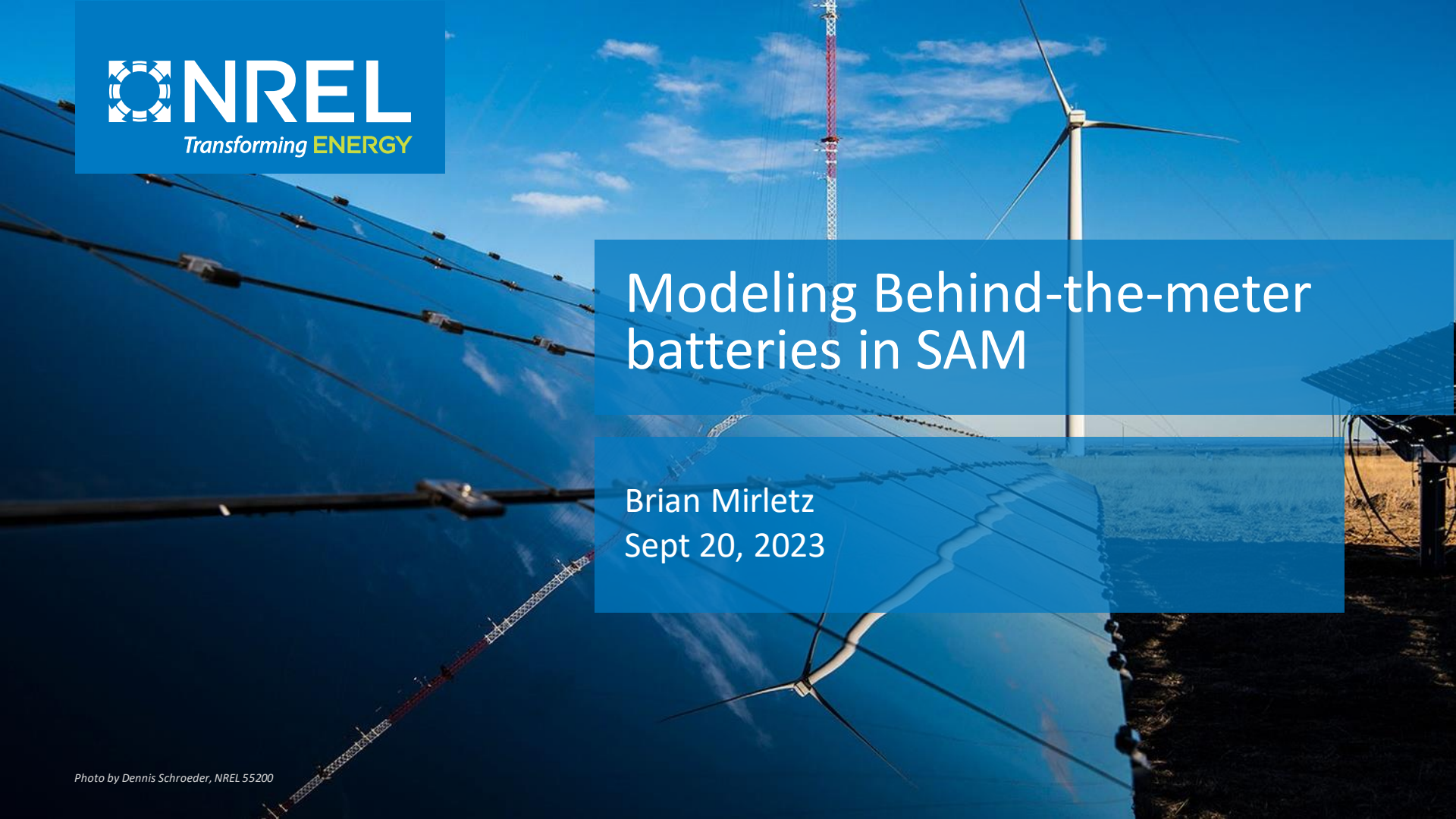


Modeling Behind-the-meter batteries in SAM

Brian Mirletz

Sept 20, 2023

Photo by Dennis Schroeder, NREL 55200

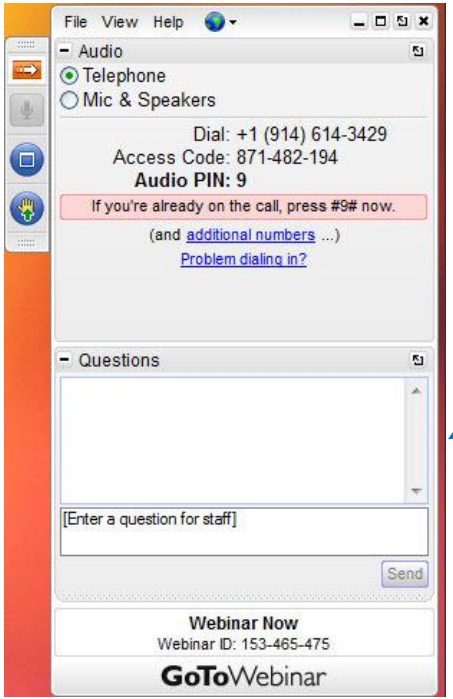
SAM Webinar Series 2023

Geothermal Electricity Technology Evaluation Model (GETEM) in SAM	January 19
Linkages between NREL's dGen, REopt and SAM Models	July 11
Financial Models for Utility-scale Projects in SAM	July 19
Modeling Utility-scale Photovoltaic Projects in SAM	August 23
Modeling Behind-the-meter (BTM) Batteries in SAM	**September 20**

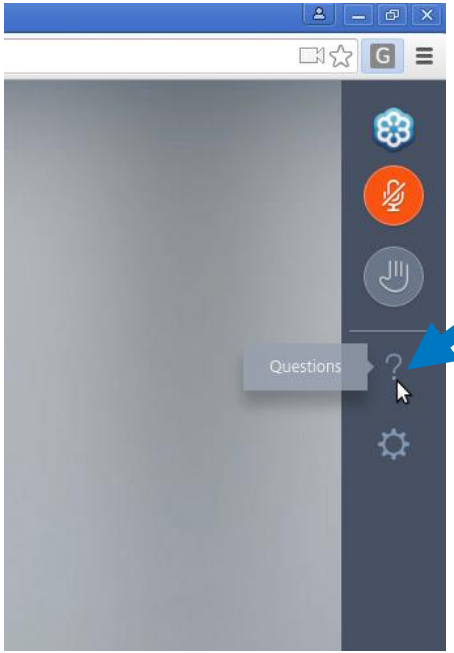
Webinars are free
- Register at https://sam.nrel.gov/events

Webinars are recorded
- https://www.youtube.com/@SAMDemoVideos
- "Videos" pages 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.

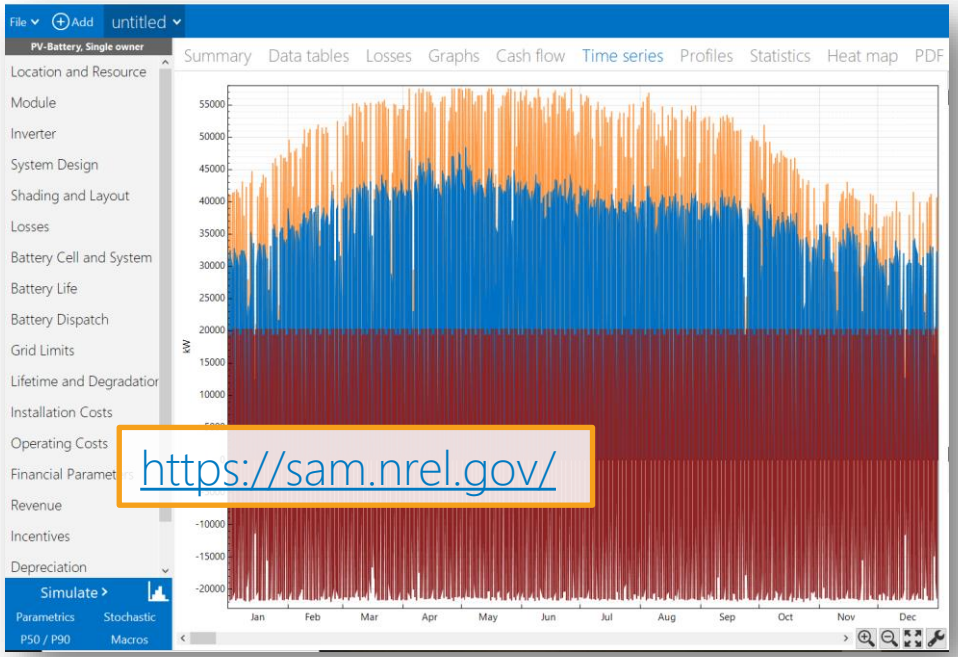
Find webinar recordings at https://sam.nrel.gov/

Agenda

1. Intro to batteries in SAM
2. Manual Dispatch
3. Optimal Dispatch using REopt
4. Grid power target based dispatch
5. Price signals dispatch
6. Which dispatch option should I use when?
7. Grid outage dispatch

System Advisor Model (SAM)

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



- ✓ Desktop application
- ✓ Software development kit with PySAM Python package
- ✓ Open source code repositories

SAM Battery Intro

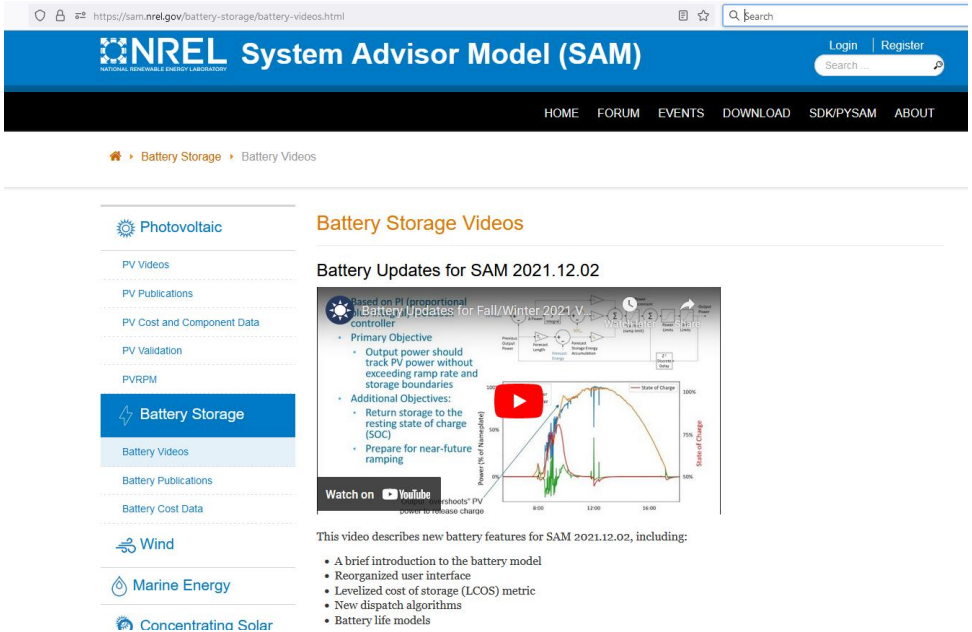
- Lithium ion, Lead acid, Flow battery chemistries
- AC or DC connected
- Battery lifetime models
- Replacements on set schedule or replace at specified capacity %
- Voltage, losses, temperature calculations

Computed Properties

Nominal bank capacity	4000	kWh (DC)	Max C-rate of discharge	0.25	per/hour
Nominal bank power	999.999	kWdc	Max C-rate of charge	0.25	per/hour
Time at maximum power	4	h	Maximum discharge current	1998.4	A
Nominal bank voltage	500.4	VDC	Maximum charge current	1998.4	A
Total number of cells	347222			**DC**	**AC**
Cells in series	139		Maximum discharge power	999.999	959.999 kW
Strings in parallel	2,498		Maximum charge power	999.999	1041.67 kW

Prior Battery Webinars

- Battery technology focus
- Behind-the-meter RE + storage system modeling
- Front-of-meter system modeling
- Lifetime models and metrics (LCOS)



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

Definitions

- Optimization: solve a set of equations to find the best possible solution
- Heuristic solution: follow a set of rules to find a good solution
- Net present value (NPV): sum of discounted cash flows over the life of the project

Battery Dispatch Options

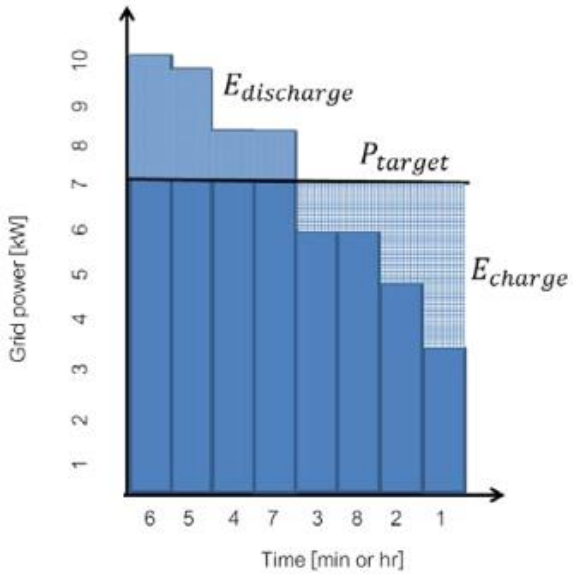
Dispatch Mode	Inputs	Use Case
Peak Shaving	Generation and Load forecast	Peak Demand Charges
Input Grid Power Targets	Monthly or time series targets	Specify more detailed peak power
Input Battery Power Targets	Time series	PySAM / outside optimization
Manual Dispatch	Schedule by hour and month	Energy Arbitrage
Utility Rate Dispatch (formerly known as Price Signals Dispatch)	Upcoming generation and Load forecast, utility rates	Mix of TOU charges and demand charges, battery degradation
Self Consumption Dispatch	Grid power target of zero	System sizing for meeting load
Grid Outage Dispatch	Current generation and critical load	Resiliency analysis

Live Demo: Manual Dispatch and REopt optimal dispatch

Fall 2023 SAM Beta

Grid Power Target

- Given a target in kW for a timestep, SAM will do it's best to dispatch the battery to meet the target
  - If grid use is greater than the target, discharge
  - If less than the target, charge
- For peak shaving:
  - 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)
  - Battery will not cycle if insufficient energy is available
  - Use monthly maximum



From DiOrio 2017

Utility Rate Dispatch

1. Forecast cost of utility bill without dispatch
2. Schedule discharge to the load for the highest cost periods according to: $P_{discharge,t} = \frac{E_{remaining,t} * C_t}{(\sum_{i=t}^{p} C_i) * dt}$
3. Schedule charging for the lowest marginal cost periods
4. Reduce discharging or charging based on expected SOC
5. Repeat 2-4 to generate plans with 0 to 12 hours of dispatch
6. Select lowest cost plan according to:

$$C_{total} = C_{utility\_bill} + C_{cycle} * n_{cycles} - E_{remaining} * C_{marginal}$$

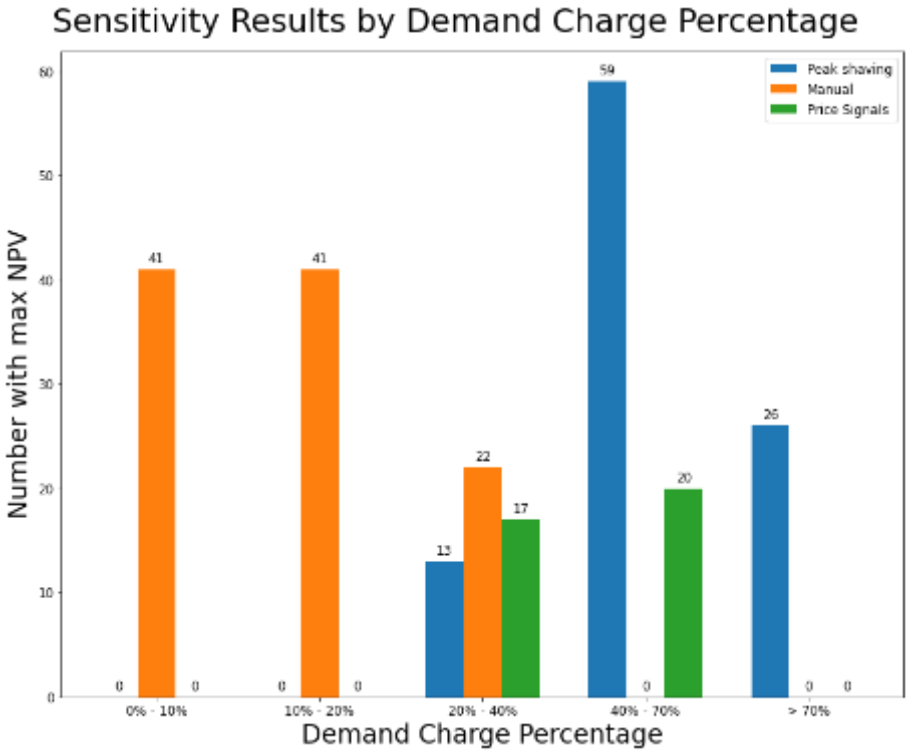
From Mirletz and Guittet 2021

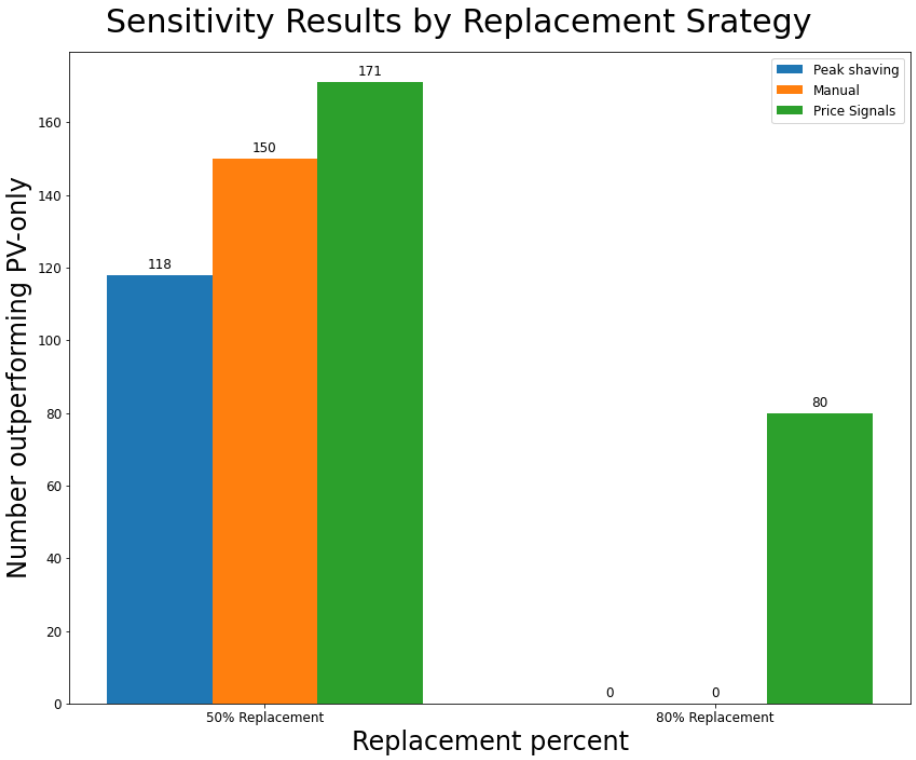
Which dispatch option should I use? Sensitivity Analysis

Parameter	Min Value	Max Value
Max Energy Charge	$0.10/kWh	$0.50/kWh
Ratio of TOU Periods	1	10
Fixed Demand Charge	$0/kW	$59.05/kW
TOU Demand Charge	$0/kW	$13.45/kW

From Mirletz and Guittet 2021

Which dispatch option should I use? Results

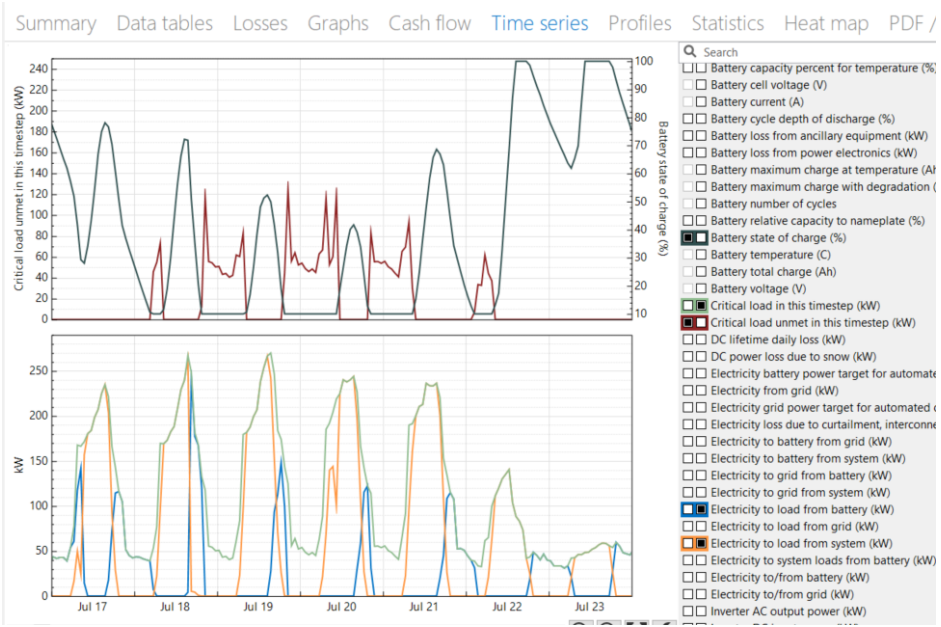




From [Mirletz and Guittet 2021]

Grid Outage Dispatch

- Only available with detailed models (not PVWatts)
- Critical Load
  - Percent of load or time series
- Autonomy Calculations
  - Hypothetical outage at every step
    - Hours of autonomy, does not affect economics
  - Meet critical load during outage steps
    - Affects utility bill, battery SOC, battery lifetime
    - Iterative method to meet all losses
      - Slower than self-consumption



Help Resources

Help System

- Press F1 key or click **Help** in SAM software
- Web version at https://sam.nrel.gov/help

SAM Forum

- https://sam.nrel.gov/forum
- Use search box to find information
- Register on website to post questions

Email

- sam.support@nrel.gov

Related Resources

- https://sam.nrel.gov/battery-storage/battery-publications.html
- https://sam.nrel.gov/battery-storage/battery-videos.html
- https://sam.nrel.gov/financial-models.html

References:

- DiOrio, N. (2017). An Overview of the Automated Dispatch Controller Algorithms in SAM. NREL/TP-6A20-68614.
- Mirletz, B.; Guittet, D. (2021). Heuristic Dispatch Based on Price Signals for Behind-the-Meter PV-Battery Systems in the System Advisor Model. NREL/CP-7A40-79575.

Thanks! Questions?

Janine Freeman Keith – 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, utility rates
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
Bill Hamilton – concentrating solar power models

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