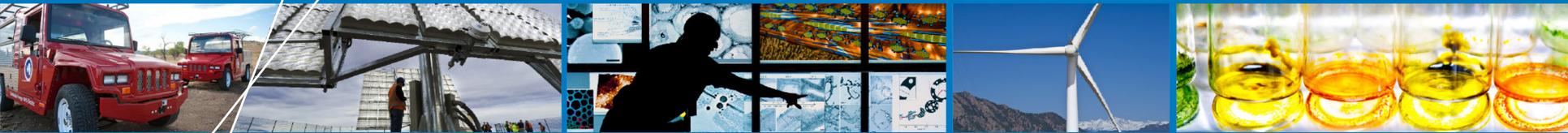


System Advisor Model Battery Storage



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September 17, 2015

Outline

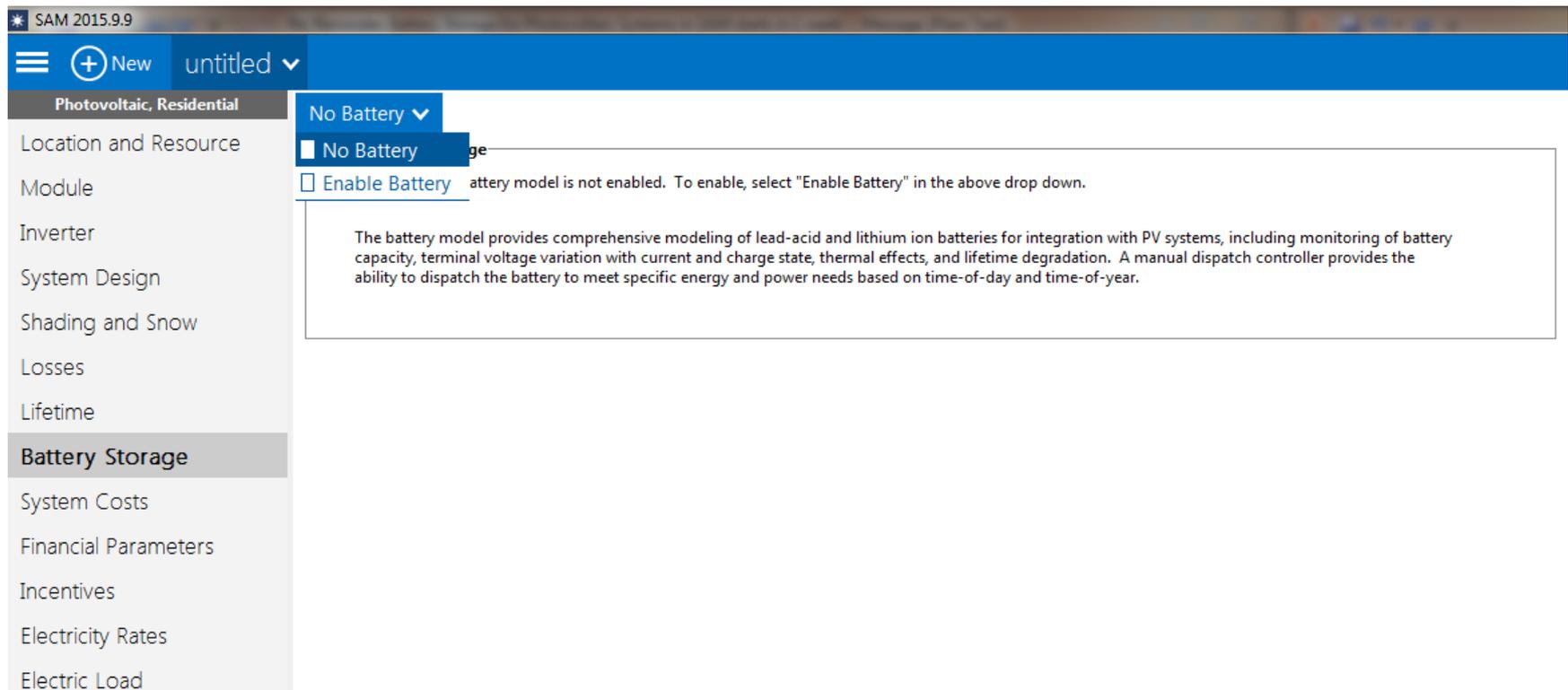
- **Overview of battery model**
- **Battery financial inputs**
- **Battery technical performance**
- **Battery dispatch**
- **Upcoming features**
- **Demonstration**
- **Q & A**

Model Overview

- **Techno-economic model for behind-the meter residential, commercial, and third-party ownership systems**
 - Lead acid & lithium ion battery chemistries
 - System lifetime analysis including battery replacement costs
 - Models for terminal voltage, capacity, temperature
 - Manual dispatch controller

Enabling Battery Model

- Must select **Start New Project -> Photovoltaic (detailed) -> Residential (distributed) or Commercial (distributed) or Third Party Ownership**
- Then, **Enable Battery** from the **Battery Storage** sidebar



Battery Financials

- **System lifetime analysis**

Single year does not capture complexity of battery replacements

- **Upfront & replacement costs**

Battery bank capacity [kWh] * price [\$/kWh]

PV simulation over analysis period ▾

PV Array Performance Degradation

Module degradation rate %/year

Applies to the array's hourly DC output.

Direct Capital Costs

Module	<input type="text" value="928"/> units	<input type="text" value="0.2"/> kWdc/unit	<input type="text" value="199.8"/> kWdc	<input type="text" value="0.71"/> \$/Wdc	▾
Inverter	<input type="text" value="5"/> units	<input type="text" value="36.0"/> kWac/unit	<input type="text" value="180.0"/> kWac	<input type="text" value="0.21"/> \$/Wdc	▾
Battery bank	<input type="text" value="3.0"/> kWh dc		<input type="text" value="600.00"/> \$/kWh dc		

- **User specified replacement criteria**

When max capacity is n % of original maximum

- **Escalation/De-escalation**

Model battery replacement costs over time

Battery Bank Replacement

- No replacements
- Replace at specified capacity
- Replace at specified schedule

Battery bank replacement threshold % capacity

Battery bank replacement schedule

Battery bank replacement cost \$/kWh

Cost escalation above inflation %/year

In Value mode, SAM applies both inflation and escalation to the first year cost to calculate out-year costs. In Schedule mode, neither inflation nor escalation applies. See Help for details.

Battery Performance

The screenshot shows the SAM 2015.6.30 software interface. The top menu bar includes 'SAM 2015.6.30', a hamburger menu, '+ New', and 'untitled'. The left sidebar lists 'Photovoltaic, Residential', 'Location and Resource', 'Module', 'Inverter', 'System Design', and 'Shading and Snow'. The main panel is titled 'Enable Battery' with a dropdown arrow. A callout box points to this dropdown with the text 'Must be enabled'. Below this is the 'Battery Bank Sizing' section, which has two radio buttons: 'Specify desired bank size' (selected) and 'Specify cells'. Under 'Specify desired bank size', there are input fields for 'Desired bank capacity' (3 kWh) and 'Desired bank voltage' (12 V). Under 'Specify cells', there are input fields for 'Total cells in series' (3) and 'Total number of strings' (1). A callout box points to these fields with the text 'Size battery bank'. Below the 'Battery Bank Sizing' section is the 'Chemistry' section, which has a dropdown menu for 'Battery type' set to 'Lithium Ion: Nickel Manganese Cobalt Oxide (NMC)'. A callout box points to this dropdown with the text 'Select battery type'.

- **Minimum necessary inputs for battery performance**
- **Other inputs can be populated by accepting defaults for battery chemistry type or manually input**
- **Remember to scale battery bank voltage as you increase capacity**

Battery Dispatch

Manual Storage Dispatch Controller

	Charge from grid	Charge from PV	Allow discharging	% capacity to discharge
Period 1:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="text" value="25"/> %
Period 2:	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="text" value="25"/> %
Period 3:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="text" value="25"/> %
Period 4:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="text" value="25"/> %
Period 5:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="text" value="25"/> %
Period 6:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="text" value="25"/> %

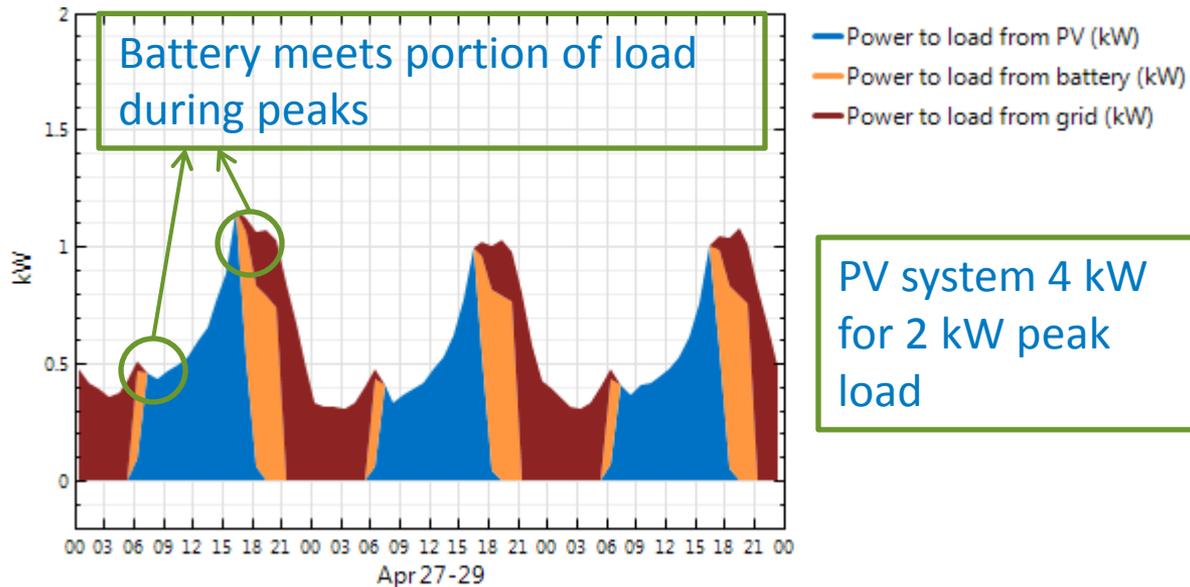
Minimum state of charge	<input type="text" value="30"/> %
Maximum state of charge	<input type="text" value="95"/> %
Minimum time at charge state	<input type="text" value="10"/> min

	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm
Jan	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1
Feb	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1
Mar	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1
Apr	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1
May	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1
Jun	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1
Jul	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1
Aug	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1
Sep	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1
Oct	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1
Nov	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1
Dec	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	4	4	4	1	1

By default, the battery controller aims to minimize energy purchases from the grid. It first tries to meet load with PV, then battery, then grid. Any PV in excess of load is used to charge the battery. Use the timing controls above to put constraints on the battery controller. See help for more details.

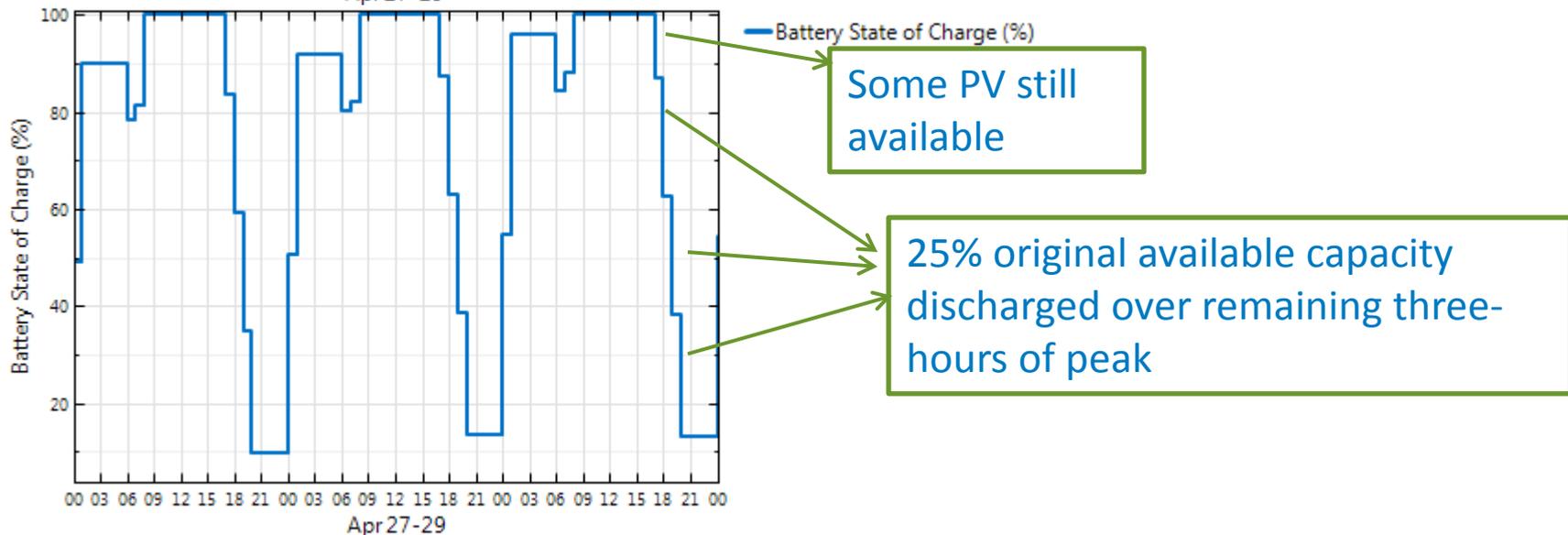
- Can specify when to charge from grid, pv, and discharge, and max energy to discharge
- Limits for state-of-charge, rapid oscillations
- Grid recharge mode

Dispatch Visualization



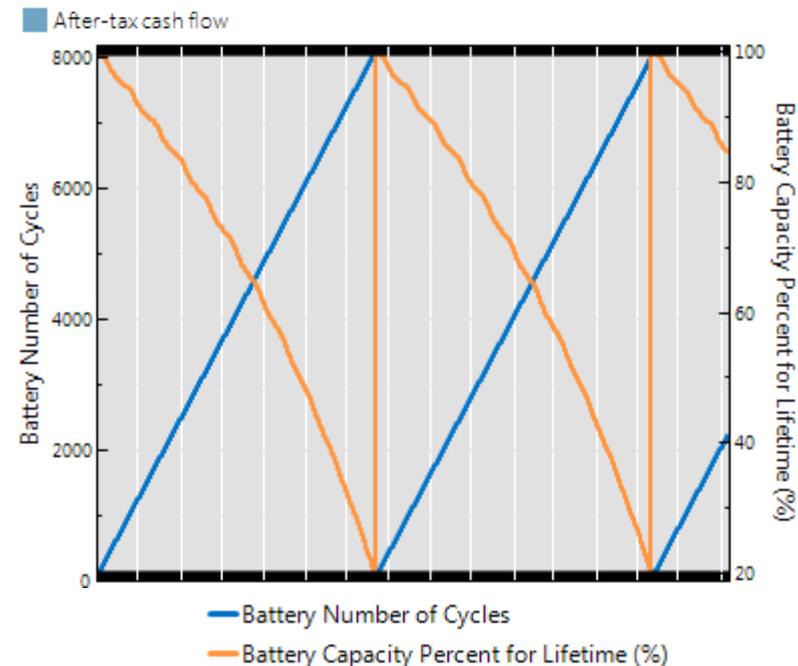
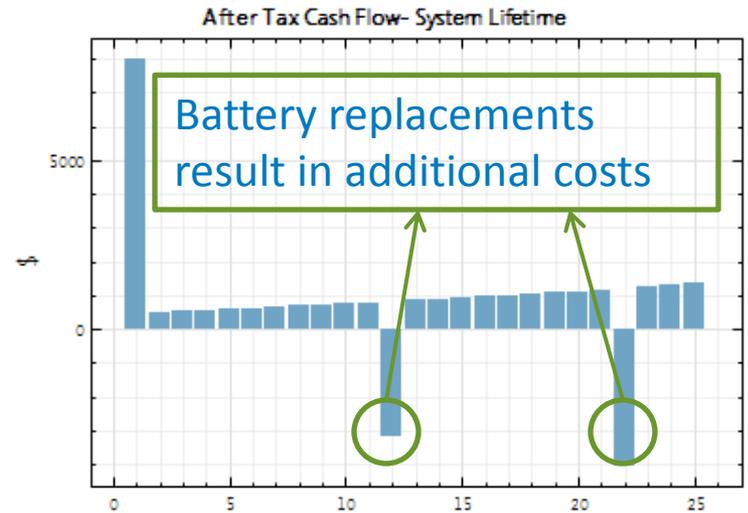
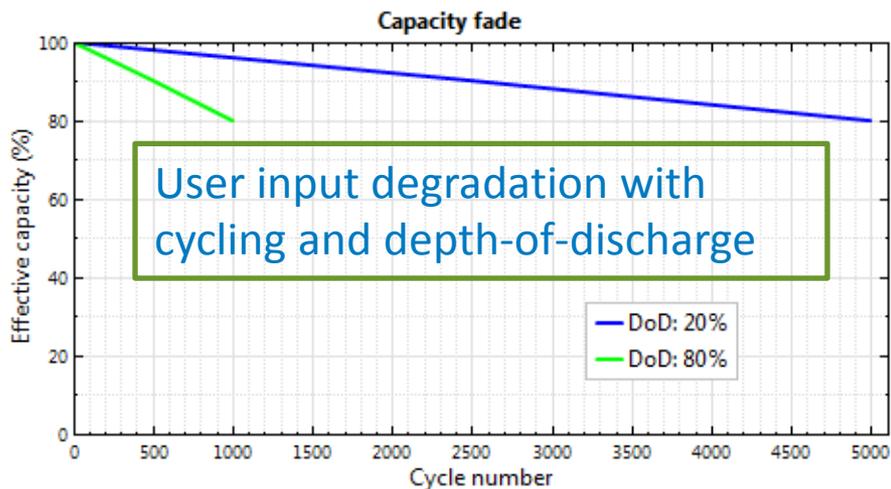
Strategy

- Charge from grid 12-2 am
- Charge from excess PV anytime available
- Discharge to meet load during morning peak
- Discharge to meet load during evening peak
- Minimum SOC: 5%



Lifetime degradation and financials

- User input *dispatch strategy*, *degradation*, *replacement criteria* and *costs* result in tailorable replacement model.



Upcoming features

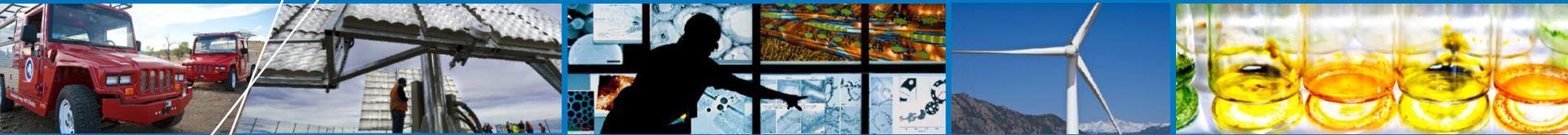
- **Automated dispatch for peak shaving**
 - 24 hour look ahead
 - Shave peaks every day based on battery capacity and ability to recharge from grid, or specify target power to shave to.
 - Rate structure not considered in dispatch decisions. Every peak is considered equal valuable.
- **Tailor amount of power to charge from grid**
- **Expected in next release (late 2015 or early 2016)**

Demonstration

Question: What is the benefit of adding batteries to PV for a commercial building in Los Angeles?

Steps:

- 1. Create a detailed PV case with Commercial financial model**
- 2. Input details about location, PV system, battery system**
- 3. Tailor dispatch strategy to electricity rates**
- 4. Compare payoff period to no-battery case**



Questions?