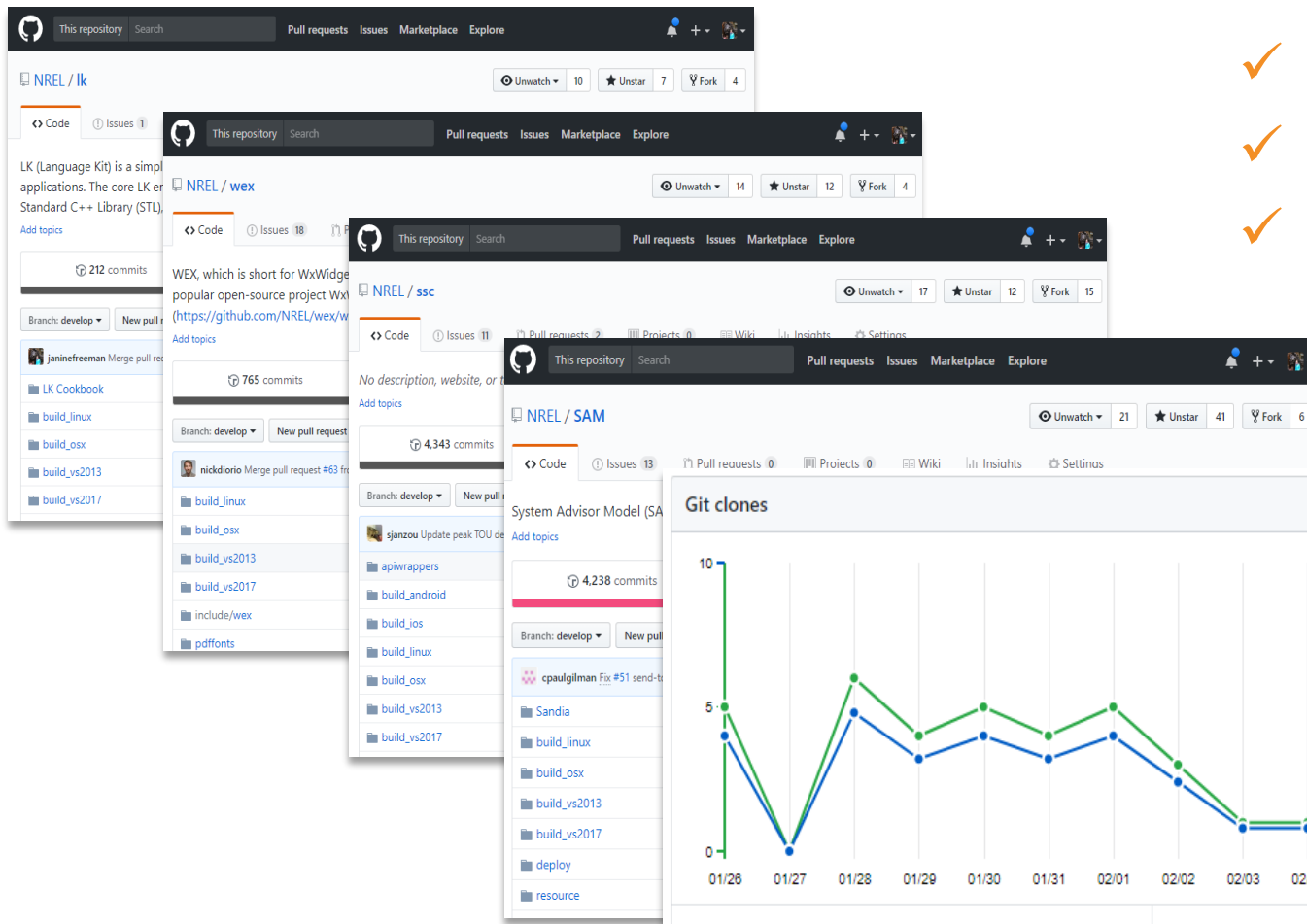
# How does SAM fit in at NREL and externally?



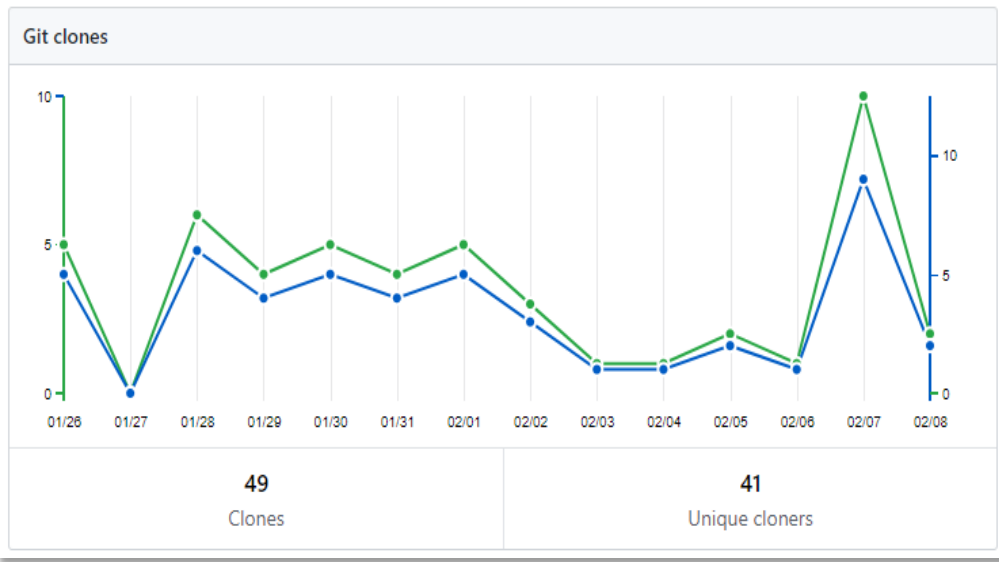
- ✓ Grid integration studies
- ✓ Renewable energy futures
- ✓ LCOE of breakthrough technologies
- ✓ Policy and utility rate design
- ✓ Technical potential studies
- ✓ Commercial applications (e.g. Southern Company, AEP, Sunrun)

# Recent Improvements

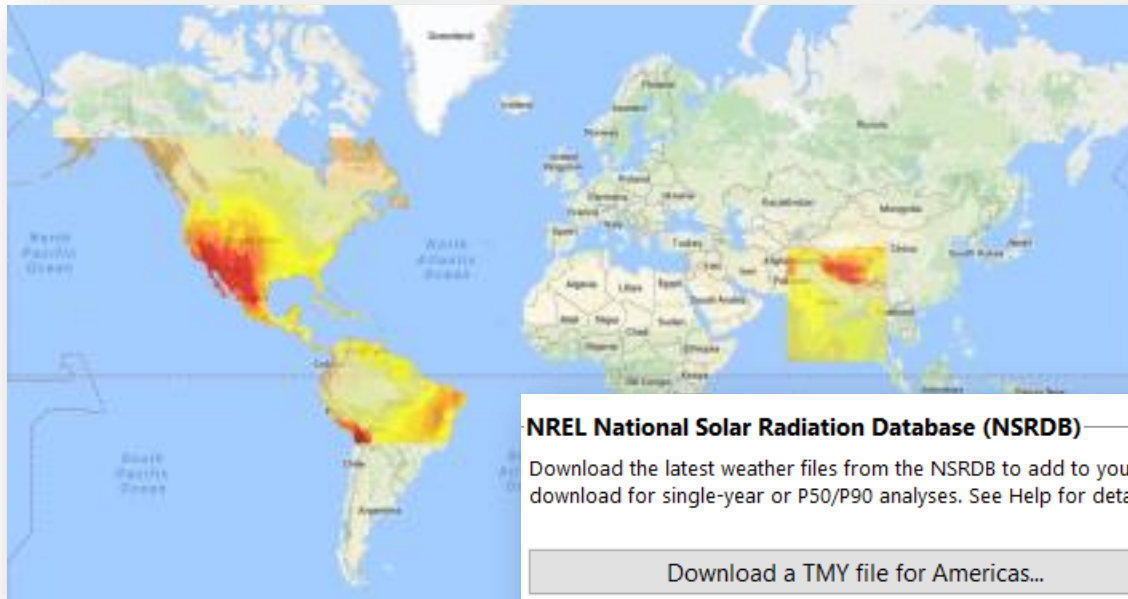
# Open Source Code



- ✓ Flexible
- ✓ Transparent
- ✓ Collaborative



<http://sam.nrel.gov/opensource>



## NREL National Solar Radiation Database (NSRDB)

Download the latest weather files from the NSRDB to add to your solar resource library: Download a typical-year (TMY) file for most long-term download for single-year or P50/P90 analyses. See Help for details.

Download a TMY file for Americas...

TMY or Single-year for Americas and Asia...

- NREL NSRDB V2 and V3 include weather data for much larger geographical extent
  - We are also collaborating with PVGIS to incorporate their data
- From SAM UI: download TMY for your location, or download multiple files of specific year data or TMYs from multiple datasets (update to V3 coming soon)
- **NEW: PVWatts V6 API that allows access to NREL NSRDB V3**



```
New Open Save Save as Find Run >
378 var( 'batt_target_power', real_array(read_text_file('C:/Users/jfreeman/Desktop/batt_target_power.csv')
379 var( 'batt_target_power_monthly', [ 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 ] );
380 var( 'batt_target_choice', 0 );
381 var( 'batt_dispatch_choice', 3 );
382 var( 'batt_pv_choice', 0 );
383 run('pvsamv1');
384 var( 'inflation_rate', 2.5 );
385 var( 'degradation', [ 0.5 ] );
386 var( 'load_escalation', [ 0 ] );
387 var( 'rate_escalation', [ 0 ] );
388 var( 'ur_metering_option', 2 );
389 var( 'ur_nm_yearend_sell_rate', 0.027890000492334366 );
390 var( 'ur_monthly_fixed_charge', 16.680000305175781 );
391 var( 'ur_monthly_min_charge', 0 );
392 var( 'ur_annual_min_charge', 0 );
393 var( 'ur_en_ts_sell_rate', 1 );
394 var( 'ur_ts_sell_rate', real_array(read_text_file('C:/Users/jfreeman/Desktop/ur_ts_sell_rate.csv')));
395 var( 'ur_ec_sched_weekday',
396 [ [ 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 3, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4 ],
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407 [ 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 3, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4 ] ] );
408 var( 'ur_ec_sched_weekend',
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420 [ 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4 ] ] );
421 var( 'ur_ec_tou_mat',
422 [ [ 1, 1, 9.9999996802856925e+037, 0, 0.26686999201774597, 0.26686999201774597 ],
423 [ 2, 1, 9.9999996802856925e+037, 0, 0.083279997110366821, 0.083279997110366821 ],
424 [ 3, 1, 9.9999996802856925e+037, 0, 0.22056999802589417, 0.22056999802589417 ],
425 [ 4, 1, 9.9999996802856925e+037, 0, 0.083259999752044678, 0.083259999752044678 ] ] );
426 var( 'ur_dc_enable', 0 );
427 var( 'ur_dc_sched_weekday',
428 [ [ 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 ],
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432 [ 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 ] ] );
```

Code Language

Choose a language:

- JSON for inputs
- LK for SDKtool
- C
- MATLAB
- Python 2
- Python 3
- Java
- Android Studio (Android)**
- C#
- VBA

OK Cancel

- **NEW! Android and iOS wrappers**
- UI feature to automatically generate code for use with SDK





- Calendar life degradation model for lithium-ion batteries
- All-iron flow batteries and flow battery model improvements
- Improved battery dispatch control
- DC-connected battery model improvements
  - See Will Hobbs' presentation on Thursday!

**Calendar degradation**

None     
  Lithium-ion model     
  Enter custom

**Lithium-ion model coefficients**

q0  fraction  
 a  1/sqrt(day)  
 b  K       $q = q0 - k\_cal * \text{sqrt}(t)$   
 c  K       $k\_cal = a * \exp[b(1/T - 1/296)] * \exp[c(\text{SOC}/T - 1/296)]$

**Custom degradation**

	Battery age (days)	Capacity (%)
Import...	0	100
Export...	3650	80
Copy	7300	50
Paste		

Rows:

**Capacity fade**

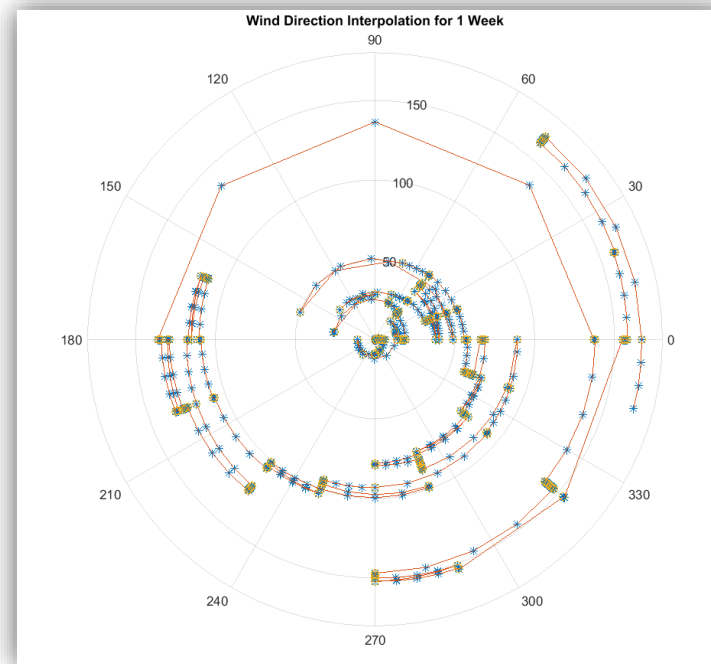
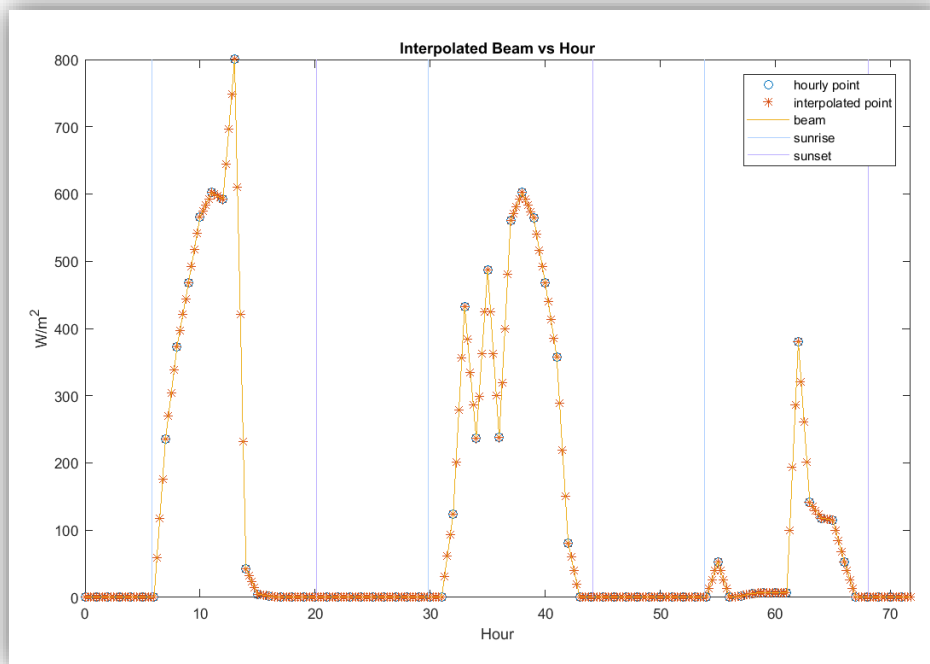
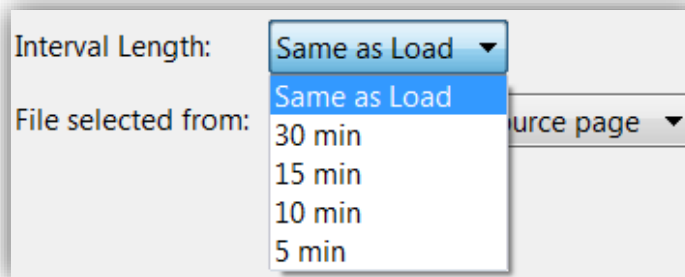
Effective capacity (%)

Age of battery (days)

— [ T = 20C, SOC=50% ]  
 — [ T = 30C, SOC=100% ]  
 — [ T = 40C, SOC=50% ]  
 — [ T = 50C, SOC=100% ]



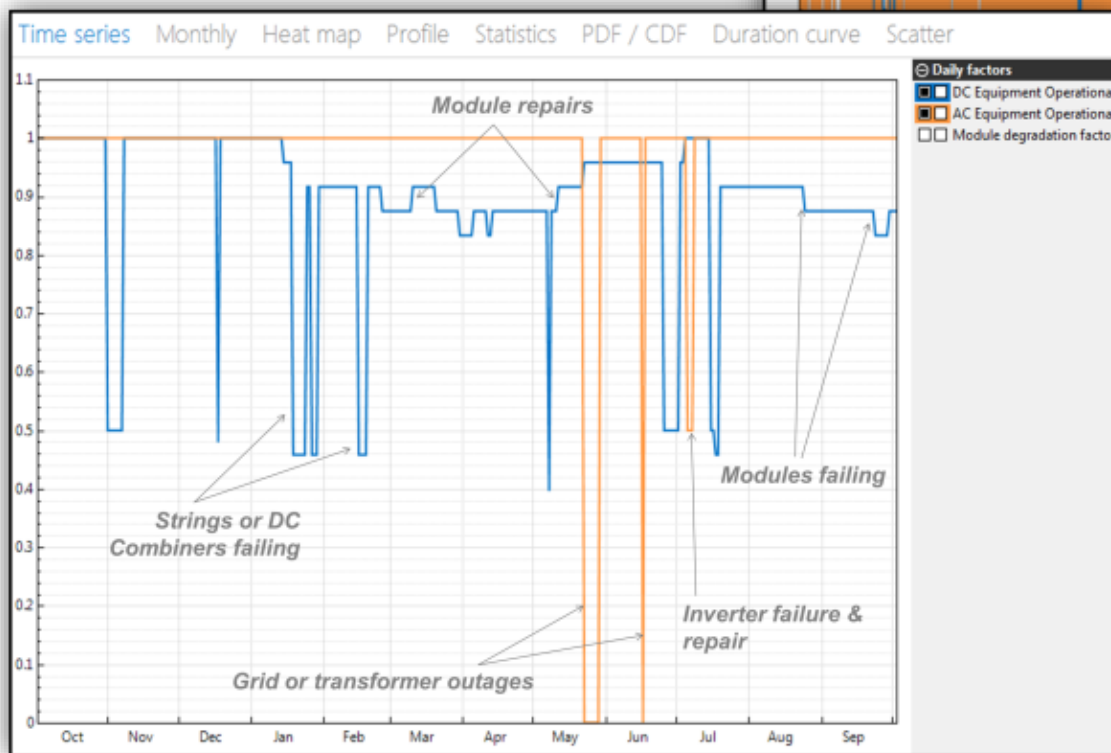
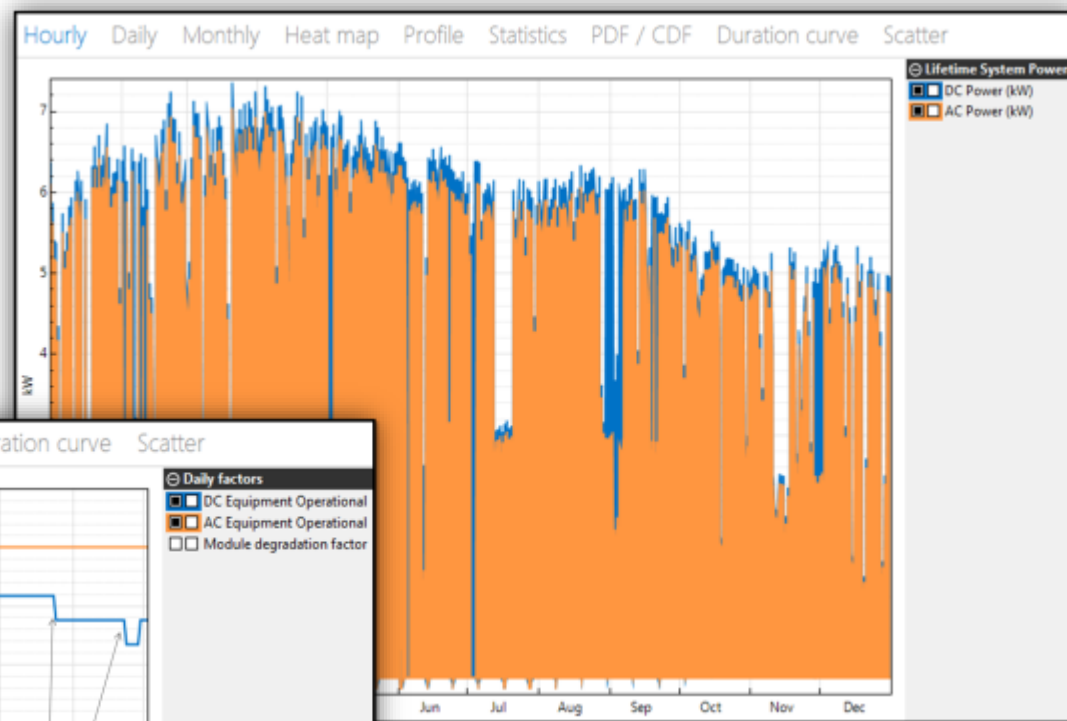
Easily interpolate hourly weather files to sub-hourly to match load profiles





Released Beta version of the Photovoltaic Reliability Performance Model (PV-RPM) that has been implemented in SAM LK scripting language

<http://sam.nrel.gov/pvrpm>



Samples failure distributions for components in a PV system and predicts failure times, replacement costs, and performance/cost impacts for a more realistic representation of LCOE of PV systems

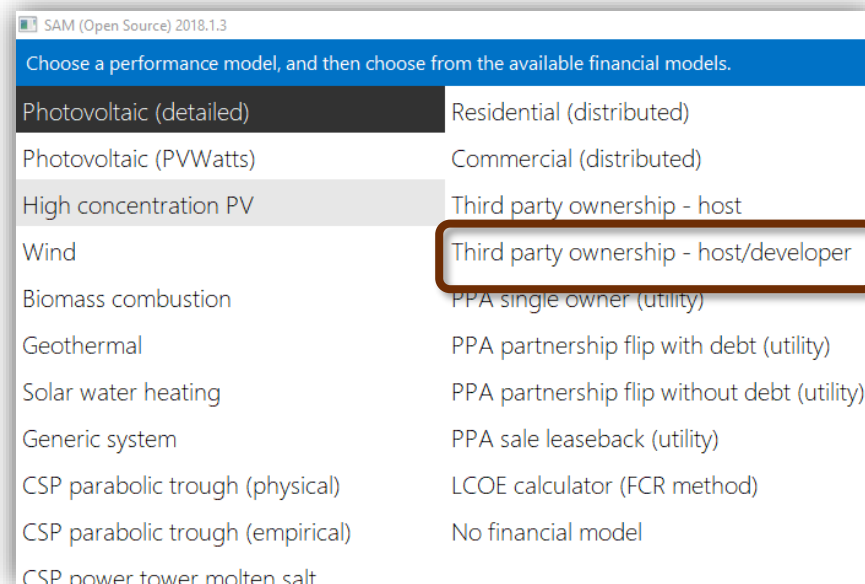
Coming Soon



Dual-perspective financial model combines:

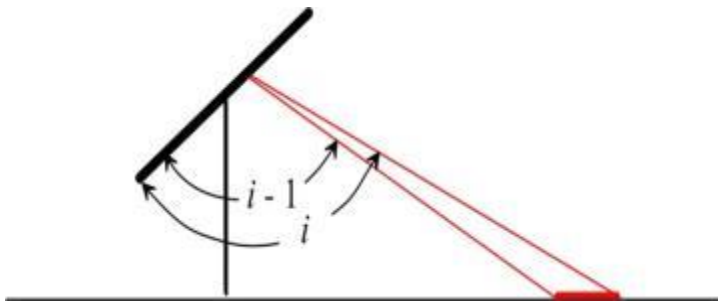
1. Single owner cashflow model: calculates PPA required for financial viability to developer
2. Third party ownership model: calculates value to host with PPA price as input

To evaluate PPA prices that make system financially viable to both parties (military bases, housing authorities, etc.)





Implementing bifacial model developed by Marion et al into main workflow of SAM



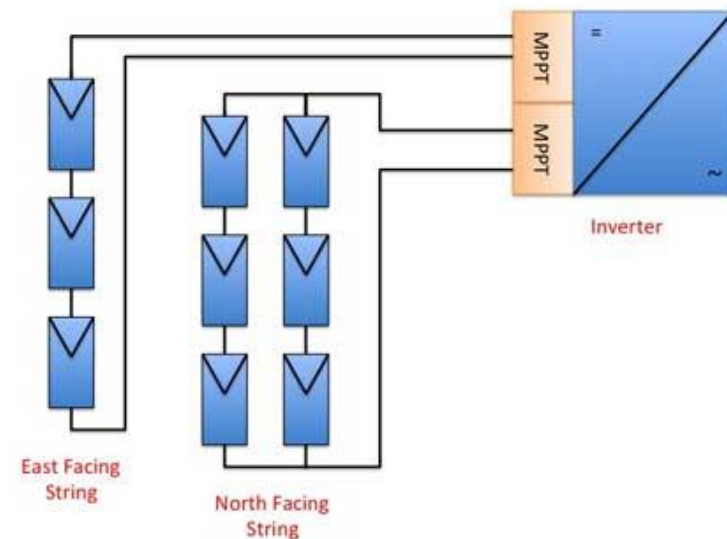
"A Practical Irradiance Model for Bifacial PV Modules", Marion et al, 44<sup>th</sup> IEEE PVSC, June 2017



In conjunction with Southern Company, implementing a PV+Battery+Fuel Cell model within SAM



- Ability to model inverters with multiple MPPT inputs
  - Different subarray orientations
  - Varying string lengths
  - etc
- Requires re-architecting core PV model code
  - Simultaneously designing to simplify possible future projects





# Proposed Work



- Open Source Model
  - Incorporating user contributions, open source community support
  - Better align PV model with pvlb
- Platform Improvements
  - Keep up to date in rapidly evolving battery, utility rate, and financial modeling worlds
  - Better connection with NREL building load modeling resources
- PV Model Improvements
  - Battery model: resiliency calculations, optimal sizing, optimized dispatch
  - Smart inverter and off-MPPT operation for realistic grid integration studies
  - Improved shorter timestep modeling
- Stakeholder engagement, foundational maintenance, technical support

**Thank you for your 15 letters of support!!**



## Establish consensus methods for quantifying energy uncertainty in energy production estimates

- Propagate modeling uncertainty into annual energy estimates
  - Identify & quantify sources of uncertainty
  - Identify & implement methods to efficiently propagate uncertainty to desired energy estimate metrics
  - Publish methodologies (both in literature and in open source code)
- Quantify & publish reliability uncertainty using operational data
- Propagate reliability uncertainty into energy estimates using the PV-RPM model as a foundation
- Quantify and represent weather uncertainty, leveraging long-term historical datasets

**We need your involvement!!**



- **Crowd-sourced component database**
- Floating PV, BIPV, Transparent/shifted spectrum PV
- Using spectral data from the new spectral NSRDB
- Importing measured data and tools for automated comparison

# 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

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

[www.nrel.gov](http://www.nrel.gov)

<http://sam.nrel.gov>

