System Advisor Model (SAM)

Darice Guittet

BTMS face to face meeting

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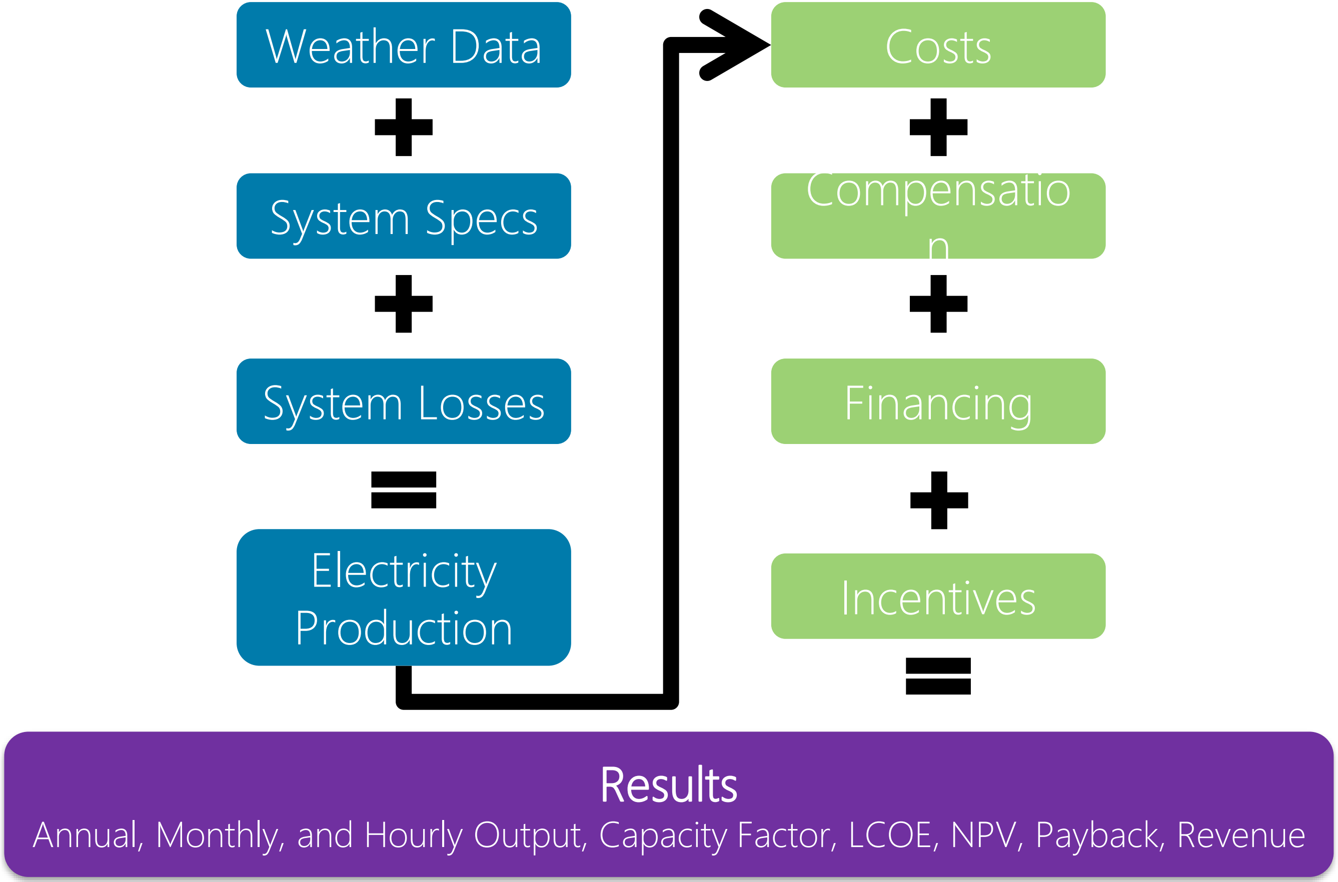
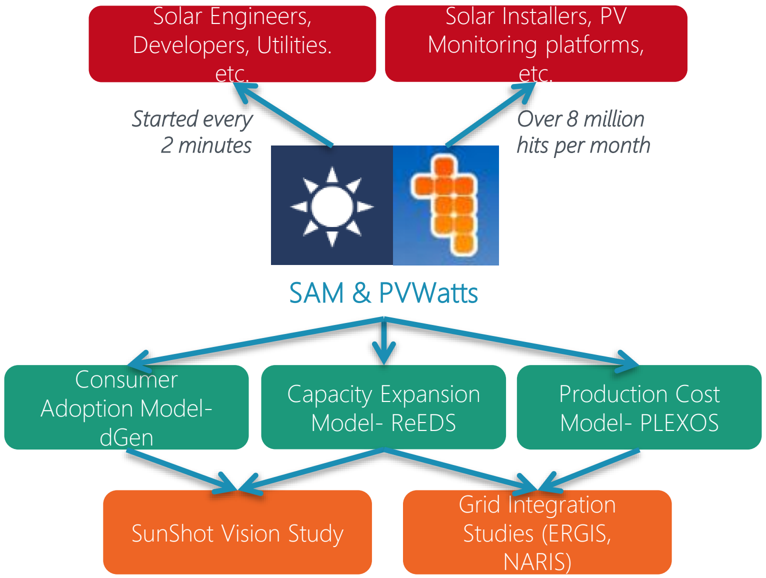
Steps to Modeling Renewable Energy



How does SAM fit in at NREL and externally?



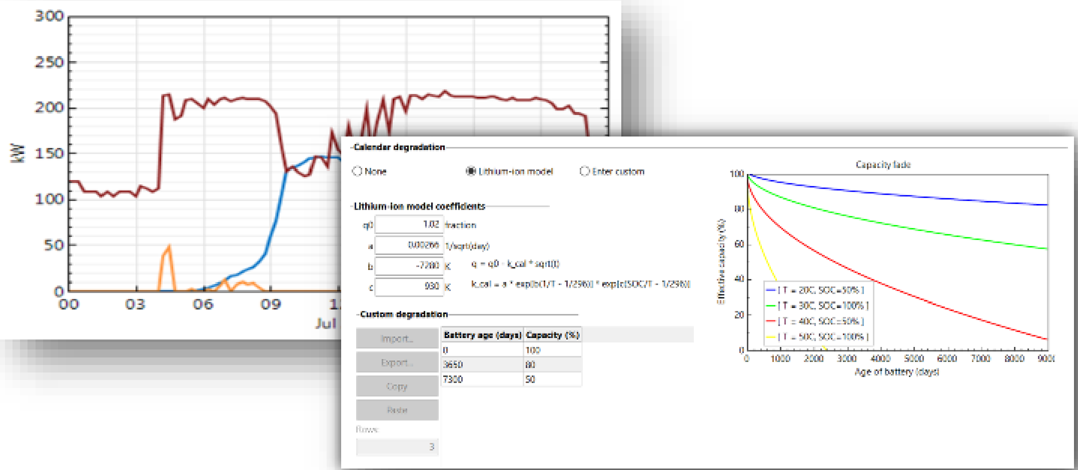
- ✓ Grid integration studies
- ✓ Renewable energy futures
- ✓ LCOE of breakthrough technologies
- ✓ Policy and utility rate design
- ✓ Technical potential studies
- ✓ Commercial applications (e.g. Southern Company, AEP, Sunrun)

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
  - iOS / Android
- Web Services API (PVWatts Only)
- *NEW: Open-source SAM code*

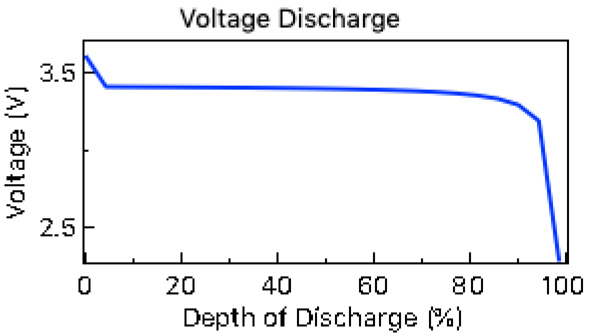
Detailed Battery Model

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

Voltage Versus SOC Model



C-rate of discharge curve	0.43	
Fully charged cell voltage	3.6	V
Exponential zone cell voltage	3.4	V
Nominal zone cell voltage	3.3	V
Charge removed at exponential point	2.17	%
Charge removed at nominal point	88.9	%

$$V_t(q_{t-1}, Q_t, I_t) = E_0 - K\frac{Q_t}{q_{t-1} - I_t\Delta t} + Ae^{-B(Q_t - q_{t-1} - I\Delta t)} - RI_t$$

Steady-state (constant current) model

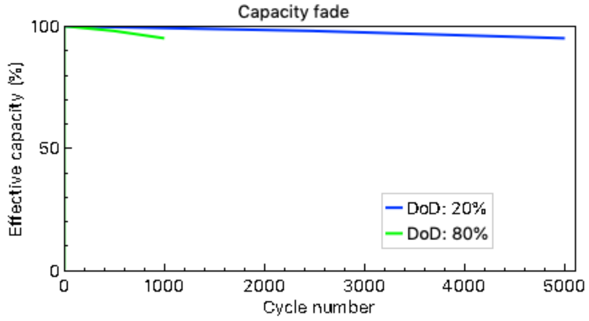
Voltage a function of

- Coefficient of polarization
- Current density inversely proportional to remaining capacity
- Internal resistance
- Empirical expression for initial voltage drop

O. Tremblay, L. Dessaint and A. Dekkiche, "A Generic Battery Model for the Dynamic Simulation of Hybrid Electric Vehicles," *2007 IEEE Vehicle Power and Propulsion Conference*, Arlington, TX, 2007, pp. 284-289.

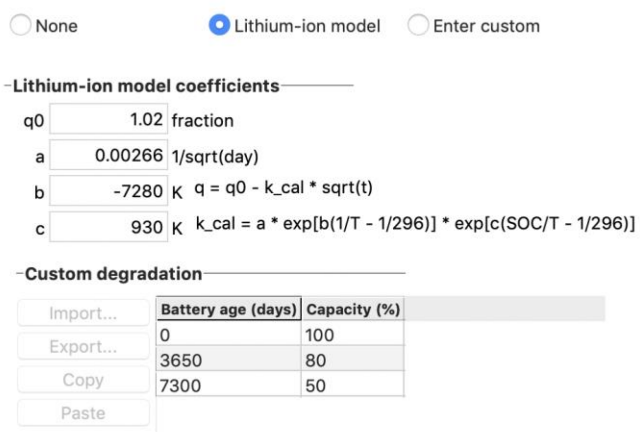
Cycle Degradation

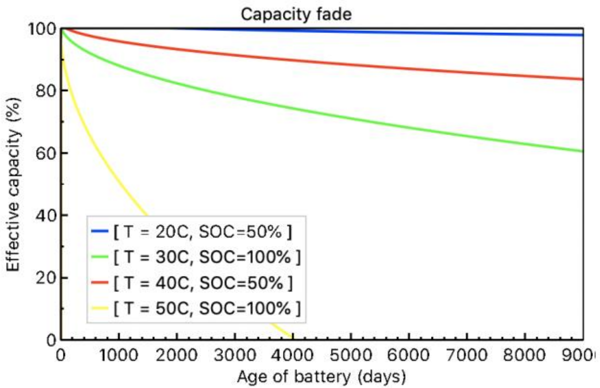
Depth-of-discharge (%)	Cycles Elapsed	Capacity (%)
20	0	100
20	2500	98
20	5000	95
80	0	100
80	500	98
80	1000	95



- Capacity remaining a function of DOD and number of cycles
- Provided as a table that's bilinearly interpolated

Calendar Degradation

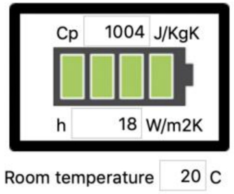




Storage capacity fade:

1. function of high or low temperature and SOC
2. table of days versus remaining capacity

Thermal



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Temp (C)	Capacity(%)
-10	60
0	80
25	100
40	100

$$T(t) = (T_0 - T_{amb})e^{-\frac{Aht}{mCp}} + \frac{I^2R}{Ah} + T_{amb}$$

$$T_{avg} = (T_0 - T_{amb})\frac{mCp}{Aht}(1 - e^{-\frac{Aht}{mCp}}) + \frac{I^2R}{Ah} + T_{amb}$$

Lumped system analysis assumes spatially uniform heat distribution

Heat transfer a function of:

- heat generated by the cell's internal resistance
- heat transferred to ambient conditions by convection

Additions

- Resistance change with temperature as table
- Adding a temperature column for cycle degradation table
- Heat dissipation as output
- Using calendar * cycle fade rather than taking the minimum of the two