



# Batteries in SAM 2020: Front-of-Meter Systems

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2020 SAM Webinars  
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# SAM Webinars for 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

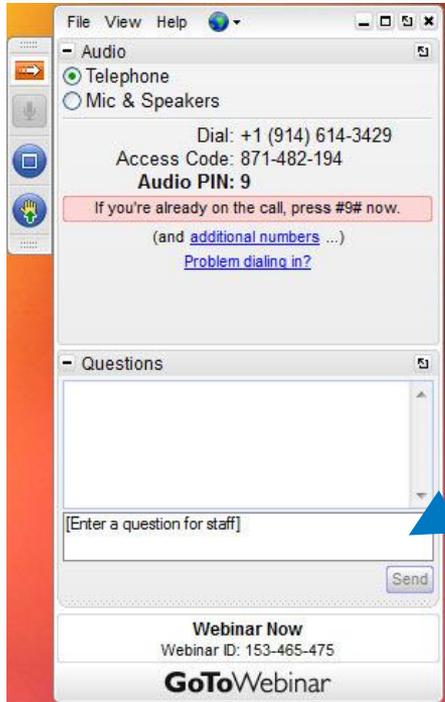
**Front-of-Meter Systems Sep 16**

PySAM Workshop Oct 14

Register for free at: <https://sam.nrel.gov/events.html>

*Find webinar recordings at <https://sam.nrel.gov/>*

# Questions and Answers



Desktop application



Instant Join Viewer

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

# Outline

- 1 Quick SAM overview**

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- 2 Front-of-meter storage considerations**

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- 3 Example 1: Manual dispatch**

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- 4 Example 2: Automated dispatch options**

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- 5 Example 3: DC-connected vs AC-connected**

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- 6 Example 4: Generic System – Battery tricks, Merchant Plant**

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- 7 Questions and answers**

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# What is SAM?

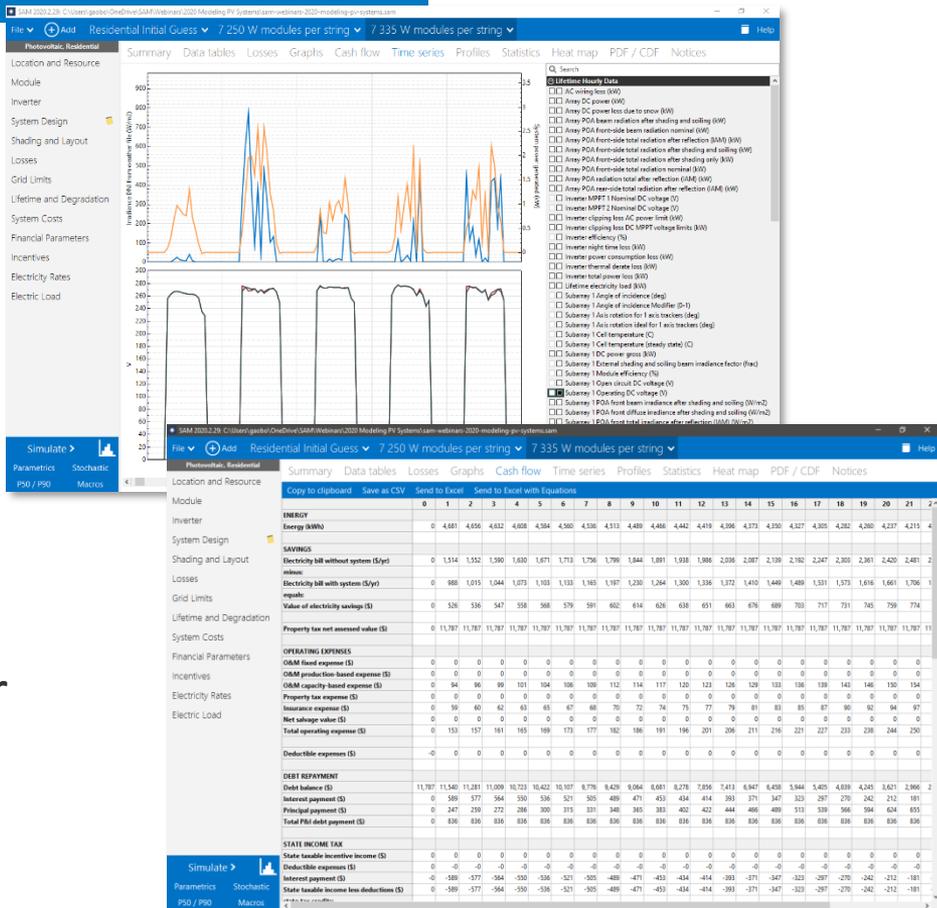
## The System Advisor Model

Free computer software developed and distributed by the U.S. Department of Energy's National Renewable Energy Laboratory

Calculates:

- A power system's energy output over one year
- A power project's cash flow over years of operation

"Introduction to SAM 2020.2.29"  
<https://sam.nrel.gov>



# Front-of-Meter Battery system

Installed as part of a power generation project, or standalone storage project

Earns revenue through power sales: Power purchase agreement (PPA) or Merchant Plant

Is a project profitable given its cost and energy production?



# FOM Storage Considerations

**Dispatch storage to maximize value of generated power and minimize cost**

**Predict replacement cost based on battery degradation**

**Respond to generation profiles of solar PV or wind**

**Consider variable power pricing**

**Operate within policy requirements such as charge energy source and interconnection limits**

# Battery Storage Model in SAM

## Available with Detailed PV and Generic System model

- Generic system can use generation profile as input
- Also simple PVWatts version

## Financial model determines type of storage system

- FOM: Power Purchase Agreement (PPA) or Merchant Plant financial models
- Behind-the-Meter (BTM): Residential, Commercial, Third Party Ownership models

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
  - Single Owner
  - Partnership Flip with Debt
  - Partnership Flip without Debt
  - Sale Leaseback
- > Distributed
  - Merchant Plant

# Design steps for a PV-storage system

**Choose a weather file**

**Design and size the PV system**

**Design and size the battery system**

**Choose battery dispatch options**

**Choose battery lifetime options**

**Define costs**

# Design steps for a PV-storage system

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Design and size the battery system

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Modeling PV Systems,

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

Battery Focus on Technology,

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

# Battery Inputs

Today's examples will use default inputs except for:

- Battery desired capacity and power
- DC / AC sizing
- Dispatch options

For more on other inputs, see recorded webinars at <https://sam.nrel.gov/battery-storage/battery-videos>

**Battery Bank Sizing**

Set desired bank size

Desired bank capacity  kWh  ▾

Desired bank power  kW  ▾

**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

DC to DC conversion efficiency  % AC to DC conversion efficiency  %

Inverter efficiency cutoff  % DC to AC conversion efficiency  %

# Manual Dispatch

Use a dispatch periods with month-by-hour schedule to tell SAM when to charge and discharge the battery

No automatic decision making

How battery is cycled determines replacement frequency

Select a rectangle in schedule matrix and type a number to assign times to each Period number.

Manual Dispatch

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

Copy Schedules from TOU/TOD Schedules

	Weekday												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	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm			
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# Live Demonstration

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Example 1: Manual Dispatch

# “Automated” Dispatch

**Decision in each time step (hourly or sub-hourly)**

Charge from grid?

Charge from system?

Discharge?

*DiOrio, N.; Denholm, P.; Hobbs, W. (2020). A Model for Evaluating the Configuration and Dispatch of PV Plus Battery Power Plants. Applied Energy Vol 262 March 2020.*

# Basic Rules for Automatic Dispatch

**For PV DC-connected PV-battery, charge from system if array power exceeds inverter power**

**Charge from system if more valuable to sell power later**

- But leave room for future clipped power (PV DC-connected only)

**Charge from grid if purchase price is less than future power price**

**Discharge to grid if in high power price period**

# Automated Dispatch Considerations

## **SAM automatically dispatches battery to maximize revenue**

Value of electricity sold to grid

- Determined by power price

Cost of electricity to charge battery

- Determined by power price or retail purchase rate

Cost of cycling battery

- Excessive cycling increases wear and replacement frequency

# Live Demonstration

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Example 2: Automated Dispatch Options

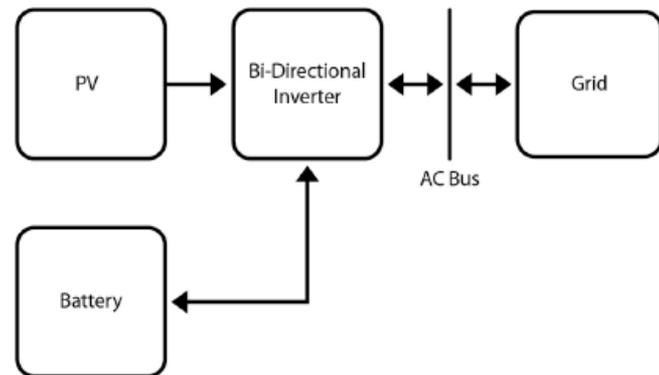
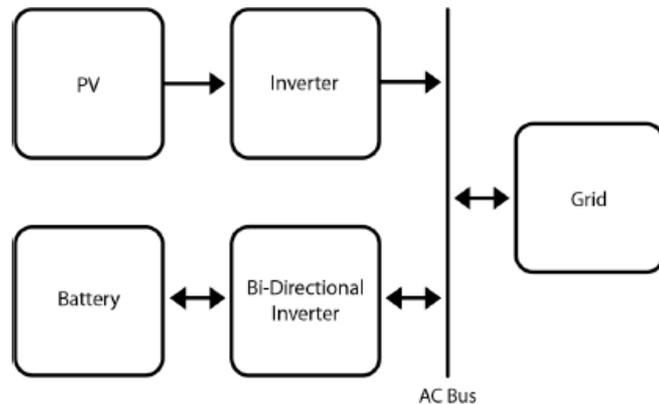
# DC-connected vs AC-connected

## DC-connected battery can charge directly from PV array

- Increase DC/AC ratio by reducing inverter power limiting

## AC-connected battery practical for retrofits

- Separate converter hardware for PV array and battery simplifies design



# Live Demonstration

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Example 3: DC- vs AC-connected Battery

# Generic System - Battery

Set capacity factor to zero for battery-only system

Import generation profile to model battery with wind or other power system

# Merchant Plant

Time series power price

Capacity requirement: Simulation fails if system does not meet capacity requirement in any time step

Automated battery dispatch responds to market power price

# Live Demonstration

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Generic System – Battery Tricks

Merchant Plant

# Thank you!

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