# REopt® Lite Overview – Resilience Analysis

## Clear Sky Tampa Bay

Kathleen Krah
December 2021

Note: Between time of presentation and time of publication, the tool previously called REopt® Lite has been renamed REopt®, with the addition of several new capabilities.

# Solar Energy Innovation Network

The Solar Energy Innovation Network supports teams across the United States that are pursuing novel applications of solar and other distributed energy resources (DERs) by providing critical technical expertise and facilitating stakeholder engagement. This support gives the teams the wide range of tools necessary to realize their innovations in real-world contexts.

Teams are composed of diverse stakeholders to ensure that all perspectives are heard, key barriers are identified, and the resulting solutions are robust and ready for replication in other contexts. The Innovation Network is a collaborative research effort led by the National Renewable Energy Laboratory and supported by the U.S. Department of Energy's Solar Energy Technologies Office. For more information, visit [www.nrel.gov/solar/market-research-analysis/solar-energy-innovation-network.html](www.nrel.gov/solar/market-research-analysis/solar-energy-innovation-network.html).

## Approach

- Teams identify local and regional challenges, and receive technical and financial assistance to formulate and test innovations and validate new models
- Teams meet in person for several multiday workshops to further refine solutions and learn from other teams
- Research and innovative solutions are shared through peer network and stakeholders nationally.

## Objective

- Develop innovative solutions that make solar energy adoption easier and enable adoption by stakeholders facing similar challenges across the United States.

SOLAR ENERGY INNOVATION NETWORK
U.S. DEPARTMENT OF ENERGY

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

BERKELEY LAB
Lawrence Berkeley National Laboratory

RMI
ENERGY. TRANSFORMED.

# Slide Deck Overview

- Through the Solar Energy Innovation Network (SEIN), the Clear Sky Tampa Bay team, led by the Tampa Bay Regional Planning Council (TBRPC), developed a toolkit to help local governments prioritize sites for solar photovoltaics (PV) and battery energy storage in the context of resilience and emergency management. More information about the Clear Sky Tampa Bay project can be found at www.tbrpc.org/clearsky/.

- At a high level, the Clear Sky Tampa Bay process involves:
    1. Identifying sites based on community resilience needs and priorities ("Where do we need a resilient energy solution?")
    2. Screening and prioritizing sites for solar PV and storage suitability based on site conditions and other factors
    3. **Using REopt Lite to screen down-selected facilities to prioritize sites based on resilience project economics.**

- This slide deck focuses on **Step 3** above, and provides:
    - A general overview of REopt Lite
    - Suggestions and examples tailored to the Clear Sky Tampa Bay team about how to use REopt Lite for additional analysis.

# General REopt Lite Tool Overview

# Will PV + Storage Work for Your Site?

**Solar PV Resource**

**Technology Costs & Incentives**

**Utility Cost & Consumption**

**Financial Parameters**

**Energy Goals (e.g., Cost Savings, Renewable Energy Targets, Emissions Reductions, Resilience)**

# REopt Lite: Free Web Tool to Optimize Economic and Resilience Benefits of DERs

***Formulated as a mixed-integer linear program, REopt Lite provides an integrated, cost-optimal energy solution.***

## Drivers

**Goals**
Minimize Cost
Increase Resilience
Reduce Emissions

**Economics**
Technology Costs
Incentives
Financial Parameters

**Utility Costs**
Energy Charges
Demand Charges
Escalation Rates

## Technology Options

**Renewable Generation**
Solar PV, Wind

**Conventional Generation**
Electric Grid
Diesel Generators

**Energy Storage**
Batteries
Hot Water & Chilled Water TES

**Combined Heat & Power**
Internal Combustion Engine
Combustion Turbine
Fuel Cells
Microturbine
Backpressure Steam Turbine
Absorption Chiller

## REopt Lite

reopt.nrel.gov/tool

Electric Loads

Heating & Cooling Loads

## Optimized Minimum Cost Solution

**Technologies**
Technology Mix
Technology Size

**Operations**
Optimal Dispatch

**Project Economics**
Capital and Operations & Maintenance (O&M) Costs
Net Present Value

# REopt Lite Provides Solutions for a Range of Users

*Researchers, developers, building owners, utilities, and industry use the tool to answer different questions.*

What is the optimal size of DERs to minimize my cost of energy?

How do I optimize system control across multiple value streams to maximize project value?

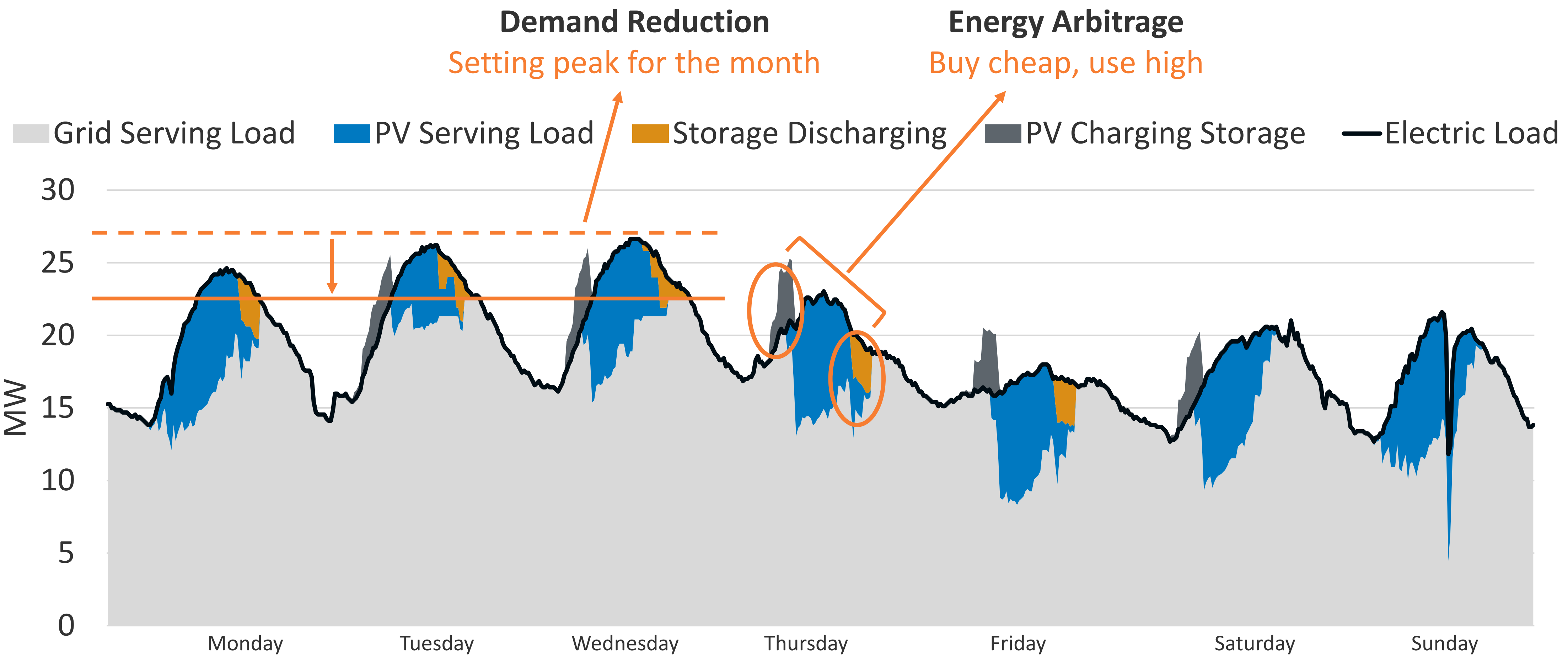
Where do market opportunities for DERs exist—both now and in the future?

What will it cost to meet a sustainability or on-site generation goal?

What is the most cost-effective way to survive a grid outage spanning 1 day? What about 9 days?

# How Does REopt Lite Work?

***REopt Lite considers the tradeoff between ownership costs and savings across multiple value streams to recommend optimal size and dispatch.***

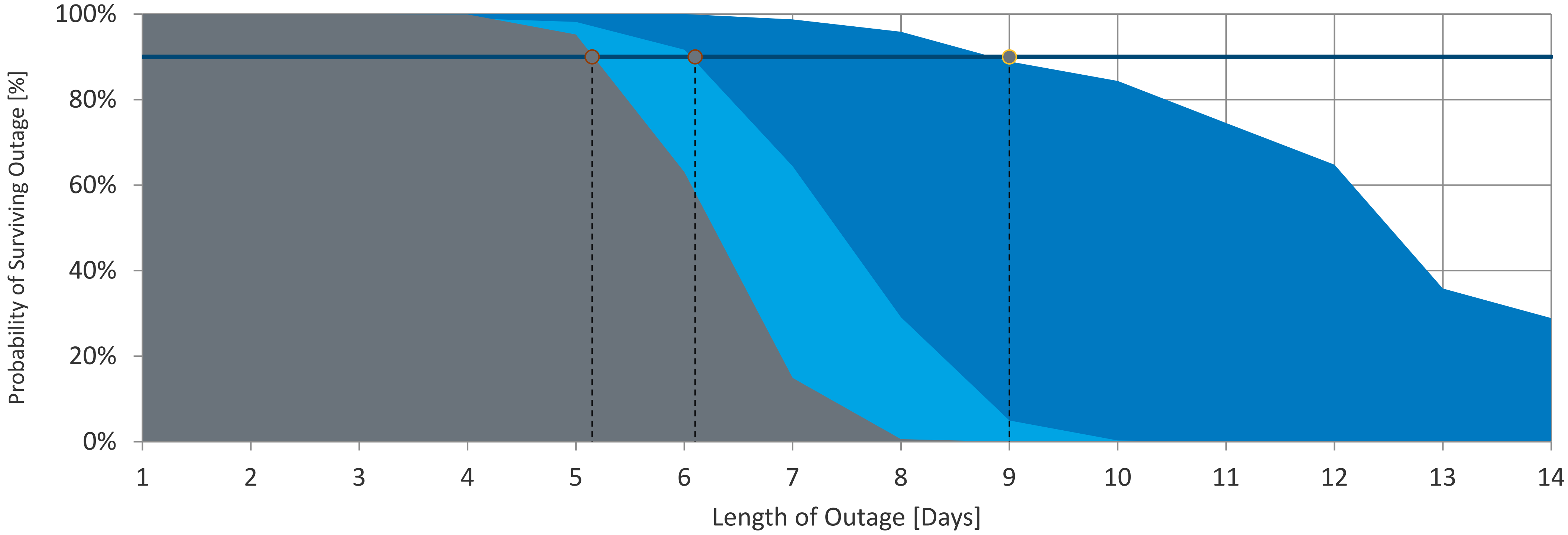



**Example of Optimal Dispatch of PV and Battery Energy Storage System (BESS)**

# How Does REopt Lite Work for Resilience?

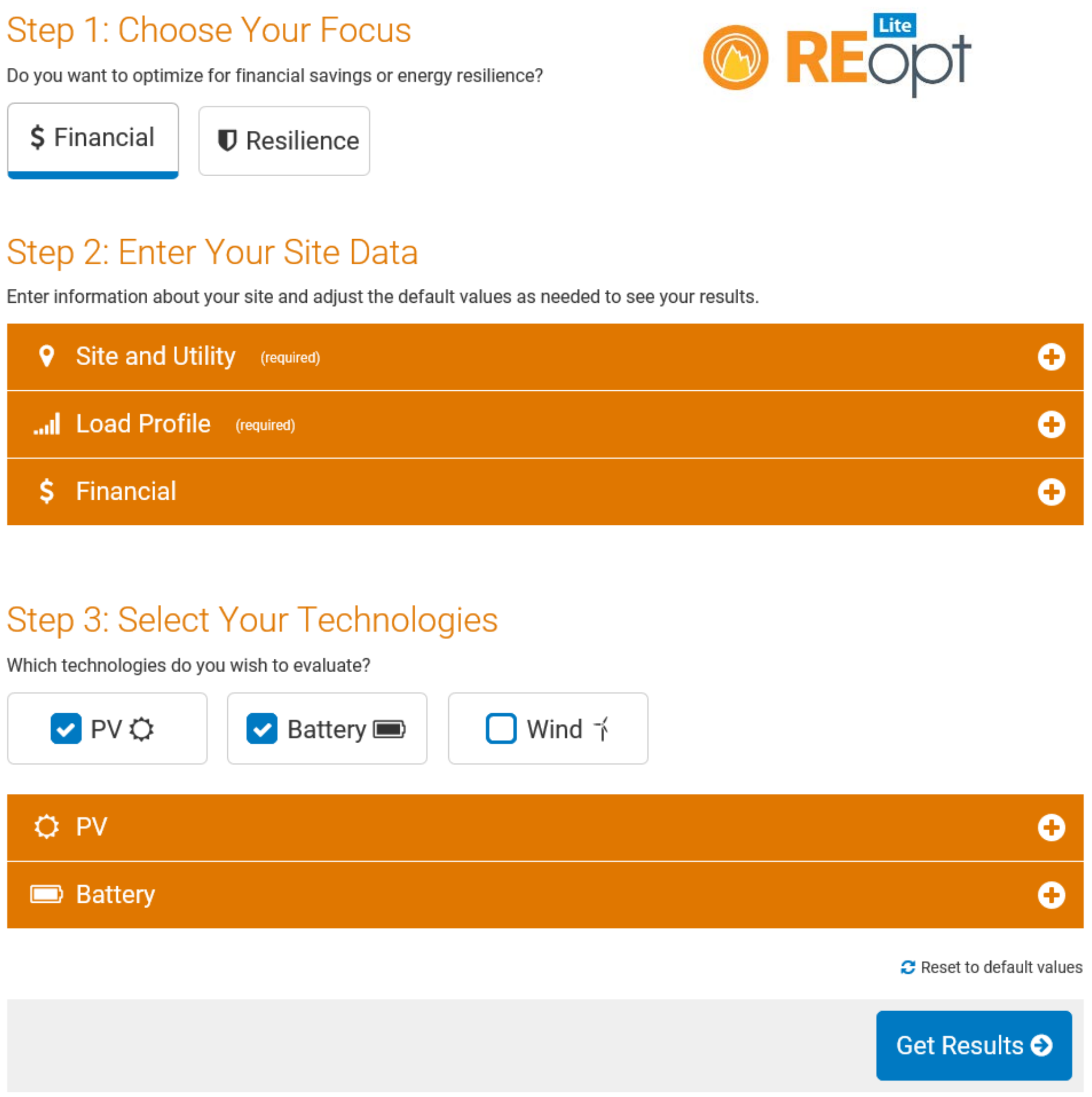
***REopt Lite evaluates thousands of random grid outages to estimate hours survived and impact on life cycle costs. It quantifies the economic and resilience benefits of DERs by comparing the number of hours the site could survive with different technology combinations.***

| | Generator | Solar PV | Storage | Life Cycle Cost | Outage |
|---|---|---|---|---|---|
| 1. Base case | 2.5 MW | - | - | $20 million | 5 days |
| 2. Lowest-cost solution | 2.5 MW | 625 kW | 175 kWh | $18.5 million | 6 days |
| 3. Proposed system | 2.5 MW | 2 MW | 500 kWh | $19.9 million | 9 days |

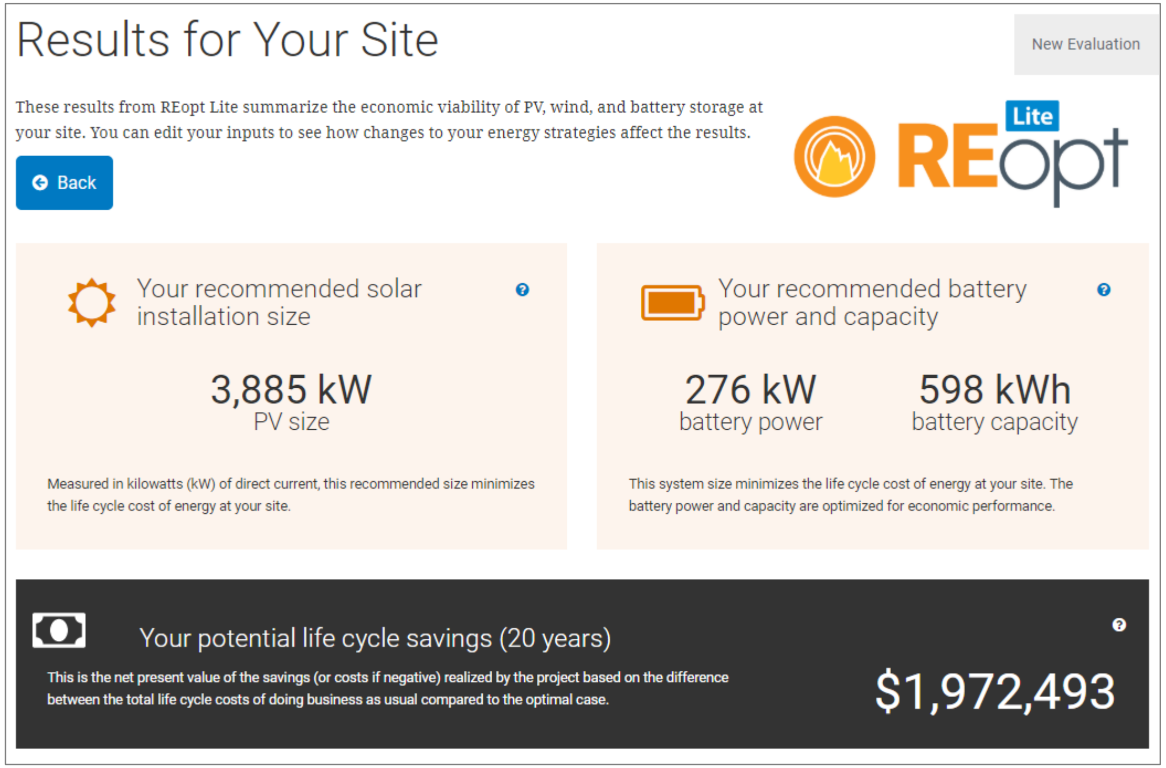


# REopt Lite Web Tool User Interface

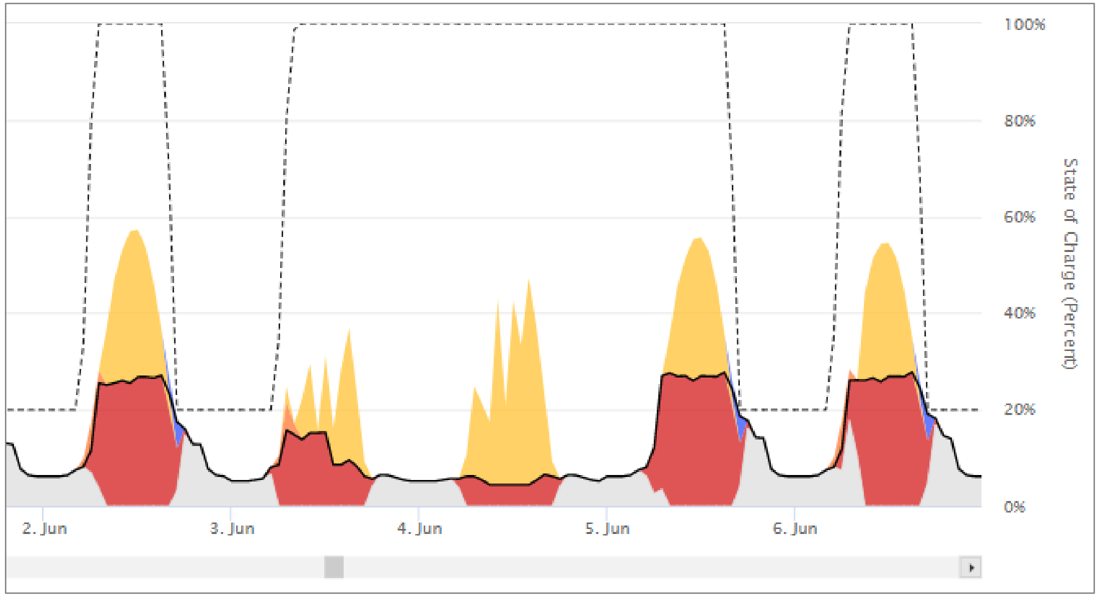
- **REopt Lite** is a web tool that offers a no-cost subset of NREL's more comprehensive REopt™ model
- **Financial mode** optimizes PV, wind, combined heat and power (CHP) and storage system sizes and dispatch strategies to minimize life cycle cost of energy
- **Resilience mode** optimizes PV, wind, CHP, and storage systems, along with backup generators, to sustain critical load during grid outages at the lowest cost
- Access REopt™ Lite at [reopt.nrel.gov/tool](reopt.nrel.gov/tool).



# REopt Lite Web Tool Key Outputs




*System Size and Net Present Value (NPV)*




*Hourly Dispatch*

| | Business As Usual | Financial | Difference |
|---|---|---|---|
| System Size, Energy Production, and System Cost | | | |
| PV Size | 0 kW | 113 kW | 113 kW |
| Annualized PV Energy Production | 0 kWh | 132,000 kWh | 132,000 kWh |
| Battery Power | 0 kW | 0 kW | 0 kW |
| Battery Capacity | 0 kWh | 0 kWh | 0 kWh |
| Net CAPEX + Replacement + O&M | $0 | $133,318 | $133,318 |
| Energy Supplied From Grid in Year 1 | 132,000 kWh | 65,384 kWh | 66,616 kWh |
| Year 1 Utility Cost — Before Tax | | | |
| Utility Energy Cost | $18,112 | -$404 | $18,515 |
| Utility Demand Cost | $0 | $0 | $0 |
| Utility Fixed Cost | $0 | $0 | $0 |
| Utility Minimum Cost Adder | $0 | $0 | $0 |

*Detailed Financial Outputs*

# Training Resources

- **REopt Lite Web Tool:** https://reopt.nrel.gov/tool
  - Help manual: https://reopt.nrel.gov/user-guides.html
  - Training videos: https://www.youtube.com/playlist?list=PLmIn8Hncs7bF4UNN7hGlhZ0UohbI4-c4b

- **REopt Lite API:** https://developer.nrel.gov/docs/energy-optimization/reopt-v1/
  - Information to access API
  - User guide

- **REopt Website:** https://reopt.nrel.gov/
  - Case studies
  - Analysis services

- To send tool feedback or ask a question, contact reopt@nrel.gov.

# REopt Lite for Clear Sky Tampa Bay

# Suggested Starting Point: General REopt Lite Training Videos

- NREL has developed REopt Lite training videos for new users (seven brief videos, totaling <30 minutes in duration) for an overview of inputs and use. **Highlighted videos are particularly relevant for the Clear Sky Tampa Bay SEIN project team (total time ~15 minutes!):**
  - Inputs Overview (2:57 min)
  - Load Profile Input (1:37 min)
  - Advanced Utility Rate Input (6:57 min)
  - Resilience Inputs (2:48 min)
  - Financial Outputs (2:56 min)
  - Resilience Outputs (5:13 min)
  - API Overview (3:43 min).

- These videos will help users understand the model inputs and their potential impacts on results and provide guidance on interpreting model outputs.

- The following slides will step through the inputs that may be particularly important for the Clear Sky Tampa Bay analyses and toolkit, with suggestions for how to model sites, interpret results, and *iterate on analysis* of a particular site.

# Suggested REopt Workflow for Clear Sky Tampa Bay Toolkit (Step 3)

1. *Identify sites based on community resilience needs and priorities ("Where do we need a resilient energy solution?")*
2. *Screen and prioritize sites that are more suited for solar PV and storage based on site conditions and other factors*
3. **Use REopt Lite to screen down-selected facilities and prioritize sites based on resilience project economics, answering questions such as:**
   - **What size solar PV and/or battery storage could help my site survive an electric grid outage? What are the project economics (e.g., NPV), considering bill savings from grid-connected operations as well as the resilience provided?**
   - **How do the system size and economics of this resilient solution compare to the system sizes and economics identified for purely grid-connected cost savings?**

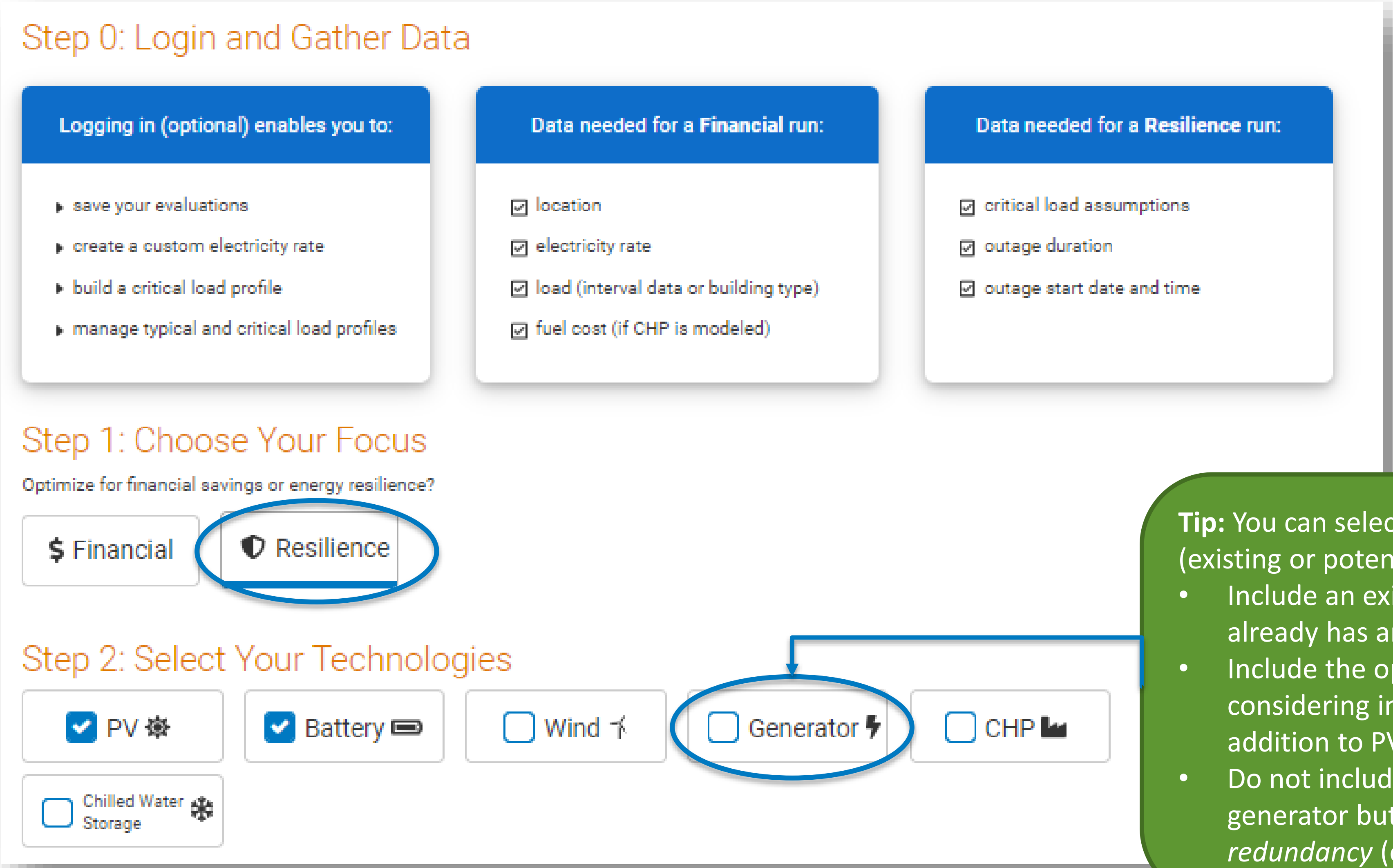
**A. Conduct a resilience analysis**

- Considerations in selecting inputs include:
  - What loads do I want this system to support in the case of an electric grid outage?
  - How long would I want these systems to sustain these critical loads? (E.g., 2 hours? 2 days? 2 weeks?)
  - When are outages likely to occur at my site (e.g., seasonal extreme weather)?
  - What are some worst-case scenarios for outage timing (e.g., seasons of low solar resource, nighttime outages, peak load events)?
  - How much space (e.g., land, roof, carport areas) is/could be available for PV at this site?
- Considerations in interpreting results include:
  - How does the outage survivability of the system proposed compare to outages occurring at other times of year?
  - Does this system and its outage survivability meet the resilience needs/goals of this site?
  - What are the proposed system sizes and NPV? How do the system sizes proposed for resilience compare to the those proposed purely for grid-connected cost savings? How does the NPV of the business-as-usual case compare to the financial cost-optimal case? (E.g., what is the "cost of resilience?")

**B. Iterate, and consider adjusting inputs such as:**

- Outage timing and/or duration
- Critical load
- System size, such as maxing out PV to cover the space available at the site or iteratively increasing system sizes to evaluate how much and at what cost a larger system could increase site resilience to grid outages.

# Select Focus & Technologies



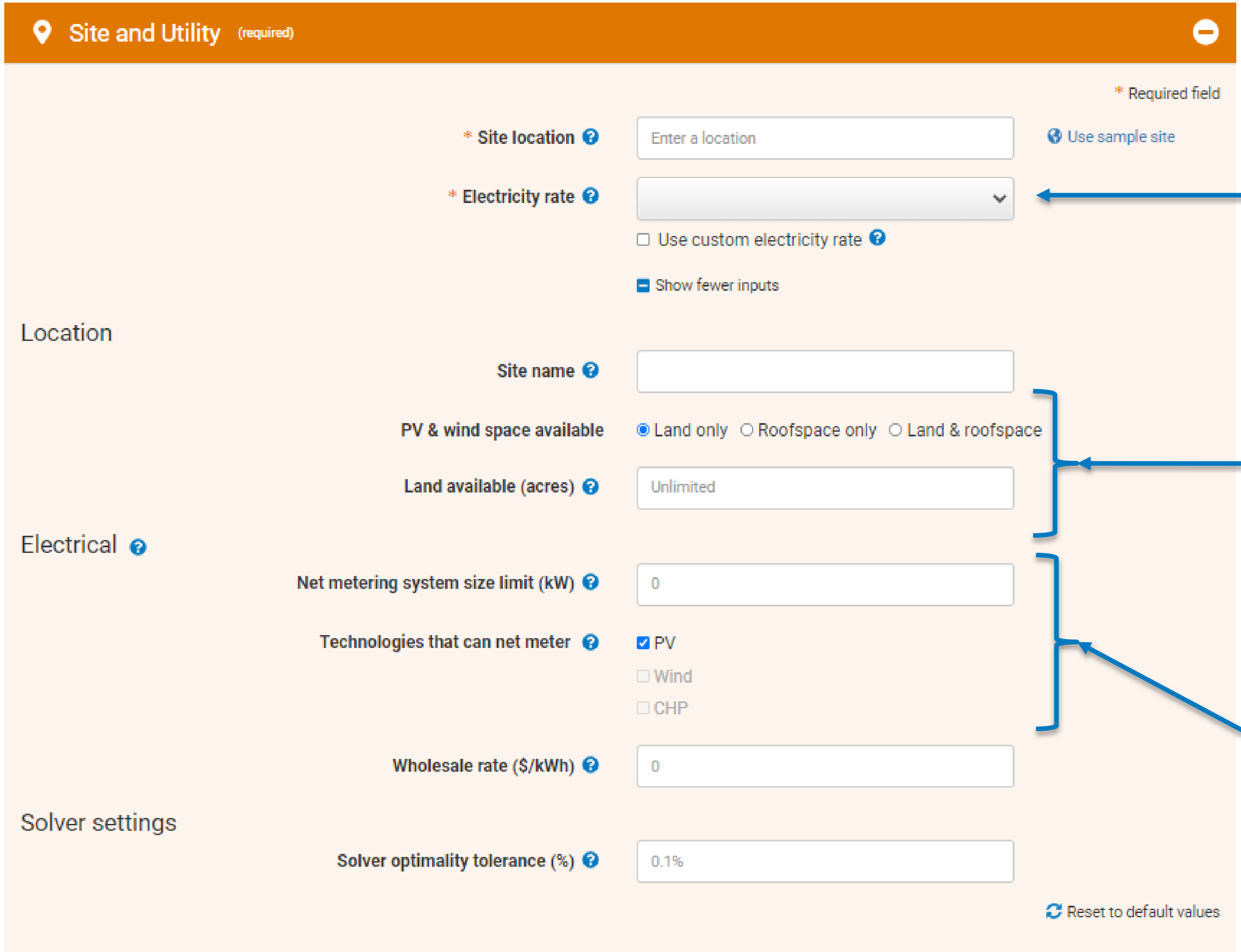

**Tip:** Before running analysis, click "Log In/Register" (top right corner of web interface) in order to create custom loads, critical loads, and utility rates and to ensure access to inputs and results in the future. Note: If you don't have a Gmail account, you can create a Google account with a non-Gmail email address.

**Tip:** You can select whether to consider a backup generator (existing or potential installation).

- Include an existing backup generator in your model if the site already has an existing generator.
- Include the option to build a new generator if the site is considering installing a new generator instead of or in addition to PV/battery.
- Do not include a generator if the site already has a backup generator but is considering PV/battery to provide additional *redundancy* (e.g., N+2) in case the generator is unavailable.

# Site and Utility Inputs

## Step 3: Enter Your Site Data




**Tip:** After entering your location, try to find your electricity rate in the dropdown list. Alternatively, you can enter a custom annual, monthly, or detailed utility rate.

**Tip:** If you know how much land and/or roof space is available for PV at your site, enter it here. These are not required inputs, but if entered, they will constrain system sizes to those realistic for the area(s) available.

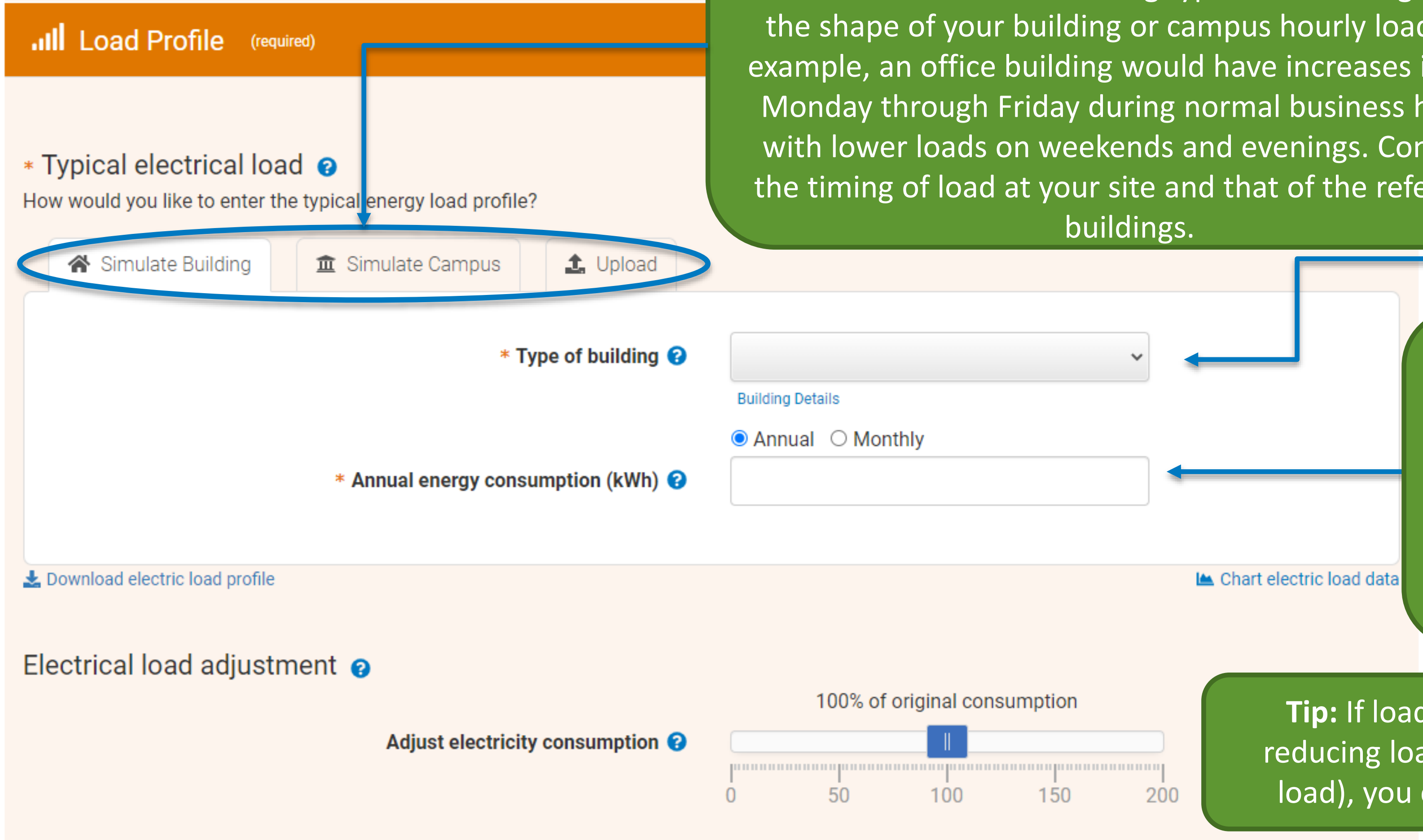
**Tip:** Look up state and utility net metering limits. NC Clean Energy Technology Center's Database of State Incentives for Renewables & Efficiency (DSIRE) (https://www.dsireusa.org/) is a good place to start. For example, Florida's net metering limit is 2 MW: https://programs.dsireusa.org/system/program/detail/2880/net-metering.

# Load Profile Assumptions

**DOE Commercial Reference Buildings:**

- Hospital
- Hotel - Large
- Hotel - Small
- Midrise Apartment
- Office - Large
- Office - Medium
- Office - Small
- Outpatient Health Care
- Restaurant - Full Service
- Restaurant - Fast Food
- Retail Store
- School - Primary
- School - Secondary
- Strip Mall
- Supermarket
- Warehouse

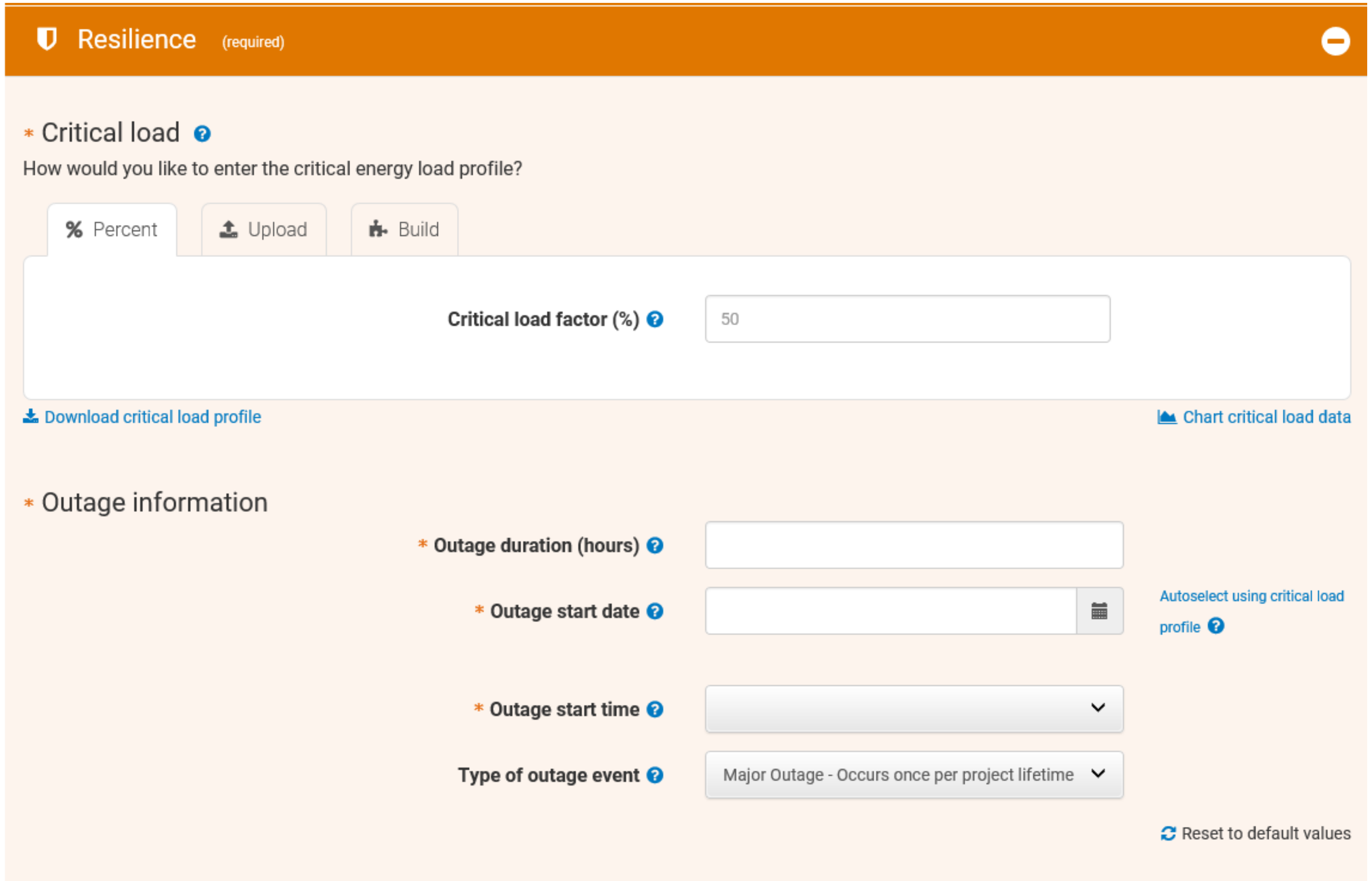
**Tip:** If you have actual hourly interval data, select "Upload." However, at the screening level, you can simply simulate the building or campus by selecting the commercial reference building type that best aligns with the shape of your building or campus hourly load. For example, an office building would have increases in load Monday through Friday during normal business hours, with lower loads on weekends and evenings. Consider the timing of load at your site and that of the reference buildings.




**Tip:** If simulating your site's hourly loads, use the annual energy consumption input to scale the simulated hourly profile to the magnitude of your site's consumption on a monthly or annual basis. **Entering data at monthly resolution will provide higher fidelity than annual data.** If you don't have this data, the default annual consumption will be based on building type and location/climate zone.

**Tip:** If load changes are expected (e.g., energy efficiency measures reducing load, additional construction or higher occupancy increasing load), you can use this slider to scale the load modeled up or down.

# Resilience Inputs



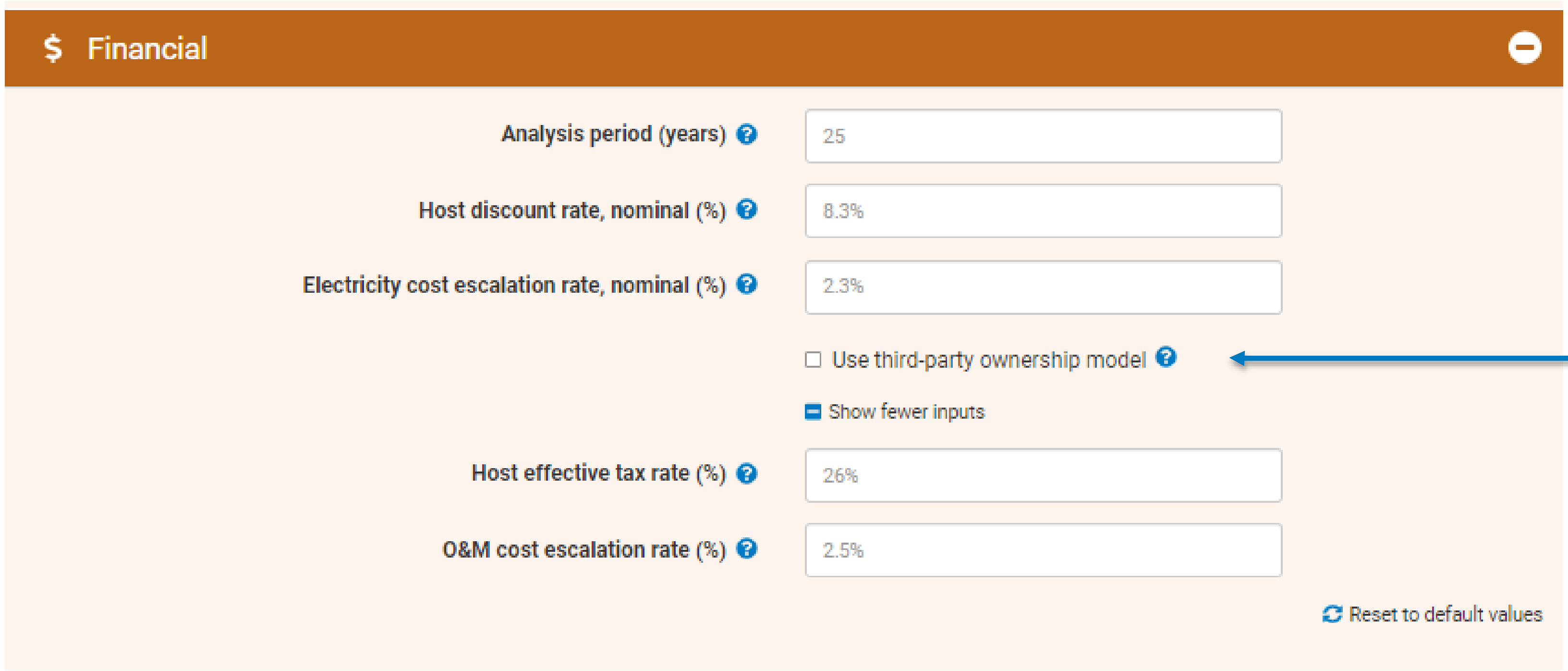

What loads need to be met during the outage?

**Tip:** This input will vary based on building type and criticality. You can enter a percentage of the typical overall load, upload interval data, or use the Critical Load Builder to estimate this input.

When is the outage expected to occur, and how long will it last?

**Tip:** Consider outage timing and duration, seasonal weather events, timing of peak loads (e.g., summer air conditioning load), timing of peak solar, timing of peak net load (load minus solar generation), and daytime vs. nighttime outage start.
**Consider option to “Autoselect using critical load profile,” which starts the outage during the annual peak demand as a potential worst-case scenario.**

# Financial Assumptions

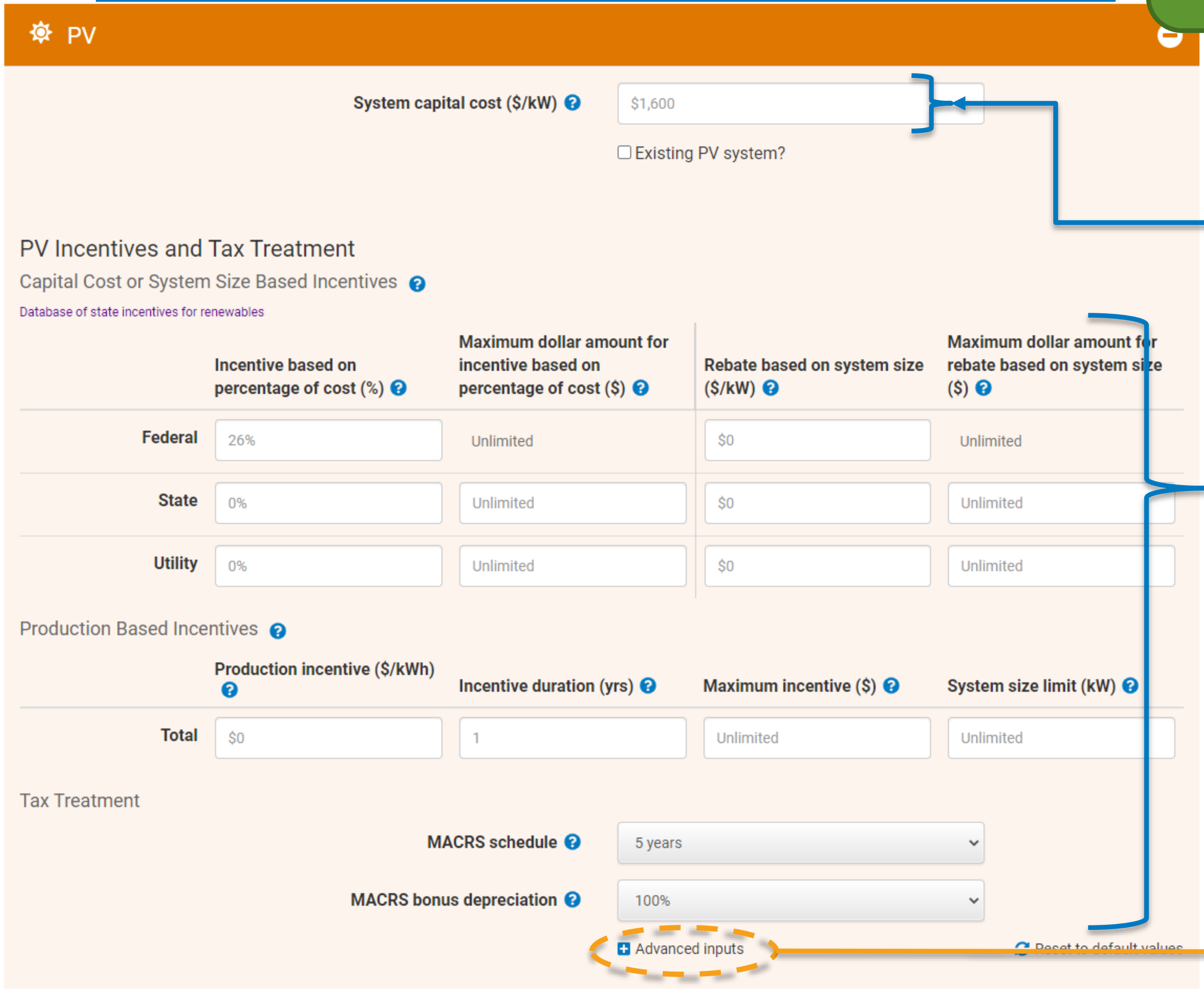



**Tip:** Inputs can be edited or left as default values. When running a multi-site screening, for an apples-to-apples comparison between different sites in the same city or county, it is recommended to keep financial assumptions consistent unless there is a reason they would differ.

**Tip:** The default ownership model is direct purchase by the site/organization ("host"), who then owns and operates the system directly. If the host is not a tax-paying entity, they cannot receive federal tax incentives through direct purchase. In the third-party ownership model, a developer owns and operates the system. The developer, as a tax-paying entity, could receive federal tax incentives, which are assumed to pass through to the host. However, this ownership model also requires a developer financing cost.

# Solar PV Technology Assumptions

**Tip:** Inputs can be edited or left as default values. When running a multi-site screening, for an apples-to-apples comparison between different sites in the same city or county, keep technology assumptions consistent unless they explicitly vary between sites.



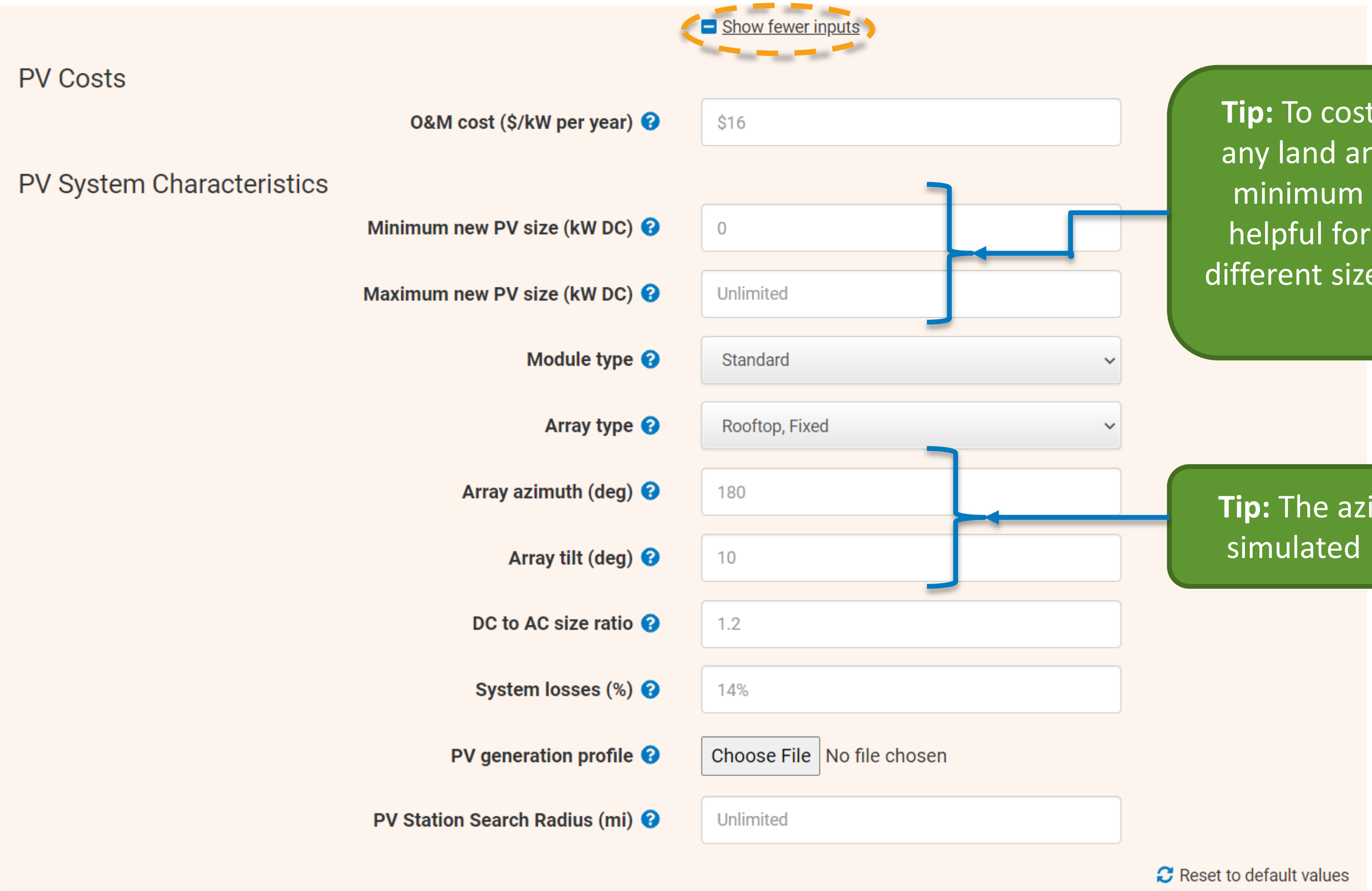

**Tip:** Capital cost assumptions tend to be a key driving factor of project cost effectiveness.

**Tip:** Note that non-tax-paying entities (e.g., cities/counties) are not eligible for federal tax incentives but may benefit from them in a third-party ownership scenario. Thus, these incentives should be set to zero for a municipal screening, unless the scenario is considering third-party financing.

See next slide

# Solar PV Technology Assumptions – Advanced Inputs

**Tip:** Inputs can be edited or left as default values. When running a multi-site screening, for an apples-to-apples comparison between different sites in the same city or county, keep technology assumptions consistent unless they explicitly vary between sites.

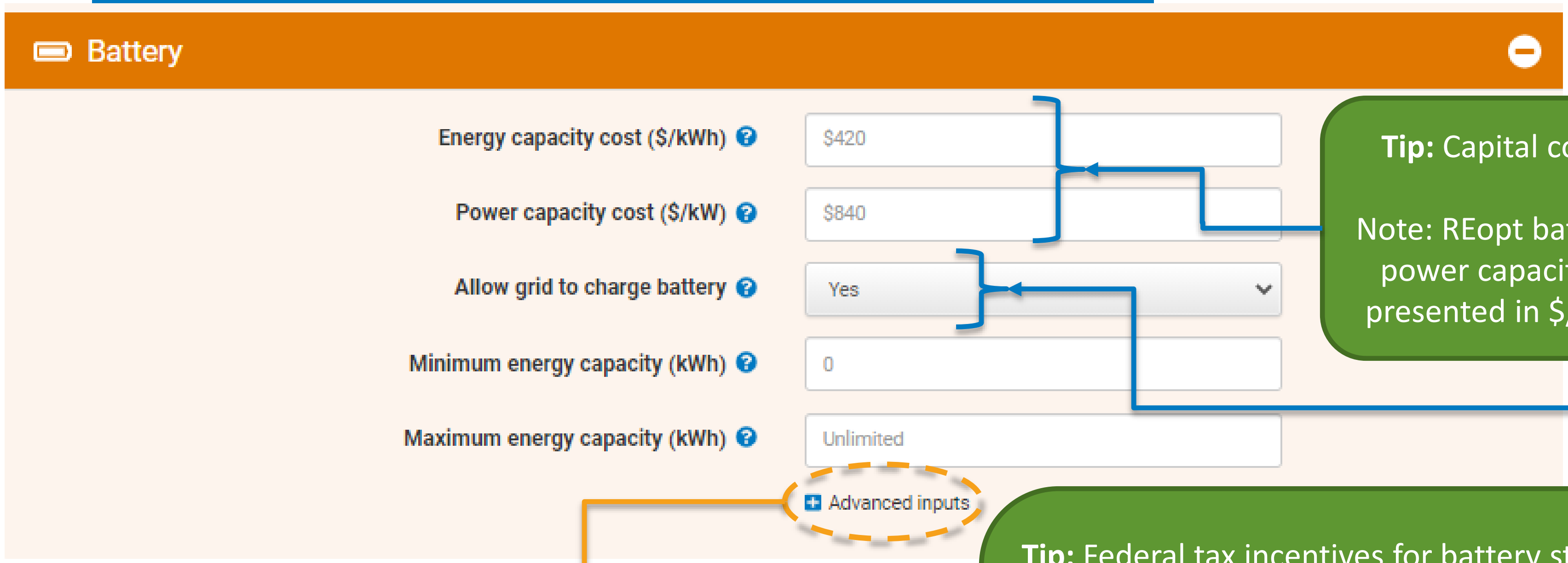



**Tip:** To cost-optimally size your PV system without restriction (aside from any land and/or roof area limitations entered in the "Site" section), leave minimum and maximum size inputs as-is. However, these inputs can be helpful for future iterations of analysis to compare project economics of different sized systems. **A fixed system size can be evaluated by setting the minimum size = maximum size.**

**Tip:** The azimuth (direction the panel is facing) and array tilt angle impact simulated PV performance, along with the other parameters listed here.

# Battery Storage Technology Assumptions

**Tip:** Inputs can be edited or left as default values. When running a multi-site screening, for an apples-to-apples comparison between different sites in the same city or county, keep technology assumptions consistent unless they explicitly vary between sites.




See next slide

**Tip:** Capital cost assumptions tend to be a key driving factor of project cost effectiveness.
Note: REopt battery costs are broken out into energy capacity and power capacity; estimates from battery manufacturers may be presented in $/kWh, but likely include power equipment as well.

**Tip:** Federal tax incentives for battery storage systems depend on how much they charge from PV (as opposed to the grid or conventional generation)—see next slide for more information.

- If the site does not plan to or cannot take advantage of tax incentives, enter "yes" to allow the battery to grid-charge, unless the utility does not allow battery grid charging.
- If the site does plan to take advantage of tax incentives, including through a third-party developer, this input could conservatively be set to "no" to guarantee maximum incentives.

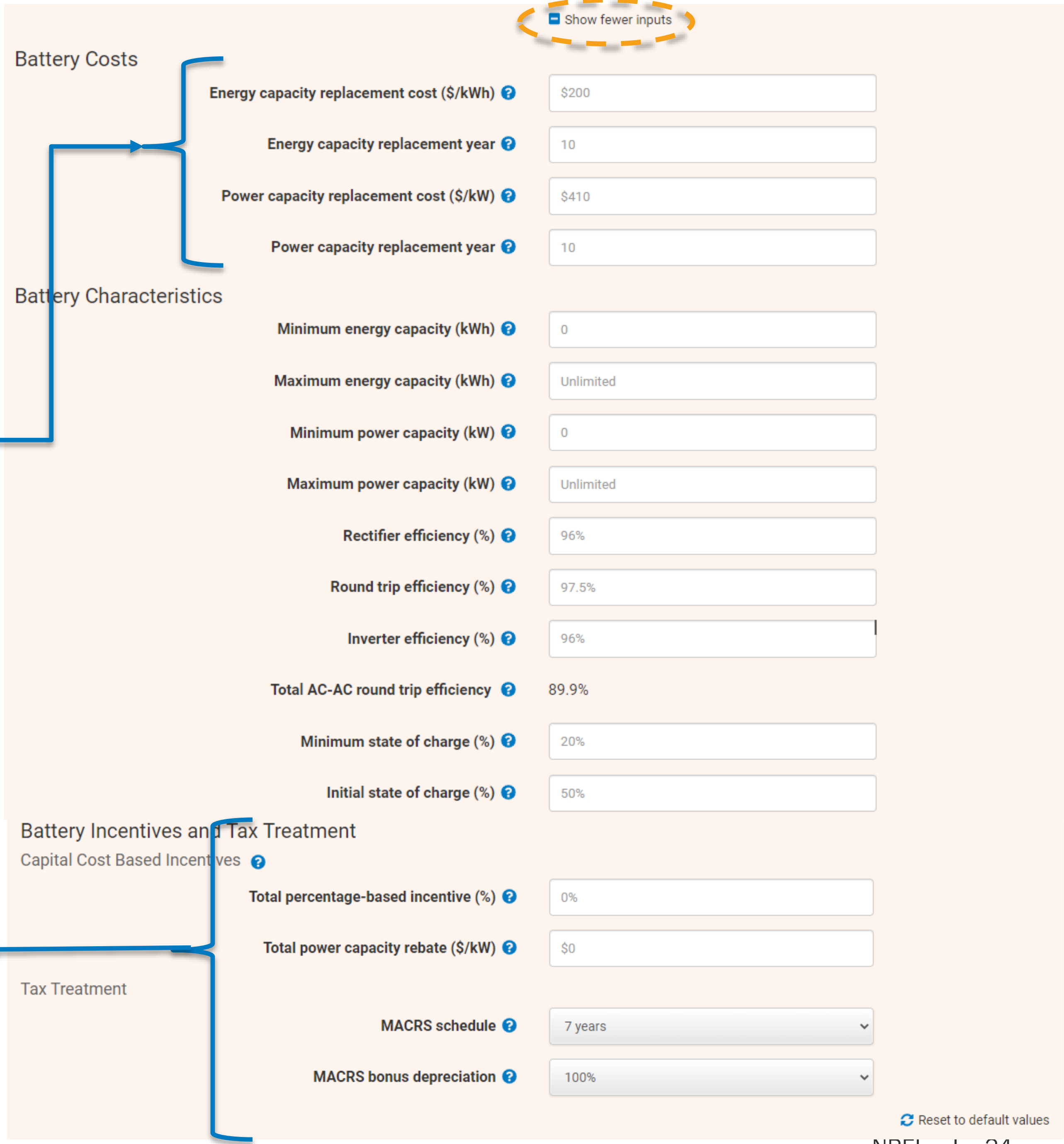
**See next slide for more information about tax incentive inputs.**

# Battery Storage Technology Assumptions – Advanced Inputs

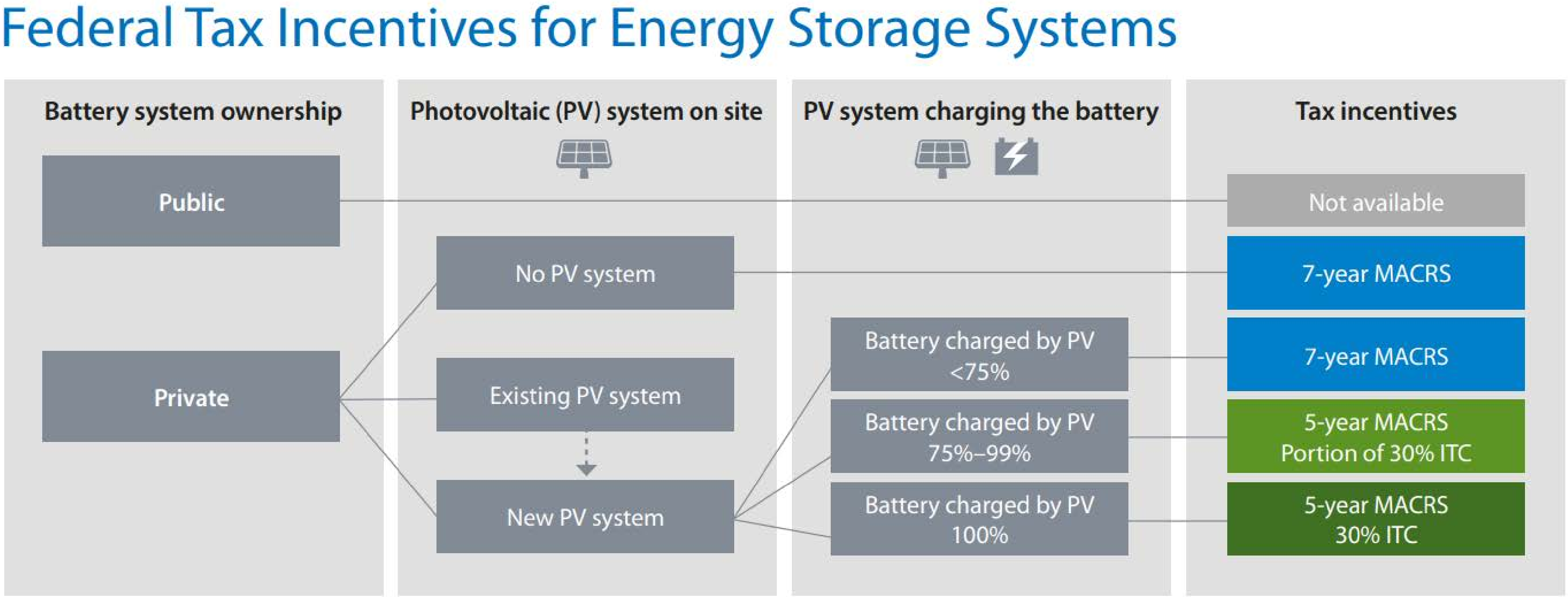
**Tip:** Because battery storage typically has a shorter lifespan than solar PV, the model assumes that the battery is replaced at some point during the analysis period (by default, in year 10).

**Tip:**

- Non-tax-paying entities (e.g., cities, counties) are not eligible for federal tax incentives, but may benefit from them in a third-party ownership scenario where the developer savings could "pass through" to the host. Thus, these incentives should be set to zero for a municipal screening, unless the scenario is considering third-party financing.
- Tax-paying entities are directly eligible for federal tax incentives and can select inputs based on their projected tax appetite.
    - See next slide for additional information about tax incentives for battery storage.



# Federal Incentives for Batteries, Based on PV System



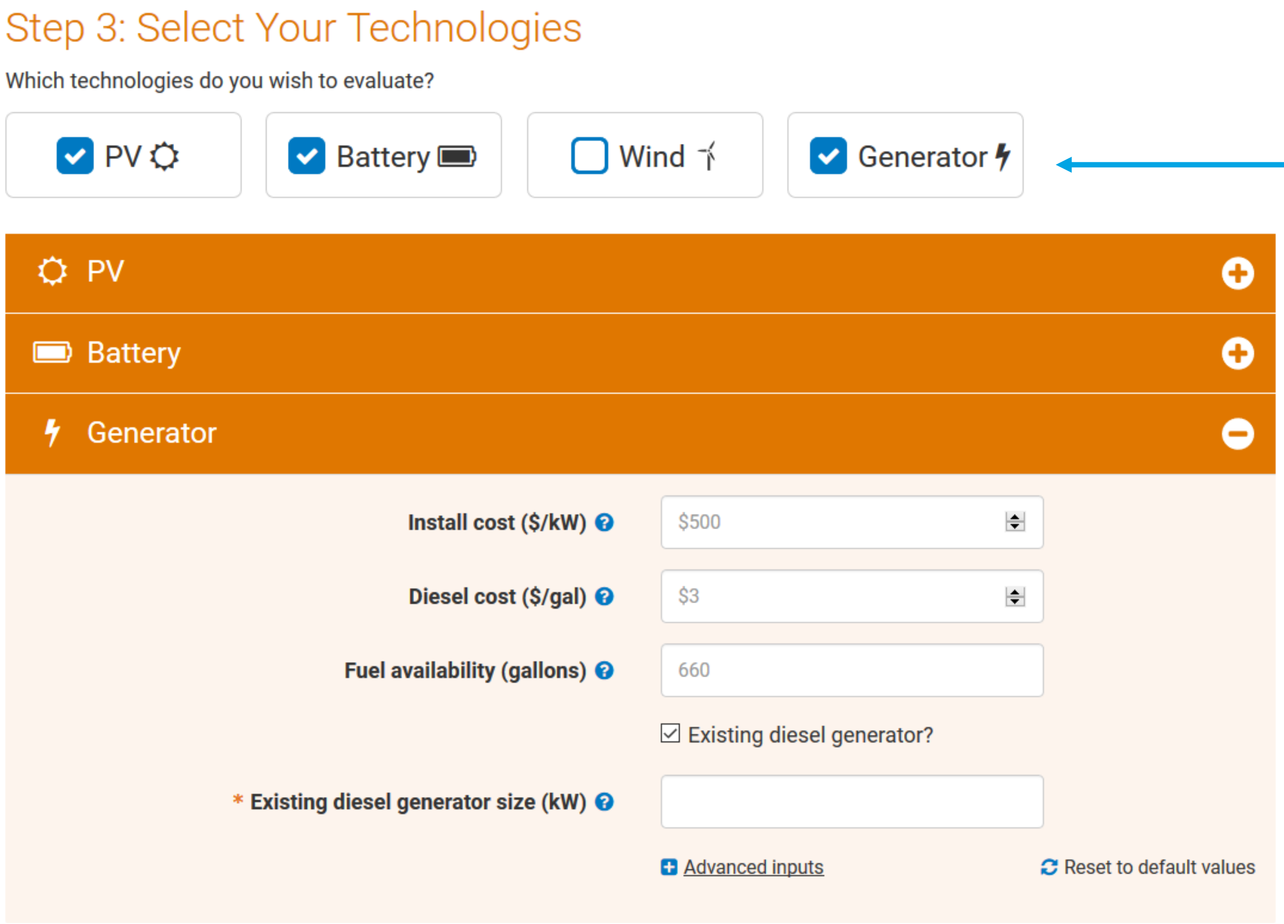

https://www.nrel.gov/docs/fy18osti/70384.pdf

**Note:** REopt Lite allows users to specify the Modified Accelerated Cost Recovery System (MACRS) depreciation schedule (0, 5, or 7 years) and Investment Tax Credit (ITC) (any %), but currently only offers two options for grid-charging of the battery: allowed or not allowed.

# Additional Resilience Input: Generator Modeling

**Tip:**

- Include an existing backup generator in your model if the site already has a generator.
- Include the option to build a new generator if the site is considering installing a new generator instead of or in addition to PV/battery.
- Do not include a generator if the site already has a backup generator but is considering PV/battery to provide additional redundancy (e.g., N+2) in case the generator is unavailable.
- Fuel availability indicates the quantity of fuel stored on-site and is assumed not to be able to be replenished during the outage.




Generator option for resilience evaluation

Specify existing generator, and/or let REopt Lite size a backup generator.

Defaults are for a diesel generator but can be modified.

# Key Results Output: System Sizes and Savings

**Tip: Recall Key Questions**
What size solar PV and/or battery storage could help my site survive an electric grid outage? What are the project economics (e.g., NPV), considering bill savings from grid-connected operations as well as the resilience provided?

Your recommended solar installation size

361 kW
PV size

Measured in kilowatts (kW) of direct current (DC), this recommended size minimizes the life cycle cost of energy at your site.

This optimized size may not be commercially available. The user is responsible for finding a commercial product that is closest in size to this optimized size.

Your recommended battery power and capacity

78 kW
battery power

253 kWh
battery capacity

This system size minimizes the life cycle cost of energy at your site. The battery power (kW-AC) and capacity (kWh) are optimized for economic performance.

This optimized size may not be commercially available. The user is responsible for finding a commercial product that is closest in size to this optimized size.

Cost-optimal system sizes are outputs of the tool.

Battery power (kW) and energy (kWh) are sized independently.

Your potential life cycle savings (25 years)

This is the net present value of the savings (or costs if negative) realized by the project based on the difference between the total life cycle costs of doing business as usual compared to the optimal case.

$209,418

NPV of savings after capital and O&M costs.

# Additional Results Output: Dispatch, Results Comparison, & Pro Forma

Compare the resilient solution to the business-as-usual case, as well as to the system sized to optimize purely grid-connected cost savings. Also, note annual renewable energy and $CO_2$ emissions impacts.

**Tip: Recall Key Questions**
How do the system sizes and economics of the resilient solution compare to the business-as-usual scenario and to the those proposed purely for grid-connected cost savings?

Download pro forma for additional, more detailed financial results.

Results Comparison

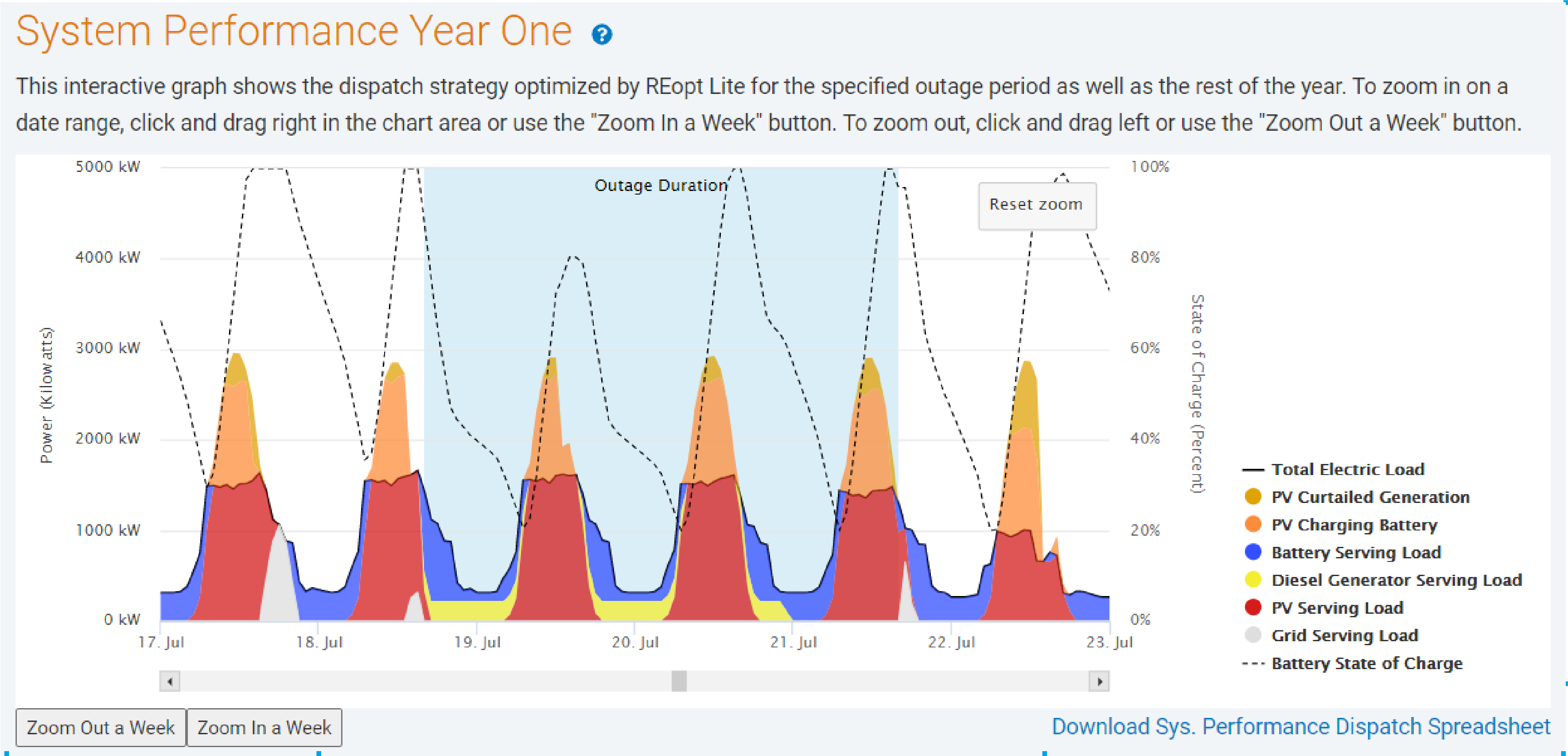
These results show how doing business as usual compares to the optimal case.

| | Business As Usual | Resilience | Financial |
|---|---|---|---|
| **System Size** | | | |
| PV Size | 0 kW | 4,392 kW | 1,758 kW |
| Battery Power | 0 kW | 1,123 kW | 0 kW |
| Battery Capacity | 0 kWh | 7,878 kWh | 0 kWh |
| Generator Size | 0 kW | 220 kW | 0 kW |
| **Energy Production and Fuel Use** | | | |
| PV Energy Production | 0 kWh | 6,927,624 kWh | 2,773,273 kWh |
| Average Annual Energy Supplied from Grid | 6,056,748 kWh | 971,034 kWh | 3,757,106 kWh |
| **Summary Generation Metrics** | | | |
| Annual Energy from Renewable Energy | N/A | 113% | 45% |
| **$CO_2$ Emissions** | | | |
| On-Site Fuels $CO_2$ Emissions in Year 1 | 0 tons | 7 tons | 0 tons |
| Grid Electricity $CO_2$ Emissions in Year 1 | 5,217 tons | 825 tons | 3,243 tons |
| Total $CO_2$ Emissions in Year 1 | 5,217 tons | 833 tons | 3,243 tons |
| Percent Reduction in $CO_2$ Emissions from BAU | N/A | 84% | N/A |
| **Year 1 Utility Electricity Cost – Before Tax** | | | |
| Utility Energy Cost | $684,958 | $109,814 | $424,891 |
| Utility Demand Cost | $0 | $0 | $0 |
| Utility Fixed Cost | $360 | $360 | $360 |
| Utility Minimum Cost Adder | $0 | $0 | $0 |
| Total Year 1 Utility Cost - Before Tax | $685,318 | $110,174 | $425,251 |
| **Life Cycle Utility Electricity Cost – After Tax** | | | |
| Utility Energy Cost | $6,563,376 | $1,052,258 | $4,071,376 |
| Utility Demand Cost | $0 | $0 | $0 |
| Utility Fixed Cost | $3,450 | $3,450 | $3,450 |
| Utility Minimum Cost Adder | $0 | $0 | $0 |
| Total Life Cycle Utility Cost - After Tax | $6,566,825 | $1,055,707 | $4,074,826 |
| **Summary Financial Metrics** | | | |
| Total Upfront Capital Cost Before Incentives | N/A | $11,389,392 | $2,813,280 |
| Capital Cost After Incentives | N/A | $7,213,664 | 1,550,292 |
| Year 1 O&M Cost, before tax | N/A | $72,473 | 28,133 |
| Lifecycle O&M and replacement costs, after tax | N/A | $1,387,156 | $274,986 |
| Net CAPEX + Life Cycle Replacement + O&M, after tax | $0 | $8,600,820 | $2,937,447 |
| Total Life Cycle Costs | $6,566,825 | $9,675,501 | $5,900,103 |
| Net Present Value | $0 | -$3,108,676 | $742,884 |
| Payback Period | N/A | 18.11 yrs | 7.4 yrs |
| Internal Rate of Return | N/A | 3.4% | 12.6% |
| PV Levelized Cost of Energy | N/A | $0.062/kWh | $0.062/kWh |

Download ProForma Spreadsheet

# Additional Results Output: Hourly Dispatch Graph

View cost-optimal hourly dispatch, including during outage and grid-connected operations.




The specified outage event is highlighted in blue (lower load).

The load is met exclusively by the PV and storage that REopt Lite selected.

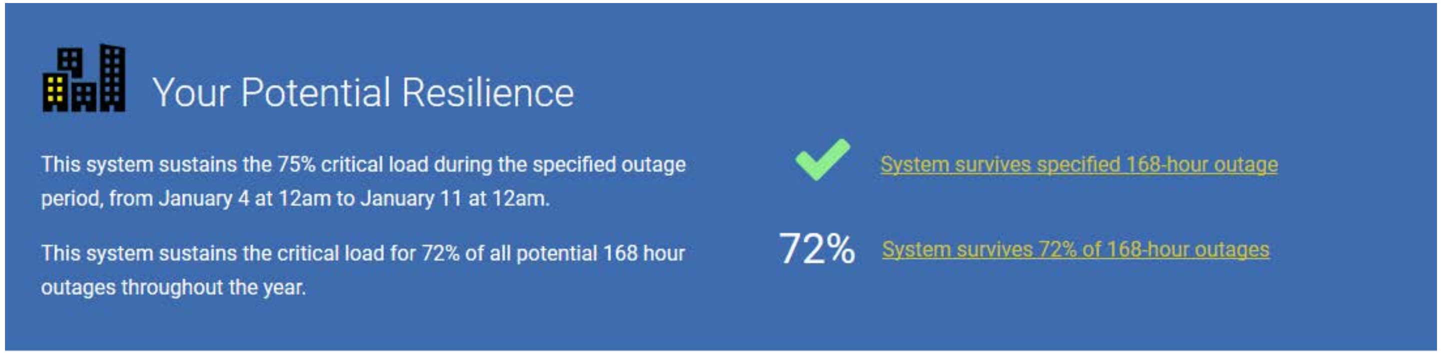
As soon as the outage ends, the site goes back to purchasing grid electricity.

Zoom in and out to look at a day, week, and year.

Download hourly data.

**Tip:** These results are helpful to understand how the system is being operated to maximize grid-connected and resilience value.

# Resilience Output: System Sized to Meet Outage




REopt Lite optimizes system size and dispatch to survive the specific user-specified outage.

**Tip: Recall Key Questions**
- How does the system's outage survivability compare to outages occurring at other times of year?
- Does this system and its outage survivability meet the resilience needs and goals of this site?

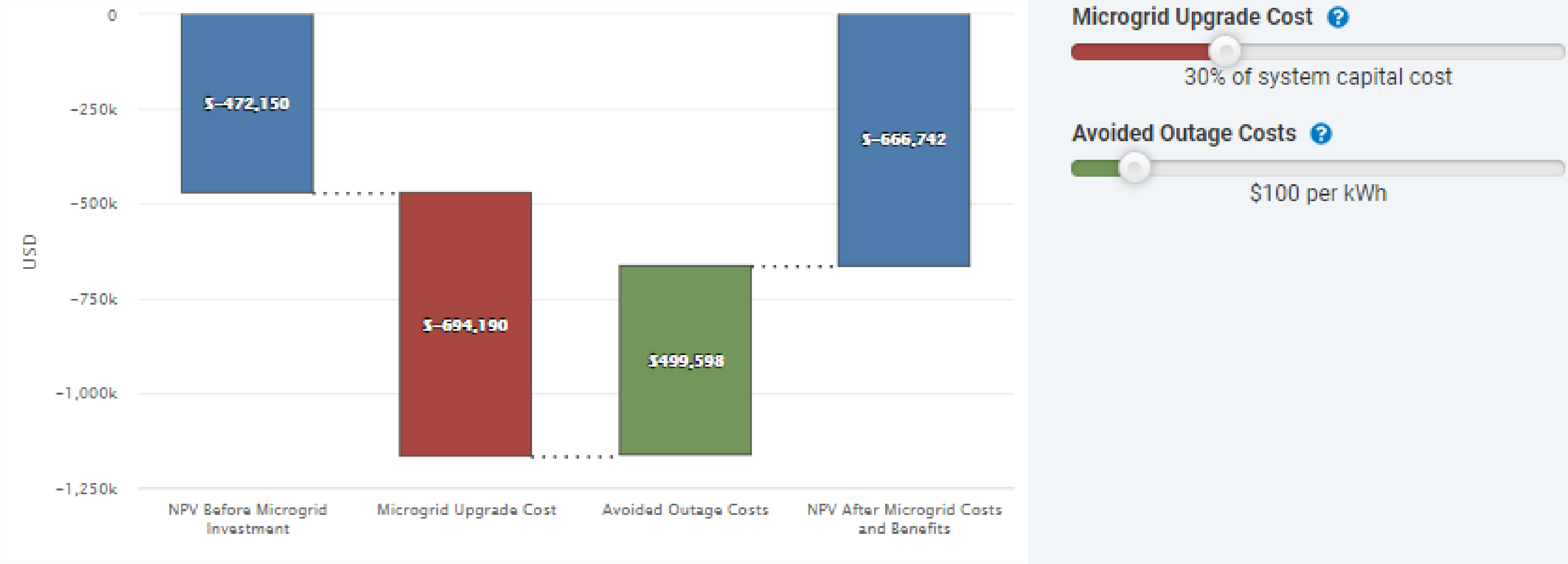

REopt Lite then simulates outages occurring throughout the year to determine the probability of the system surviving outages of various durations.

This outage survivability curve compares the survivability of the business-as-usual case, the grid-connected cost-optimal system, and resilience evaluation sizing to highlight how DERs can extend the duration that a site can continue to operate in the case of a grid outage.

# Microgrid Cost & Resilience Benefits

## Effect of Resilience Costs and Benefits

This interactive waterfall chart allows the user to consider the cumulative effect of extra costs and benefits of increased resilience on the project's net present value (NPV). Upgrading the recommended system to a microgrid allows a site to operate in both grid-connected and island-mode. This requires additional investment, which may include extra equipment such as controllers, distribution system infrastructure and communications upgrades. Economic benefit is observed when the value of avoiding the costs of an outage are considered. These microgrid upgrade costs and avoided outage costs are not factored into the optimization results. The sliders under the chart allow the user to change the Microgrid Upgrade Cost and the Avoided Outage Costs to analyze the impact on the NPV after Microgrid Costs and Benefits, while the NPV Before Microgrid Investment, which is determined by the optimization results, remains static.




Users can consider incorporating microgrid upgrade costs and/or avoided outage costs to project economics.

- **Example microgrid upgrade costs:** manual or automatic transfer switch, critical load panel, and/or additional control capabilities in the inverter for islanded operation
- **Example avoided outage costs ("value of lost load"):** loss of revenue, equipment damage, cost of injuries/life, and/or system start-up costs that would occur if the system could not continue operating through the grid outage
  - Users can use the Interruption Cost Estimate (ICE) calculator to estimate this value.

# Iterate

Users may consider running several iterations of a REopt Lite analysis to consider uncertainty in user inputs and to understand model sensitivity to these inputs.

In particular, for resilience analyses, users may consider adjusting inputs such as:

| Input | Considerations |
|---|---|
| Outage timing and/or duration | What are some possible “worst-case” outage scenarios for this site? For instance: peak load, timing of critical load (e.g., weekdays vs. weekends), low solar resource (i.e., winter), seasonal storms and increased probability of grid outages, daytime vs. nighttime outage event. |
| Critical load | Some loads may be more critical than others. Users can consider how much additional cost (or savings) would be required (or achieved) to sustain a somewhat higher (or lower) critical load, as well as considering how changing the critical load impacts outage survivability. |
| System size | Users may consider evaluating project economics of some fixed system size (e.g., maxing out PV to cover the space available at the site) or iteratively increasing system sizes to evaluate how much and at what cost a larger system could increase site resilience and outage survivability. (Users can “fix” system sizes by setting the minimum and maximum system size input to the same value.) |

# Additional Considerations & Caveats

When performing a multi-site screening to help prioritize sites with the best potential, it is important to keep assumptions that do not vary by site consistent across all sites and only vary assumptions that specifically vary by site.

Additionally, the following considerations and caveats help contextualize REopt Lite results:

- Load data reflects one year of consumption; future loads may increase, decrease, and/or shift in timing.
- Solar resource data used in REopt Lite is typical meteorological year data; year-to-year variation in weather is to be expected.
- Optimization is based on hourly modeling of loads, generation, and storage dispatch; intra-hour variability may impact savings.
- The optimized dispatch reflects the model's "perfect foresight" of modeled solar resource and load, so results present the maximum economic potential of the modeled technologies.
- Critical loads can be difficult to estimate; this contributes uncertainty to the resilience analysis.
- Additional integration costs may be required to facilitate microgrid capabilities that allow the system to operate independently in the case of grid outage.
- REopt assumes that batteries are dispatched to minimize operational costs when operating in grid-connected mode and may not be at a high state-of-charge when the outage occurs.

- REopt Lite (tool and help manual): https://reopt.nrel.gov/tool
- REopt Website (analysis services and case studies): https://reopt.nrel.gov/
- To send tool feedback or ask a question, contact reopt@nrel.gov

www.nrel.gov

NREL/PR-7A40-81636

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. 

NREL Transforming ENERGY