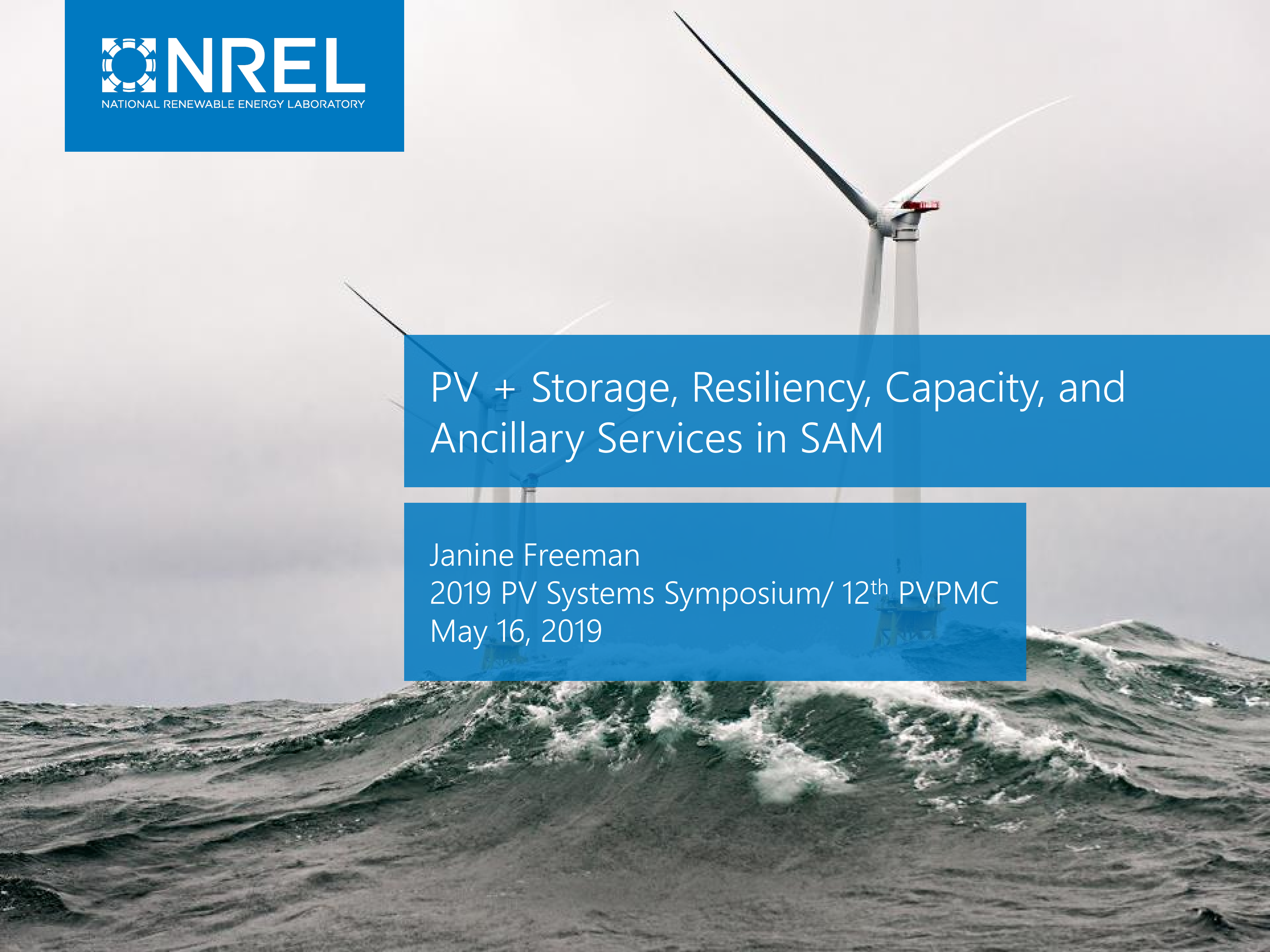


PV + Storage, Resiliency, Capacity, and Ancillary Services in SAM

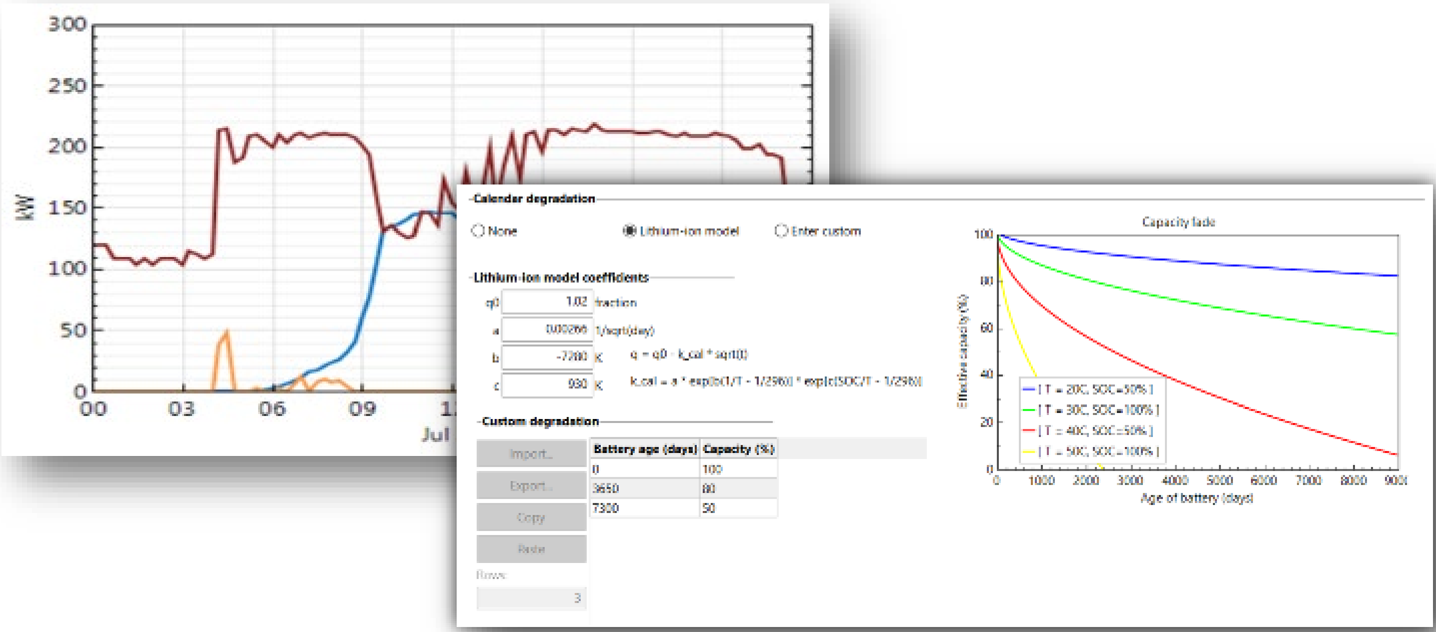
Janine Freeman

2019 PV Systems Symposium/ 12th PVPMC

May 16, 2019

Detailed Battery Model

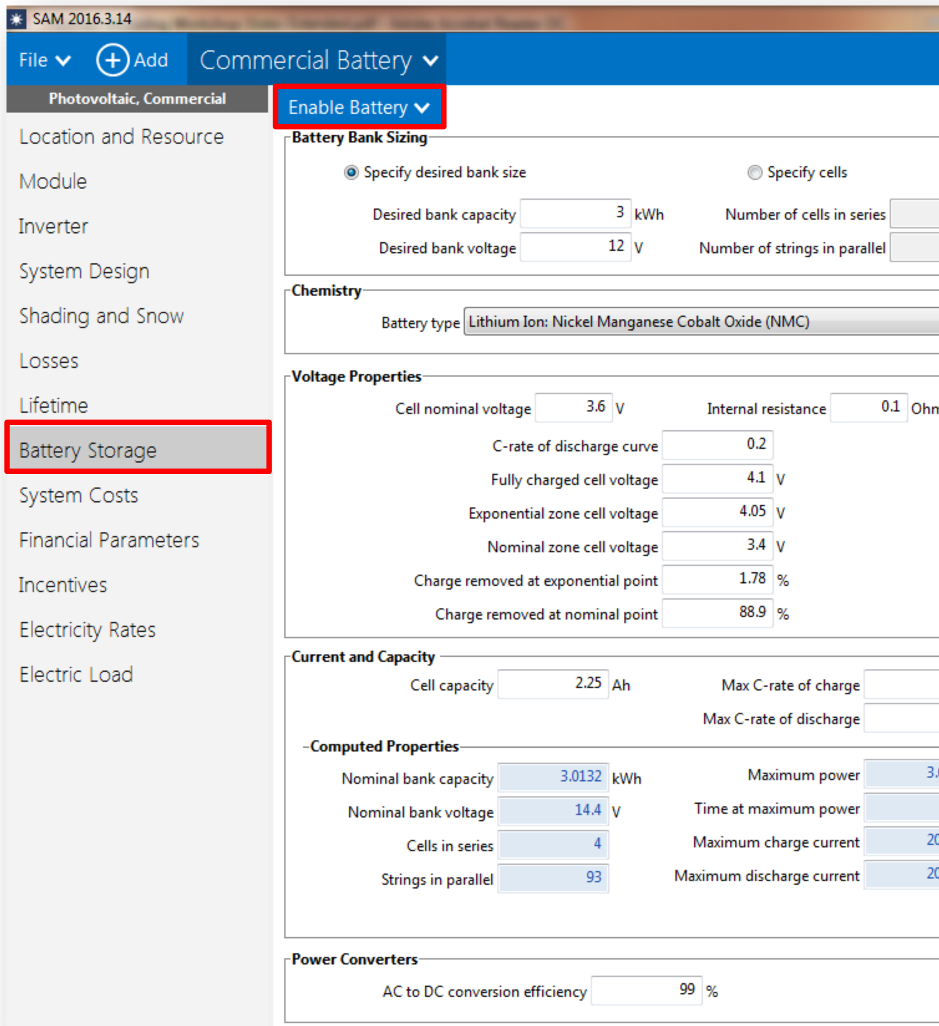
Only publicly available tool with detailed battery model that accounts for voltage characteristics, calendar and cycle degradation, etc



- ✓ Currently integrated with PV 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

Battery Performance Model

Photovoltaic (detailed)



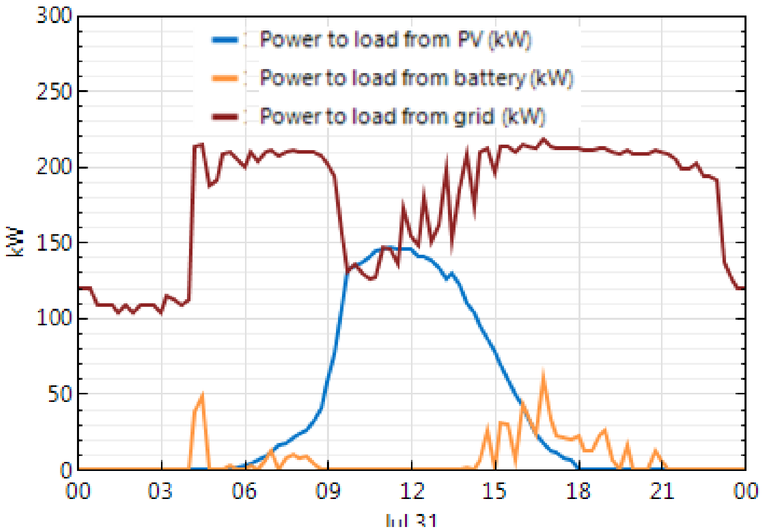
Ability to configure

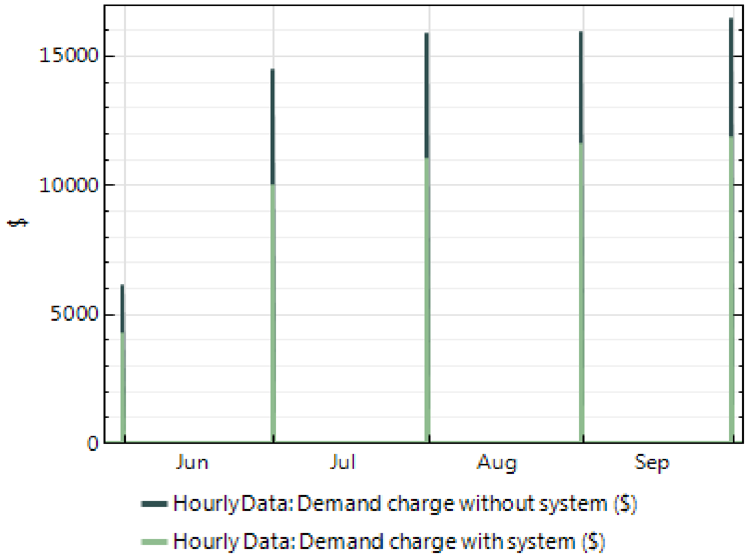
- Battery size
- Battery voltage
- Cell properties
- Chemistry type
- Max charge, discharge rates
- Battery configuration
- Power electronics efficiencies
- Battery operational limits
- Battery dispatch
- Battery lifetime properties
- Battery replacement preferences
- Battery thermal properties

Behind-the-meter Dispatch

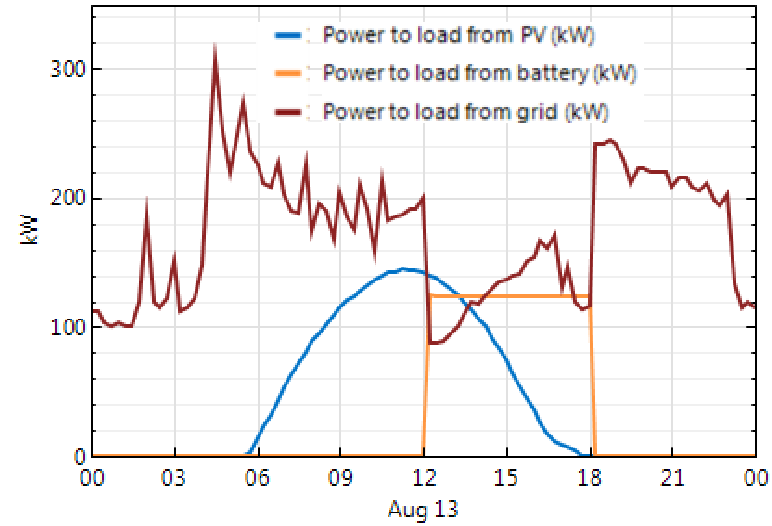
System Advisor Model

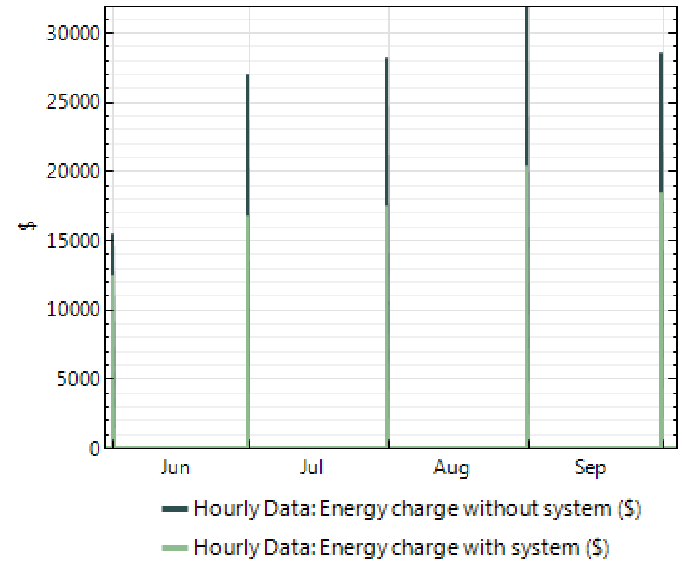
Peak shaving for demand charge reduction





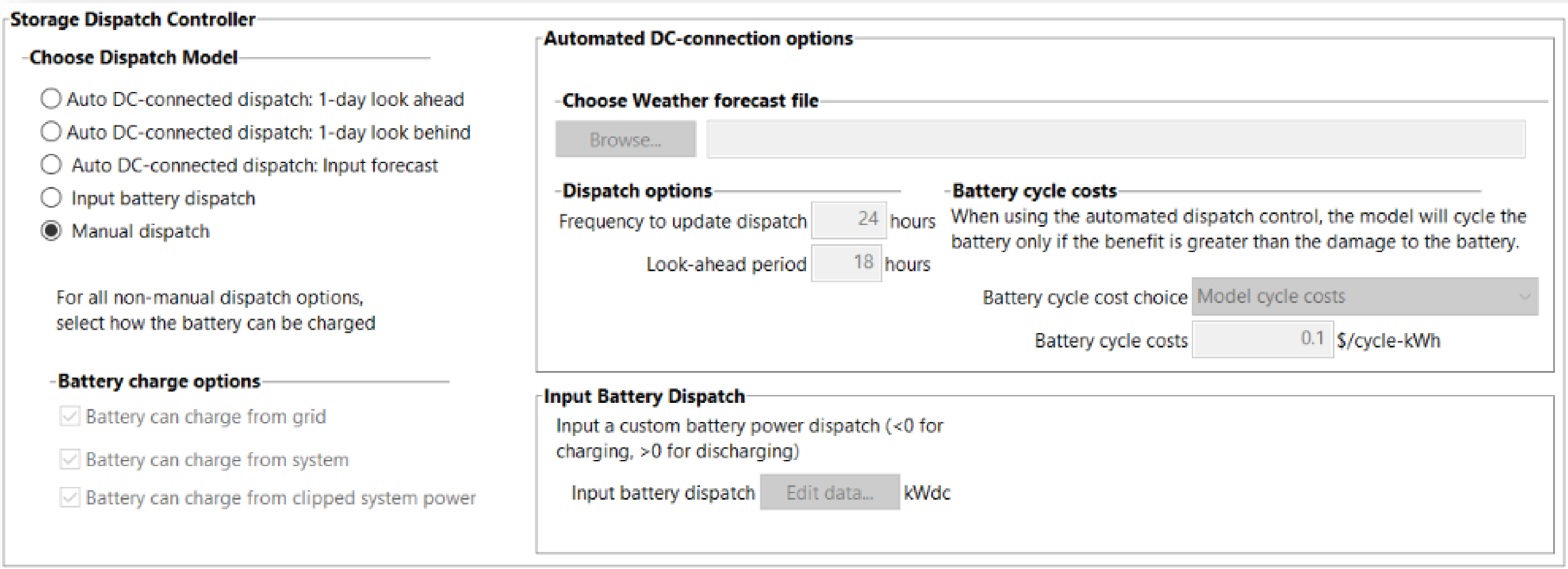
Manual dispatch for energy arbitrage





Battery Dispatch Front-of-meter

System Advisor Model



- Recently added automated control strategies for large plants with DC-connected battery systems
- Optimize dispatch to charge from PV, capture clipping, and maximize value

Upcoming Battery Model Improvements

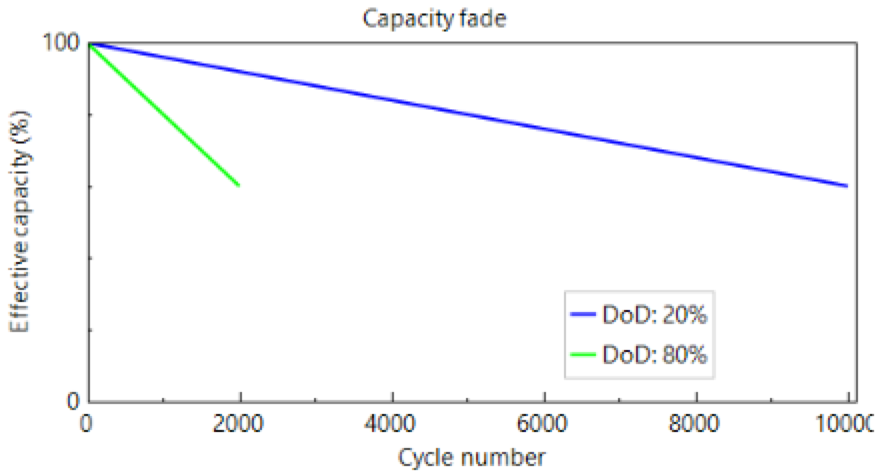
System Advisor Model

Behind-the-meter price signal optimal dispatch (end of 2019)

Image from SCE TOU-GS-2 Option B datasheet

Given the utility rate tariff, forecast PV generation, battery wear costs, generate optimal dispatch strategy

Improved battery lifetime model



Add predictive model which computes degradation based on battery characteristics and cycling

Hybrid PV + Battery + Fuel Cell

System offers multiple resources with different characteristics to improve flexibility and when meeting loads

PV

Battery

Fuel cell

Electric, Thermal Loads

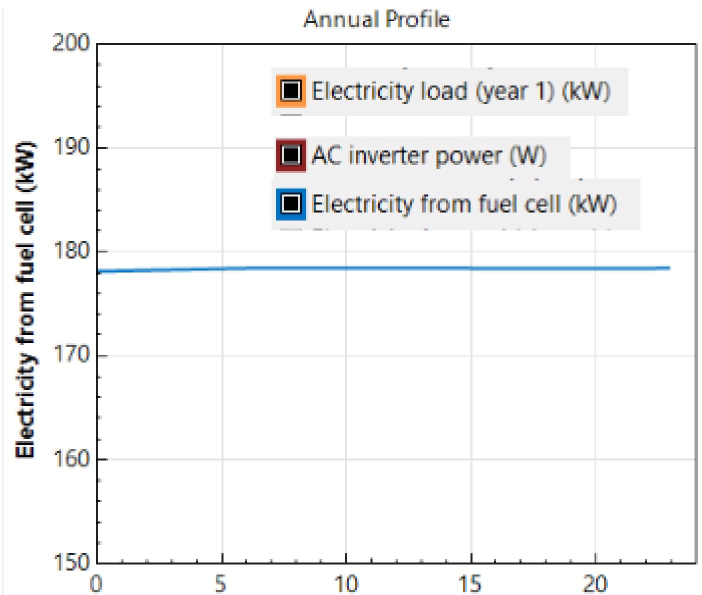
Transformer

Grid

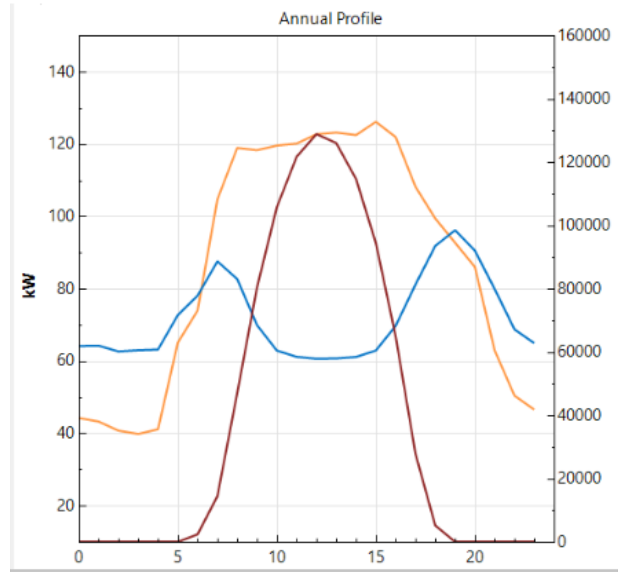
**Images from NREL image gallery*

Fuel Cell Operation

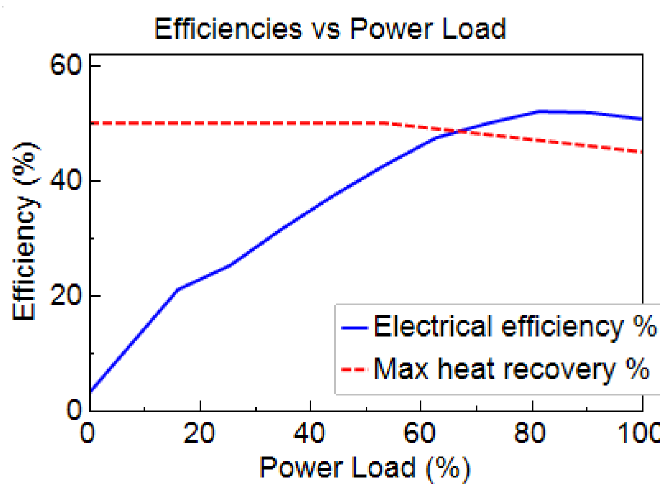
System Advisor Model



Fixed output



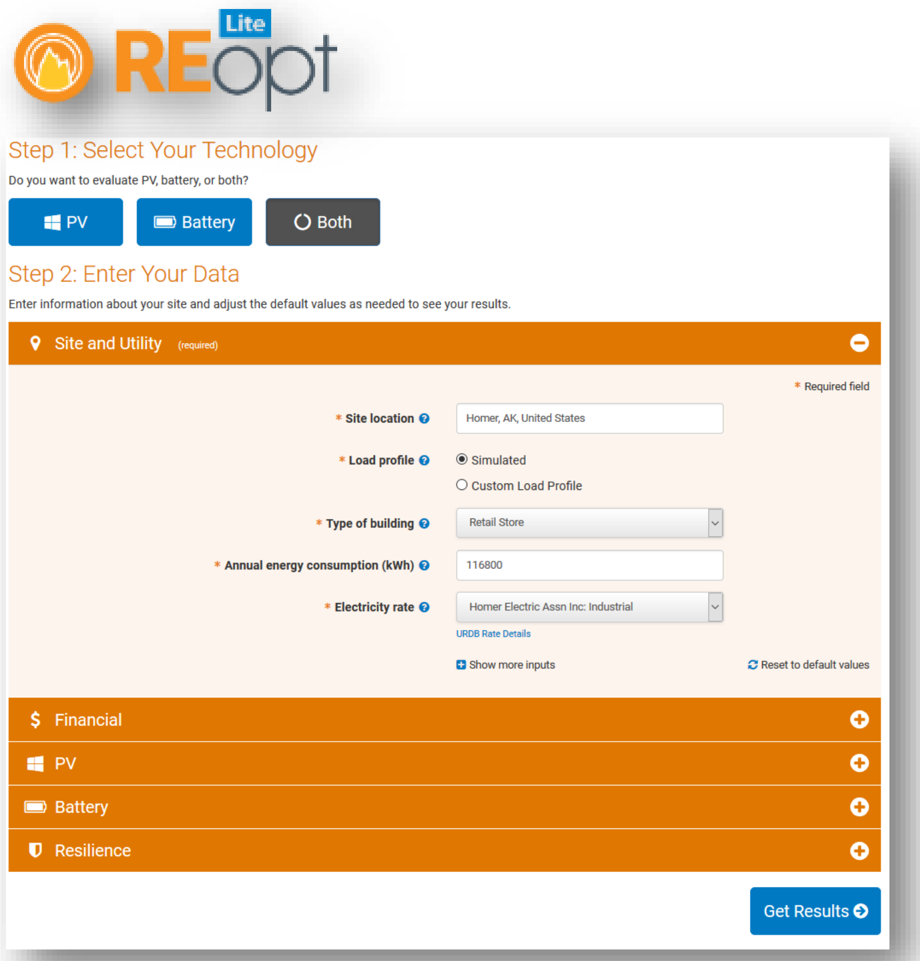
Load following



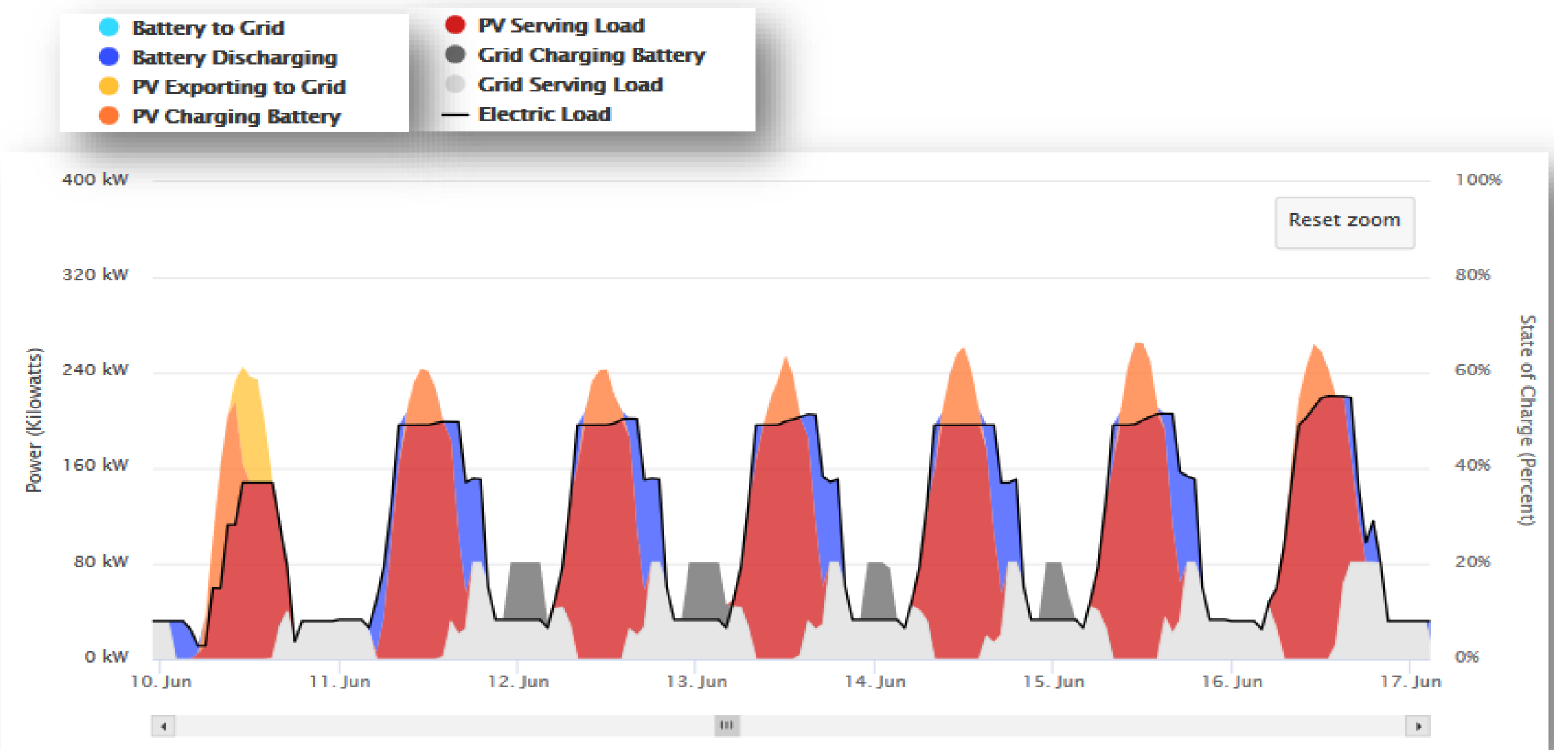
- Fuel cell operates with defined ramp rate limits, degradation rate
- Efficiencies govern fuel usage and thermal generation
- Multiple fuel cell chemistries
- Battery makes up difference between fuel cell operational limits and load following

PV + Battery for Resiliency

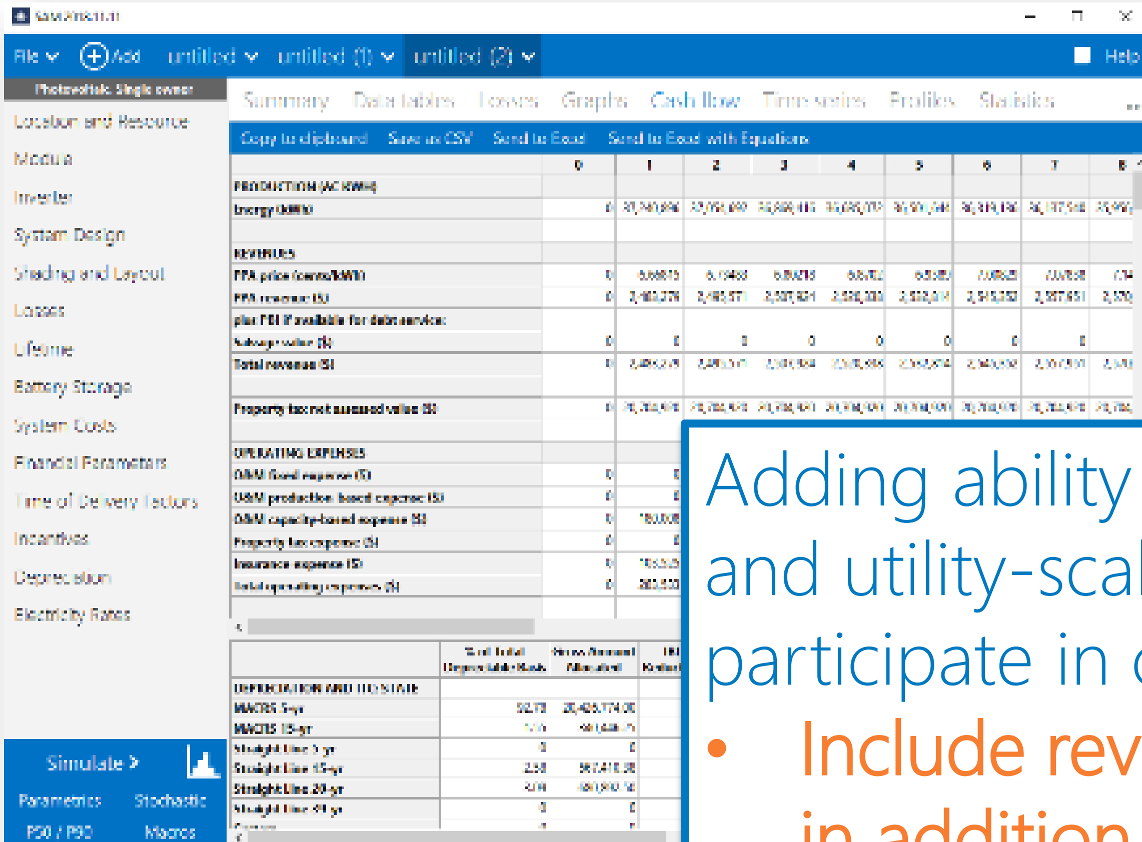
- Leverage the NREL REopt Lite methodology to:
  - Size PV+Storage systems to sustain critical load
  - Optimize PV and battery system sizes and dispatch strategy to minimize life cycle cost of energy
- Then run the optimally sized system through SAM's more detailed technology & financial models to understand realistic system performance



Output metrics quantifying resiliency of your site to withstand outages for full load, critical loads



Participation in Capacity Markets



Adding ability for commercial and utility-scale systems to participate in capacity markets

- Include revenue in cash flow in addition to PPA revenue
- Accounting for capacity credit of renewable systems

Participation in Ancillary Service Markets

Mimic merchant plant operation allowing battery to dispatch according to cleared market capacity

Multiple available revenue streams (reserves, frequency regulation, etc)

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

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