

# Batteries in SAM 2020.2.29: Behind-the-Meter Systems

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September 2, 2020

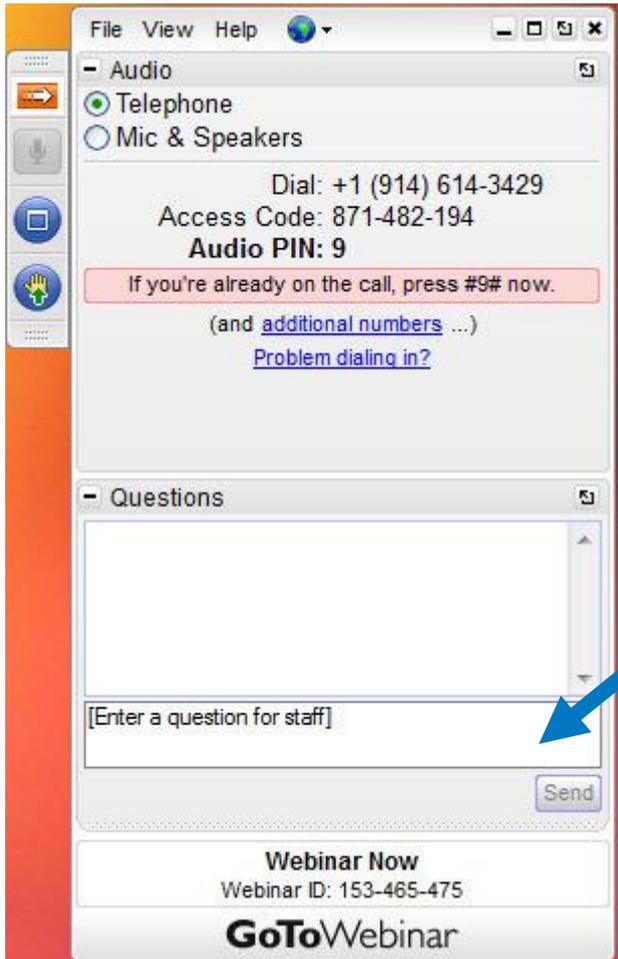


- Introduction to SAM Workshop July 22
- PV Systems in SAM 2020.2.29 Aug 5
- Batteries in SAM 2020.2.29:
  - Focus on Battery Technology Aug 19
  - **Behind-the-Meter Systems** Sep 2
  - Front-of-Meter Systems Sep 16

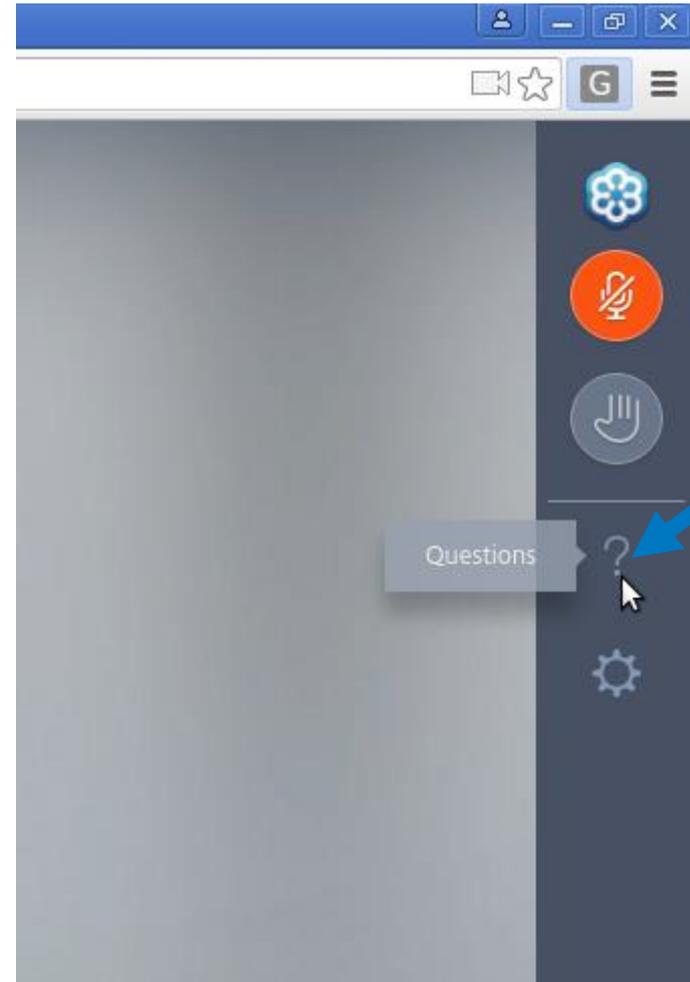
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*This webinar will be recorded and posted on the SAM website at <https://sam.nrel.gov/events.html>*

# Use the GoToWebinar control panel to ask questions



Desktop application



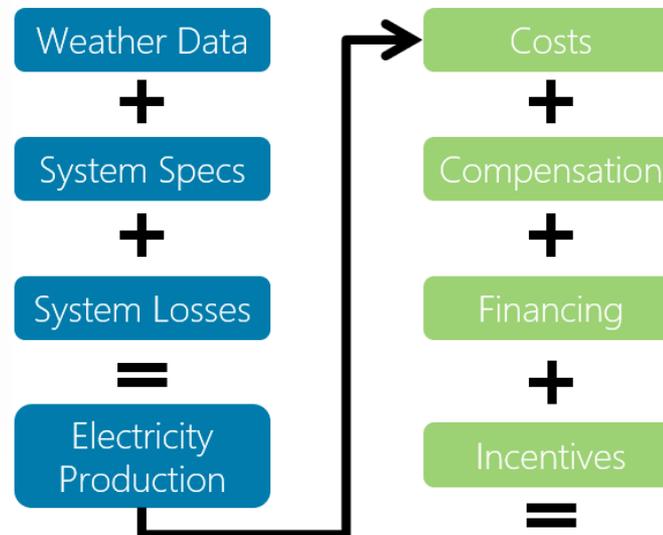
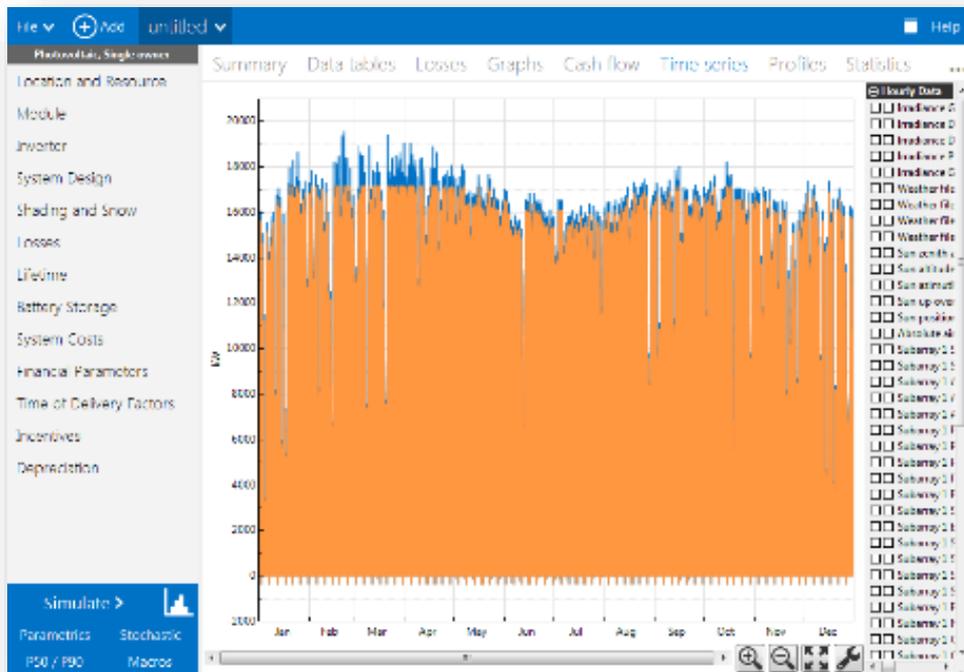
Instant Join Viewer

We will either type an answer to your question or answer it at the end of the presentation.

# System Advisor Model (SAM)



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



**Results**  
Annual, Monthly, and Hourly Output, Capacity Factor, LCOE, NPV, Payback, Revenue

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



## Technologies

Photovoltaics  
Detailed & PVWatts  
Battery Storage  
Concentrating solar power  
Fuel cell-PV-battery  
Wind  
Marine Energy  
Geothermal  
Solar water heating  
Biomass  
Generic

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## Financial

Behind-the-meter  
residential  
commercial  
third-party owned  
Power purchase agreements  
single owner  
equity flips  
sale-leaseback  
Host/developer  
Merchant plant  
Simple LCOE calculator



# Technologies

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# Financial

# Webinar Outline

1. Changes Since SAM 2018.11.11
2. Dispatch Mode Overview
3. Residential System Demo
4. Commercial System Demo
5. Generic System Demo

# Changes Since SAM 2018.11.11



SAM 2018.11.11

Choose a performance model, and then choose from the available financial models.

- Photovoltaic (detailed)
- Photovoltaic (PVWatts)
- High concentration PV
- Wind
- Biomass combustion
- Geothermal
- Solar water heating
- Generic system
- CSP parabolic trough (physical)
- CSP parabolic trough (empirical)
- CSP power tower molten salt
- CSP power tower direct steam
- CSP linear Fresnel molten salt
- CSP linear Fresnel direct steam
- CSP dish Stirling
- CSP generic model
- CSP integrated solar combined cycle
- Process heat parabolic trough
- Process heat linear direct steam

- Photovoltaic, Commercial
- Location and Resource
- Module
- Inverter
- System Design
- Shading and Layout
- Losses
- Lifetime
- Battery Storage**
- System Costs
- Financial Parameters
- Incentives
- Electricity Rates
- Electric Load

No Battery ▾

### Battery Energy Storage

By default, the battery model is not enabled. To enable, select "Enable Battery" in the above drop down.

The battery model provides comprehensive modeling of lead-acid and lithium ion batteries for integration with PV systems, including monitoring of battery capacity, terminal voltage variation with current and charge state, thermal effects, and lifetime degradation. A manual dispatch controller provides the ability to dispatch the battery to meet specific energy and power needs based on time-of-day and time-of-year.



SAM 2020.2.29

Choose a performance model, and then choose from the available financial models.

- > Photovoltaic
- ▼ Battery Storage
  - Detailed PV-Battery
  - PVWatts-Battery
  - Generic System-Battery
- > Concentrating Solar Power
- > Marine Energy
- Wind
- Fuel Cell-PV-Battery
- Geothermal
- Solar Water Heating
- Biomass Combustion
- Generic System

- > Power Purchase Agreement
- > Distributed Merchant Plant

The technology selection menu has been modified to specifically select battery-enabled and hybrid systems

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File Add untitled

PV-Battery, Residential

Location and Resource

Module

Inverter

System Design

Shading and Layout

Losses

Grid Limits

Battery Storage

Lifetime and Degradation

System Costs

Financial Parameters

Incentives

Electricity Rates

Electric Load

Chemistry

Battery type: Lithium Ion: Nickel Manganese Cobalt Oxide (NMC/Graphite)

Battery Bank Sizing

Set desired bank size

Specify cells

Desired bank capacity: 10 kWh

DC

Number of cells in series: 3

Desired bank power: 5 kW

DC

Number of strings in parallel: 1

Bank capacity and power fields are values measured before conversion and parasitic losses. If specified in AC, the DC/AC conversion efficiency is used.

Optimal Sizing and Dispatch from REopt

Use from the current case the lat/lon from Location and Resource, System Design parameters, Subarray 1 losses, System Costs, Electricity current PV system design the optimal battery power, capacity and dispatch from the REopt Lite API.

Value of lost load during outage: 100 \$/kWh

Get size and dispatch

Note: REopt downloads its own weather file from the provided lat/lon and does not use the one provided on the Location and Resource

Current and Capacity

Cell capacity: 2.25 Ah

Computed Properties

Nominal bank capacity: 10.133 kWh (DC)

Nominal bank voltage: 500.400 V (DC)

Total number of cells: 1.251

Cells in series: 139

Strings in parallel: 9

Max C-rate of discharge: 0.500 per/hour

Max C-rate of charge: 0.500 per/hour

Maximum discharge power (DC): 5.067 kWdc

Maximum charge power (DC): 5.067 kWdc

Maximum discharge power (AC): 4.800 kWac

Maximum charge power (AC): 5.208 kWac

Time at maximum power: 2.000 h

Maximum discharge current: 10.125 A

Maximum charge current: 10.125 A

The computed properties are the battery bank properties SAM uses for simulations. The nominal bank voltage is the product of the cell nominal voltage and number of cells in series. The nominal voltage is the product of the cell capacity, bank voltage, and number of strings in parallel. The C-rate is a measure of how much of the battery capacity can be charged or discharged per hour. The max power is computed from the max C-rate of discharge.

Power Converters

For the PV Battery configuration, the battery can be connected either to the DC or AC side of the PV inverter.

DC Connected

AC Connected

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File Add PV-Battery, Residential

PV-Battery, Residential

- Simulate
- Create report
- Clear all results
- Rename
- Duplicate
- Delete
- Move left
- Move right
- Change model...
- Reset inputs to default values
- Excel exchange...
- Generate code...

Help

Simulate

Parameters Stochastic  
P50 / P90 Macros

# Dispatch Mode Overview

# Behind The Meter Dispatch Modes



## Storage Dispatch Controller

### Dispatch Options

- Peak shaving one-day look ahead
- Peak shaving one-day look behind
- Input grid power targets
- Input battery power targets
- Manual dispatch

### Charge Options

For manual dispatch, charge options are defined below by dispatch period.

- Battery can charge from grid
- Battery can charge from system

### Monthly or Time Series Inputs for Grid Power Target Option

Monthly power targets

Monthly grid power targets  kWac

Time series grid power targets  kWac

Grid targets are maximum power values. SAM charges the battery when the electric load is less than the target in a given time step and discharges the battery when the load is greater than the target.

### Time Series Inputs for Battery Power Target Option

Time series battery power targets  kWdc

Battery targets are maximum power values. Use negative target values to charge the battery and positive to discharge. SAM will attempt to meet the power target within constraints of the system's operational limits.

## Manual Dispatch

	Charge from system		Charge from grid		Discharge	
	Allow	% capacity	Allow	% capacity	Allow	% capacity
Period 1:	<input checked="" type="checkbox"/>	<input type="checkbox"/> 25	<input type="checkbox"/>	<input type="checkbox"/> 25	<input type="checkbox"/>	<input type="checkbox"/> 25
Period 2:	<input checked="" type="checkbox"/>	<input type="checkbox"/> 25	<input type="checkbox"/>	<input type="checkbox"/> 25	<input checked="" type="checkbox"/>	<input type="checkbox"/> 25
Period 3:	<input type="checkbox"/>	<input type="checkbox"/> 25	<input type="checkbox"/>	<input type="checkbox"/> 25	<input checked="" type="checkbox"/>	<input type="checkbox"/> 25
Period 4:	<input type="checkbox"/>	<input type="checkbox"/> 25	<input type="checkbox"/>	<input type="checkbox"/> 25	<input checked="" type="checkbox"/>	<input type="checkbox"/> 25
Period 5:	<input type="checkbox"/>	<input type="checkbox"/> 25	<input type="checkbox"/>	<input type="checkbox"/> 25	<input type="checkbox"/>	<input type="checkbox"/> 25
Period 6:	<input type="checkbox"/>	<input type="checkbox"/> 25	<input type="checkbox"/>	<input type="checkbox"/> 25	<input type="checkbox"/>	<input type="checkbox"/> 25

To enable manual dispatch, choose the Manual Dispatch option above. For each enabled charge or discharge period the "% capacity" is the percentage of available capacity in a given time step.

Use the Copy Schedules button to overwrite the weekday and weekend schedules with schedules from either 1) energy charge schedules from the Electricity Rates page for behind-the-meter applications, or 2) TOD PPA price multipliers on the Revenue or Financial Parameters page for front-of-meter applications.

### Weekday

	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	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	1	1	1	1
Feb	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	1	1	1	1
Mar	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	1	1	1	1
Apr	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	1	1	1	1
May	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	4	4	4	4	1	1	1	1
Jun	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	4	4	4	4	1	1	1	1
Jul	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	4	4	4	4	1	1	1	1
Aug	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	4	4	4	4	1	1	1	1
Sep	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	4	4	4	4	1	1	1	1
Oct	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	4	4	4	4	1	1	1	1
Nov	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	1	1	1	1
Dec	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	1	1	1	1

### Weekend

	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	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Feb	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mar	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Apr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
May	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jun	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jul	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aug	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sep	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Oct	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nov	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dec	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



Dispatch Mode	Inputs	Use Case
<b><i>Peak Shaving (look ahead)</i></b>	Upcoming PV and Load forecast	Peak Demand Charges
<i>Peak Shaving (look behind)</i>	Yesterday's actual PV and Load	Peak Demand Charges (worst case)
Input Grid Power Targets	Monthly or time series targets	Specify more detailed peak power
<i>Custom Dispatch</i>	Time series	PySAM / outside optimization
<b>Manual Dispatch</b>	Schedule by hour and month	Energy Arbitrage

**Bold:** defaults

*Italics:* Available in PVWatts-Battery model

# Residential System Demo

Goal: Demonstrate dispatch options suited to time of use rates for behind the meter storage connected to a PV system

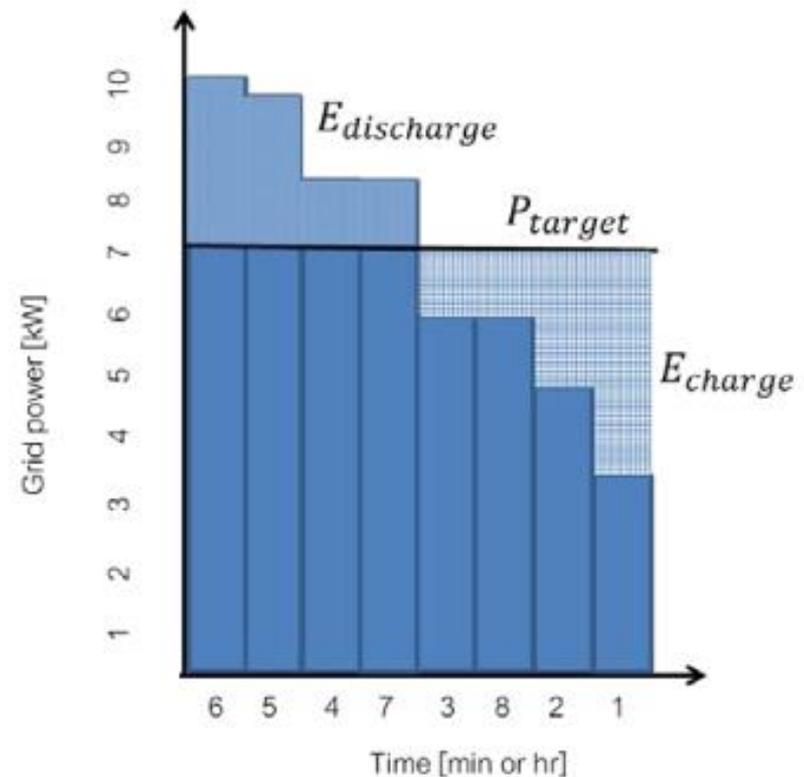
# Commercial System Demo

Goal: Demonstrate automated dispatch options for peak shaving  
and their relationship with peak demand charges

# What is a grid power target?



- Computed every 24 hours based on:
  - Battery capacity (full depth of discharge each day)
  - System energy forecast
  - Load forecast
- Sort and dispatch during the top n hours of grid use (load minus system generation)
- If grid use is greater than the target, dispatch
- If less than the target, charge
- Battery will not cycle if insufficient energy is available
- Use monthly maximum



From [DiOrio 2017](#)

# Generic System Demo

Goal: Demonstrate a wind generation profile and a stand-alone battery



- **PV Design:**

<https://sam.nrel.gov/photovoltaic/pv-videos.html>

- **Battery Model Chemistry and Sizing:**

<https://sam.nrel.gov/battery-storage/battery-videos.html>

- **Load and Utility Rates:**

<https://sam.nrel.gov/financial-models/residential-and-commercial.html>

- **Open EI Utility Rate Database:**

<https://openei.org/apps/USURDB/>

# Thank you! Questions?

Janine Freeman – project lead, photovoltaic and wind models

Nate Blair – emeritus lead, financials, costs, systems

Darice Guittet – software development, battery models

Brian Mirletz – software development, battery models

Matt Prilliman – photovoltaic and marine energy models

Steve Janzou – programming, utility rate structures (subcontractor)

Paul Gilman – user support and documentation (subcontractor)

Ty Neises – concentrating solar power models

Matt Boyd – concentrating solar power models

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

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