# Assessing PV + Storage Project Feasibility using NREL's REopt Lite Tool

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MN RE Procurement Workshop: On-Site Solar for Municipal Operations

September 10, 2019

# Agenda

1. 15 minutes: Presentation “PV + storage economic drivers”
2. 20 minutes: REopt Lite Demo and Exercise
3. 15 minutes: Exercise Debrief and Q&A

# Solar PV and Battery Storage Overview

- State, local and federal government have long history of implementing grid-connected solar PV projects for cost savings
  - Value stream is well understood: Electricity is generated when the sun is shining, and lowers utility electricity purchases
- Opportunities for grid-connected battery storage are emerging, and more complicated
  - Value stream is more complicated: there are multiple ways to provide savings, but they depend on how the battery is operated
- When configured to do so, PV + storage can provide back-up power in the event on an outage
  - This requires additional equipment at added cost

Installation of one of the 3,632 solar modules on NREL's parking garage. The garage can produce up to 1.15 megawatts Photo by Dennis Schroeder / NREL 21487

NREL and Raytheon, perform system level testing on the Miramar ZnBr Flow Battery Photo by Dennis Schroeder / NREL 32582

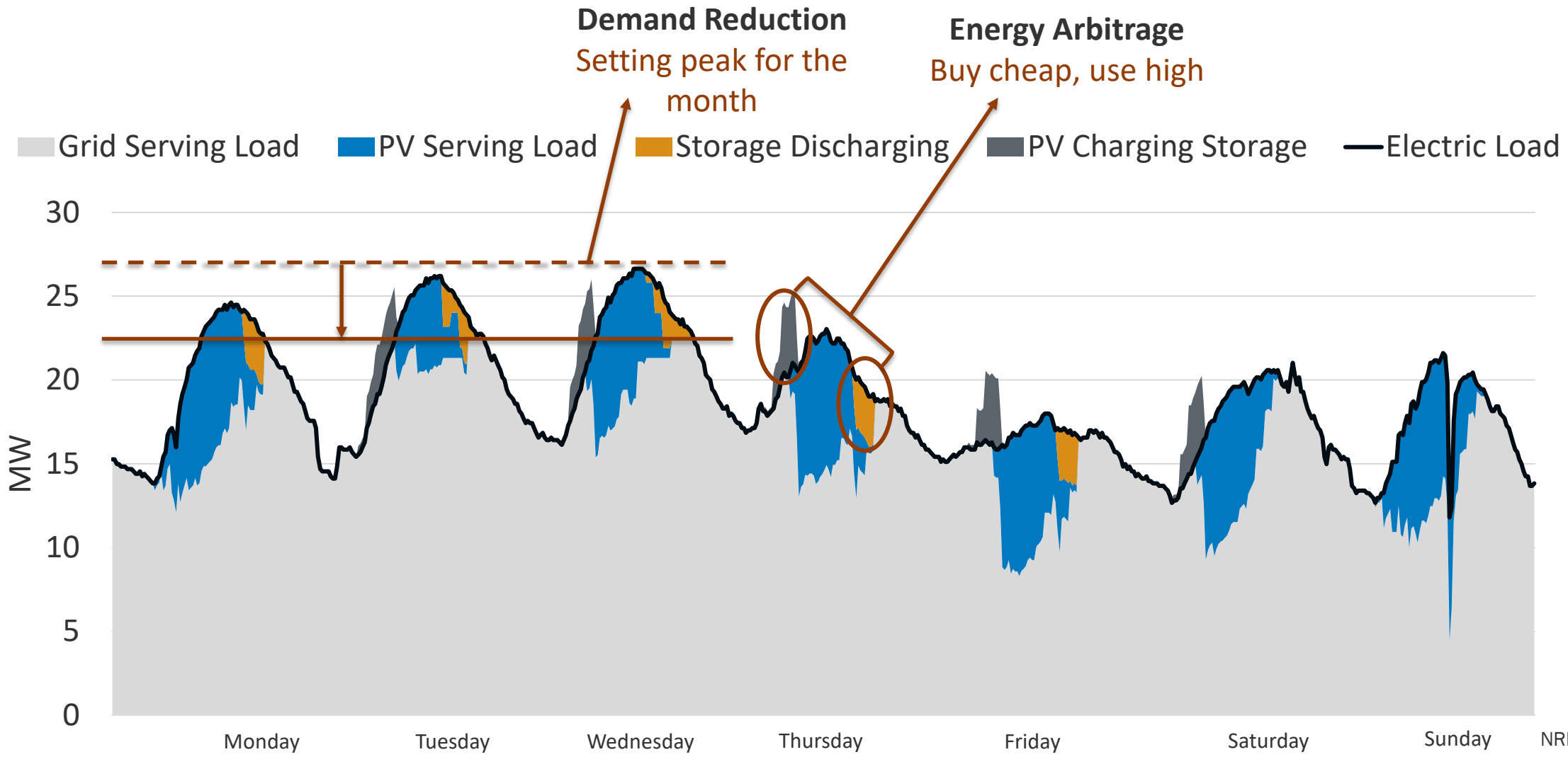
# Range of PV + Storage Use Cases

| | Off Grid PV + Storage | Grid Connected PV + Storage | Grid Connected PV + Storage with Microgrid | PV + storage for Large-scale Power Generation |
|---|---|---|---|---|
| **Purpose** | Providing continuous power in lieu of utility | Lowering cost of utility purchases | Lowering cost of utility purchases<br>Providing power during grid outage | Large-scale generation for off-site sale |
| **Why/Where it works** | • Remote sites with high fuel costs<br>• Low grid reliability | • High demand charges<br>• TOU rates<br>• Ancillary service markets | • High demand charges<br>• TOU rates<br>• Ancillary service markets<br>• Resilience requirements | • Deregulated market<br>• Interested offtaker<br>• large land-availability |
| **Primary Power Supply** | DERs (typically including generators) | Grid + DERs | Grid + DERs | Grid only |
| **Back-up** | None | None | DERs | Typically none but could be possible |

# PV + Storage Value Streams by Use Case

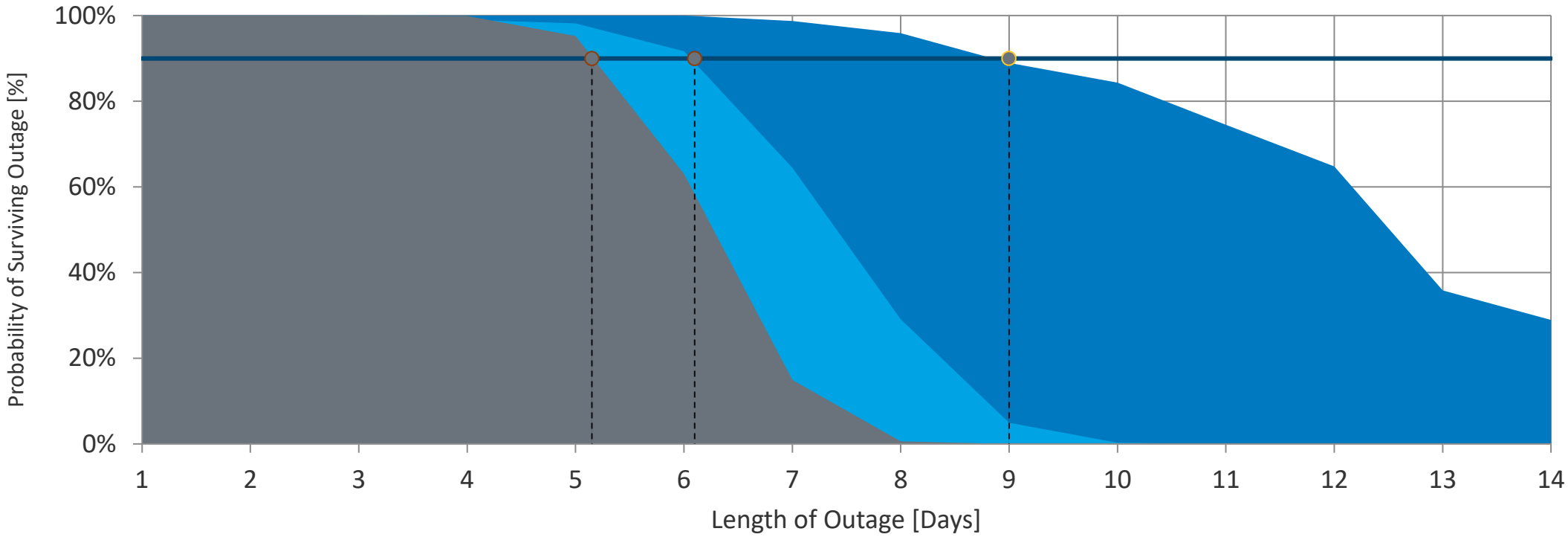
| Value Stream | Description | Off Grid | Grid Connected | Large Scale |
|---|---|---|---|---|
| **Fuel Offset** | Offset fuel cost in off-grid remote locations | X | | |
| **Demand charge reduction** | Use stored energy to reduce demand charges on utility bills | | X | |
| **Energy Arbitrage** | Energy time-of-use shift (from on-peak to off-peak hours or selling during high cost and charging during low cost) | | X | X |
| **Demand response** | Utility programs that pay customers to lower demand during system peaks | | X | |
| **Frequency regulation and capacity markets** | Stabilize frequency on moment-to-moment basis or supply spinning, non-spinning reserves (ISO/RTO) | | X | X |
| **Voltage support** | Insert or absorb reactive power to maintain voltage ranges on distribution or transmission system | | | X |
| **T&D Upgrade Deferral** | Deferring the need for transmission or distribution system upgrades, e.g. via system peak shaving | | | X |
| **Resiliency / Back-up power** | Using battery to sustain a critical load during grid outages | | X | |

# Example of Demand Reduction and Energy Arbitrage



# Surviving Outage vs. Cost Savings

| | Generator | Solar PV | Storage | Lifecycle 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 |




In a case study at a military base, NREL evaluated thousands of random grid outages and durations throughout the year and compared number of hours the site could survive with a diesel generator and fixed fuel supply vs. generator augmented with PV and battery.

# Will PV + Storage Work for Your Site?

**Solar PV Resource**

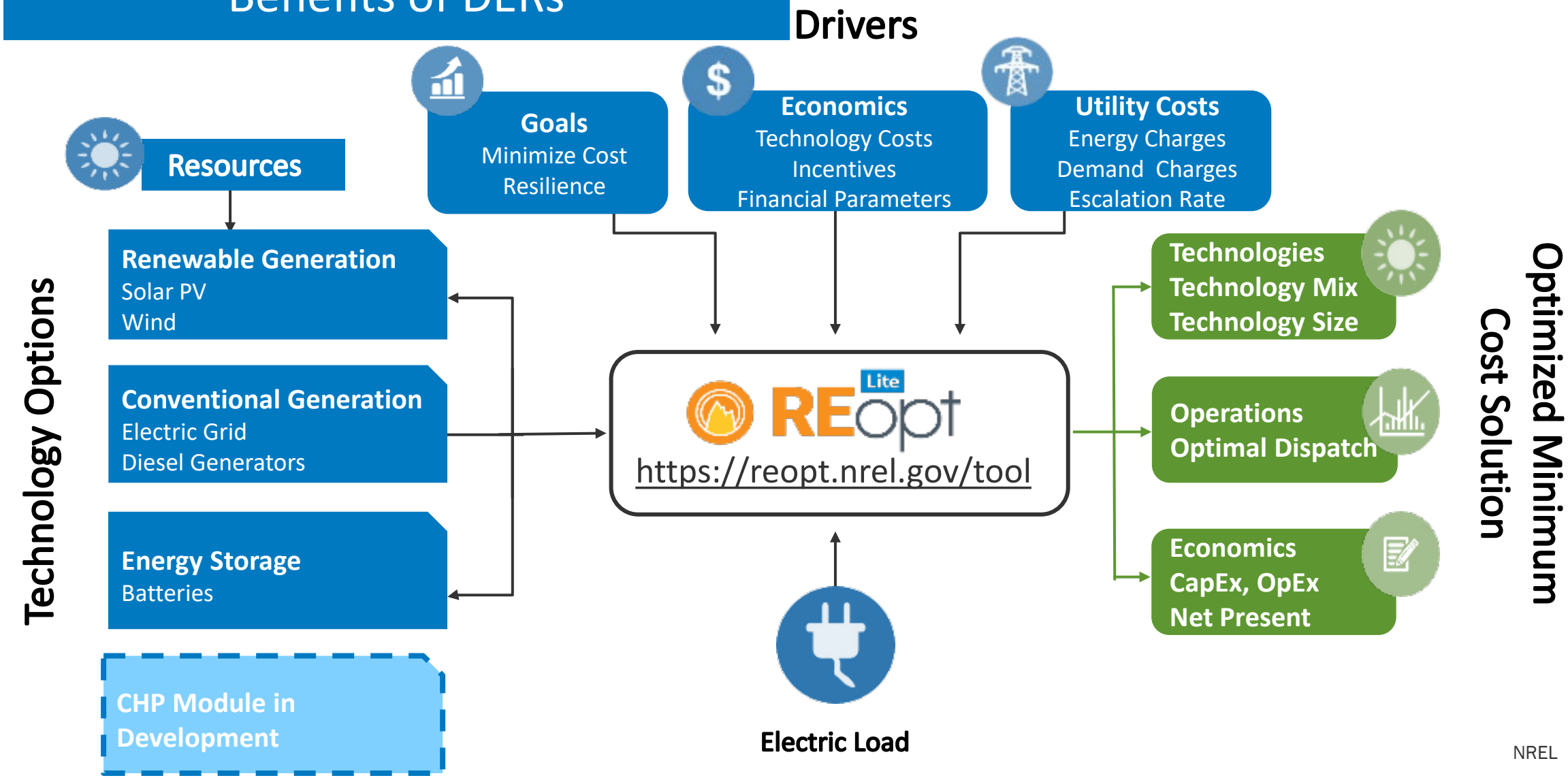
**Technology Costs & Incentives**

**Space Available**

**Utility Cost & Consumption**

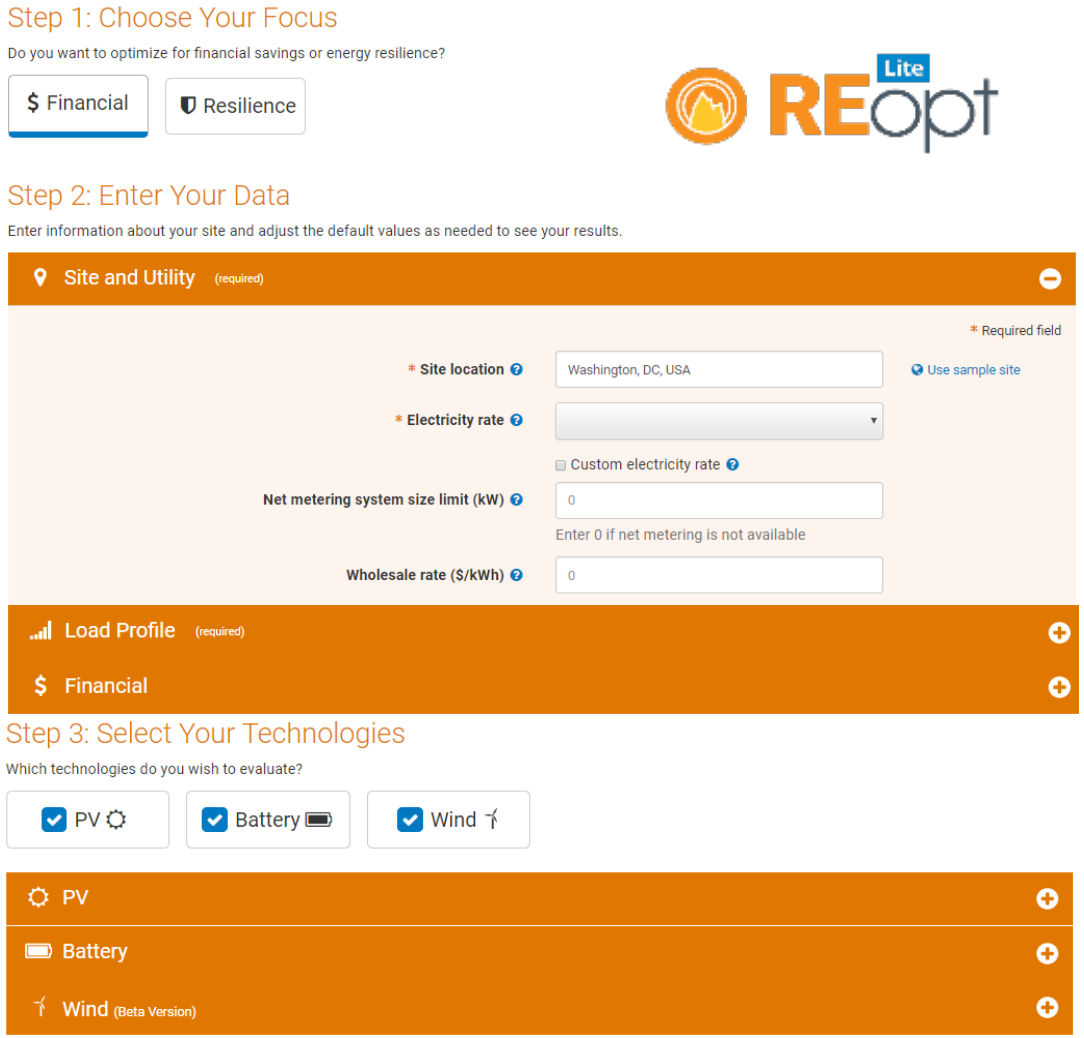
**Financial Parameters**

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



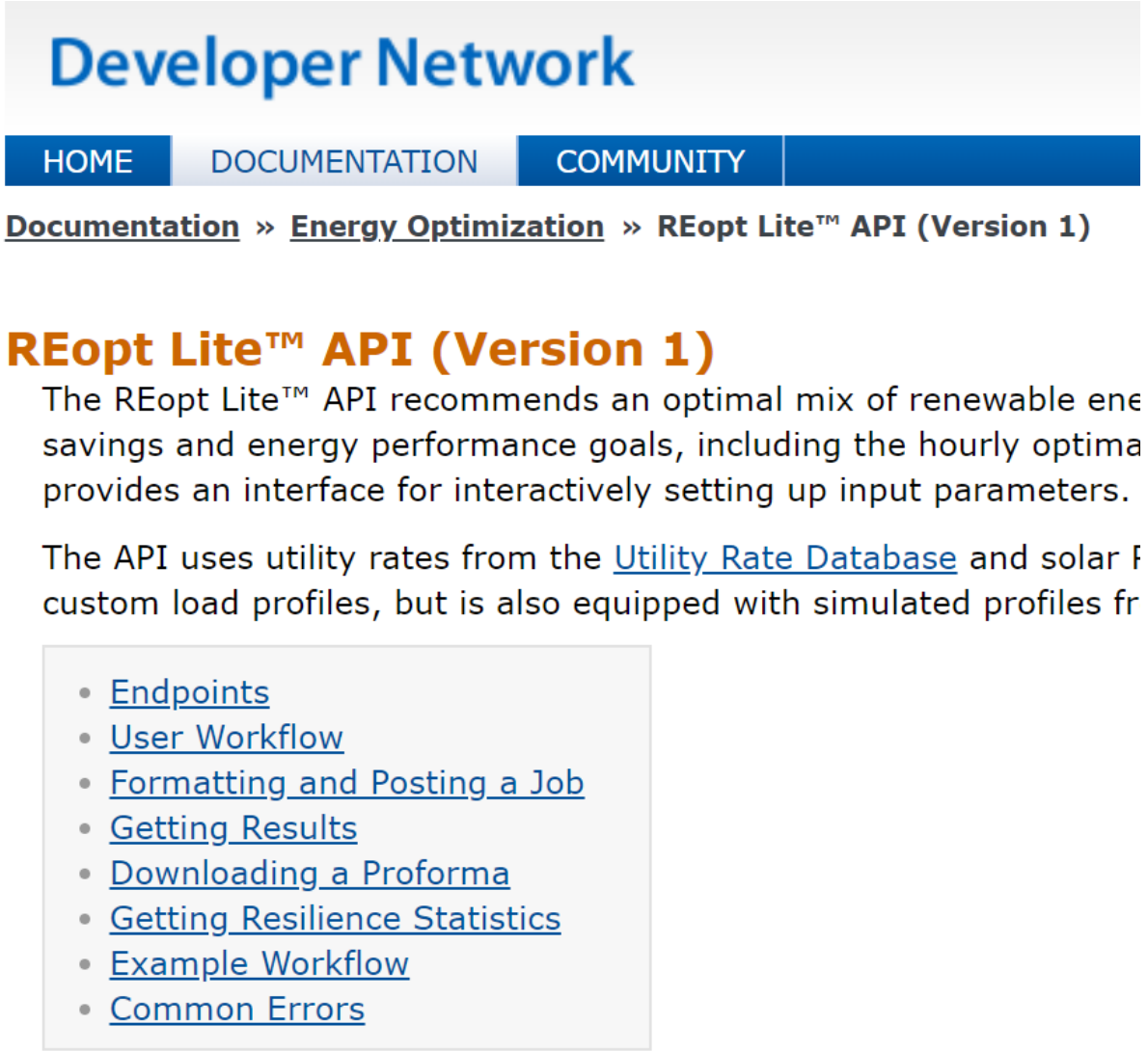
# REopt Lite Web Tool

- **REopt Lite** is a web tool that offers a no-cost subset of NREL's more comprehensive REopt model
- **Financial mode** optimizes PV, wind and battery system sizes and battery dispatch strategy to minimize life cycle cost of energy
- **Resilience mode** optimizes PV, wind, and storage systems along with exiting back-up generators to sustain critical load during grid outages
- To access REopt Lite: [https://reopt.nrel.gov/tool](https://reopt.nrel.gov/tool)



# REopt Lite API

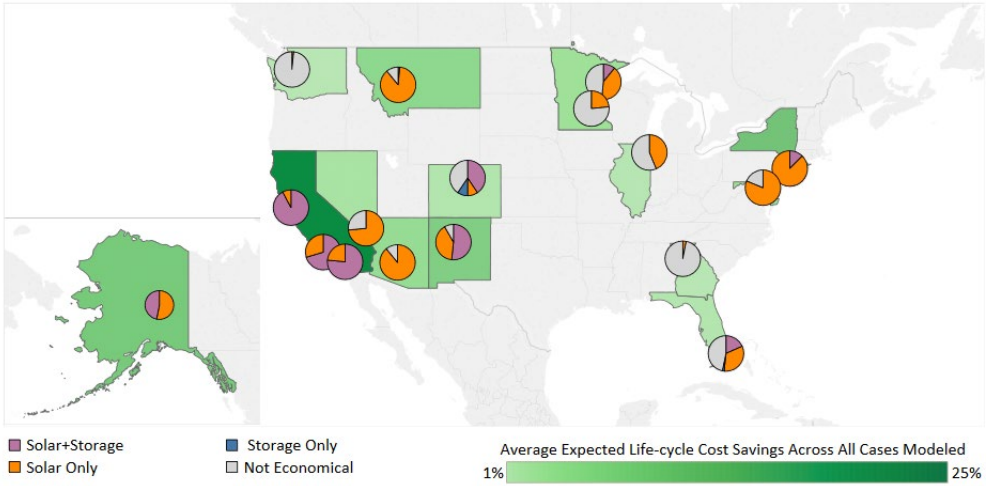
- What is an API?
  - Application Programming Interface.
  - Programmatic way of accessing REopt Lite (sending and receiving data from a server)
  - File format used for sending and receiving the data: JSON
- Advantages:
  - Multiple simulations for different sites can be run programmatically
  - Scenario analysis can be automated
  - Integration with other programs



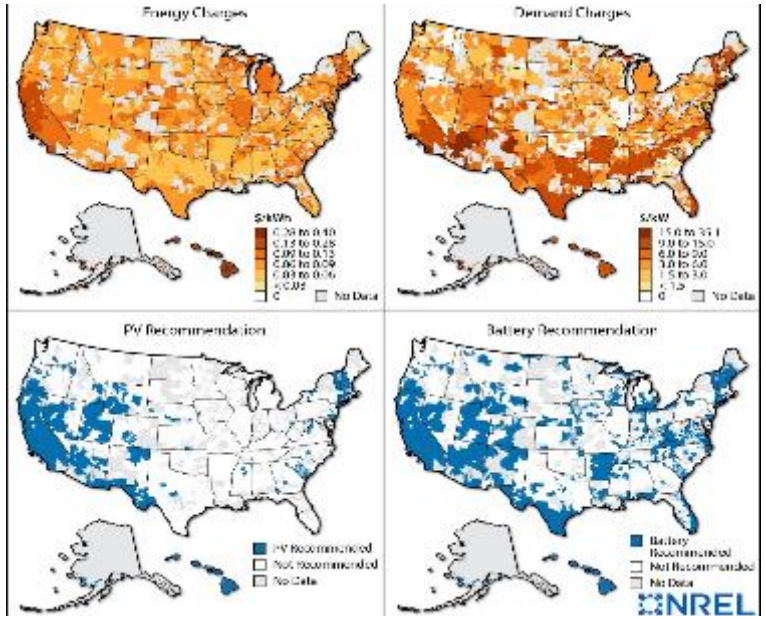

https://developer.nrel.gov/docs/energy-optimization/reopt-v1/

# Analysis Enabled by API

- The REopt Lite API enables national scale analysis of storage economics and impacts on adoption/deployment
- Analysis questions include:
  - Where in the country is storage (and PV) currently cost effective?
  - At what capital costs is storage adopted across the US?
  - How does varying utility rate, escalation rates, and incentive structures impact storage profitability?
  - How (and where) can stationary storage support DC-fast-charging electric vehicle economics and deployment?



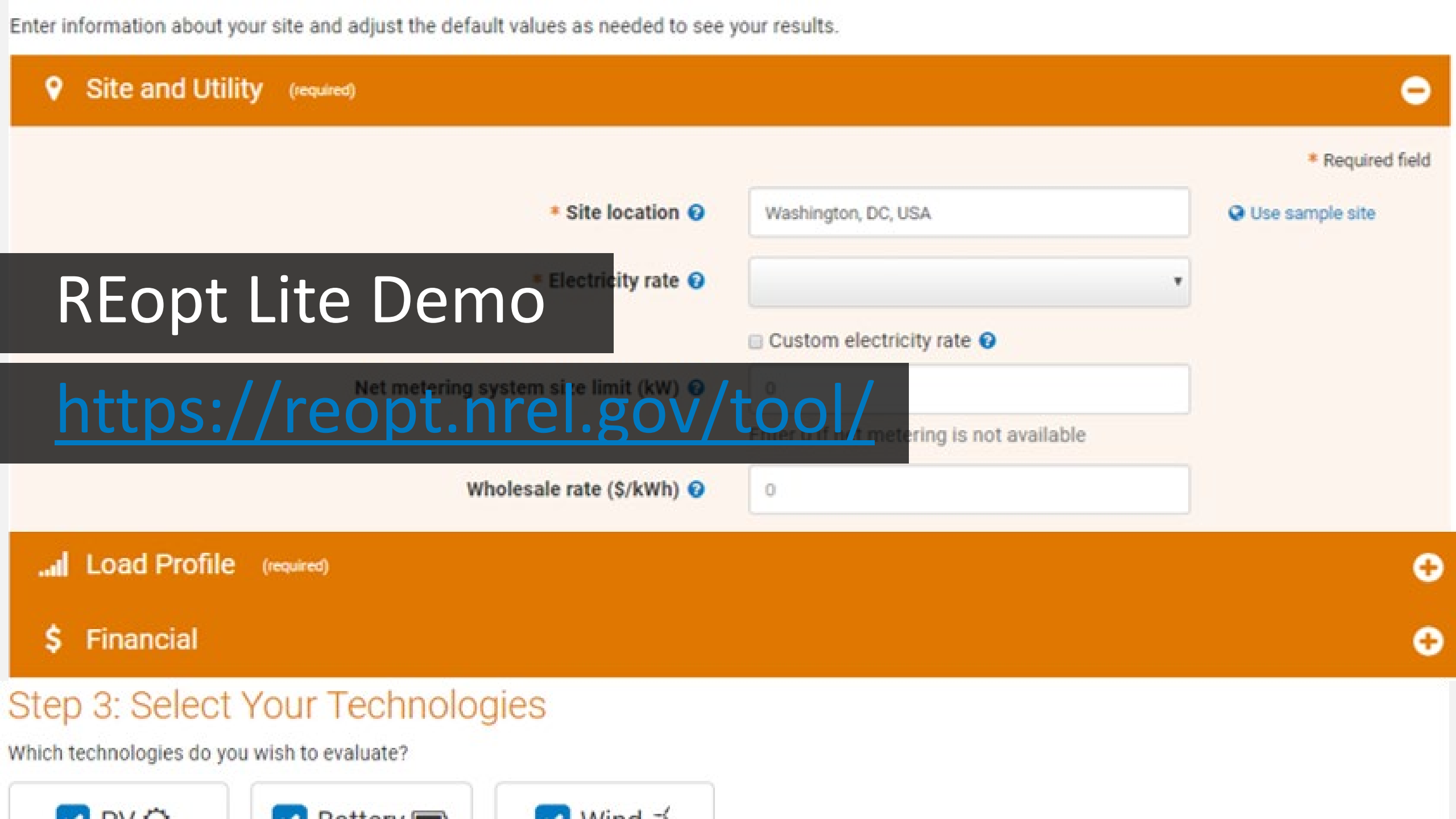

*Identifying Critical Factors in the Cost-effectiveness of Solar and Battery Storage in Commercial Buildings*
https://www.nrel.gov/docs/fy18osti/70813.pdf




*Technology Solutions To Mitigate Electricity Cost for Electric Vehicle DC Fast Charging*
https://www.sciencedirect.com/science/article/pii/S0306261919304581

# REopt Lite Demo

https://reopt.nrel.gov/tool/



# REopt Lite Exercise

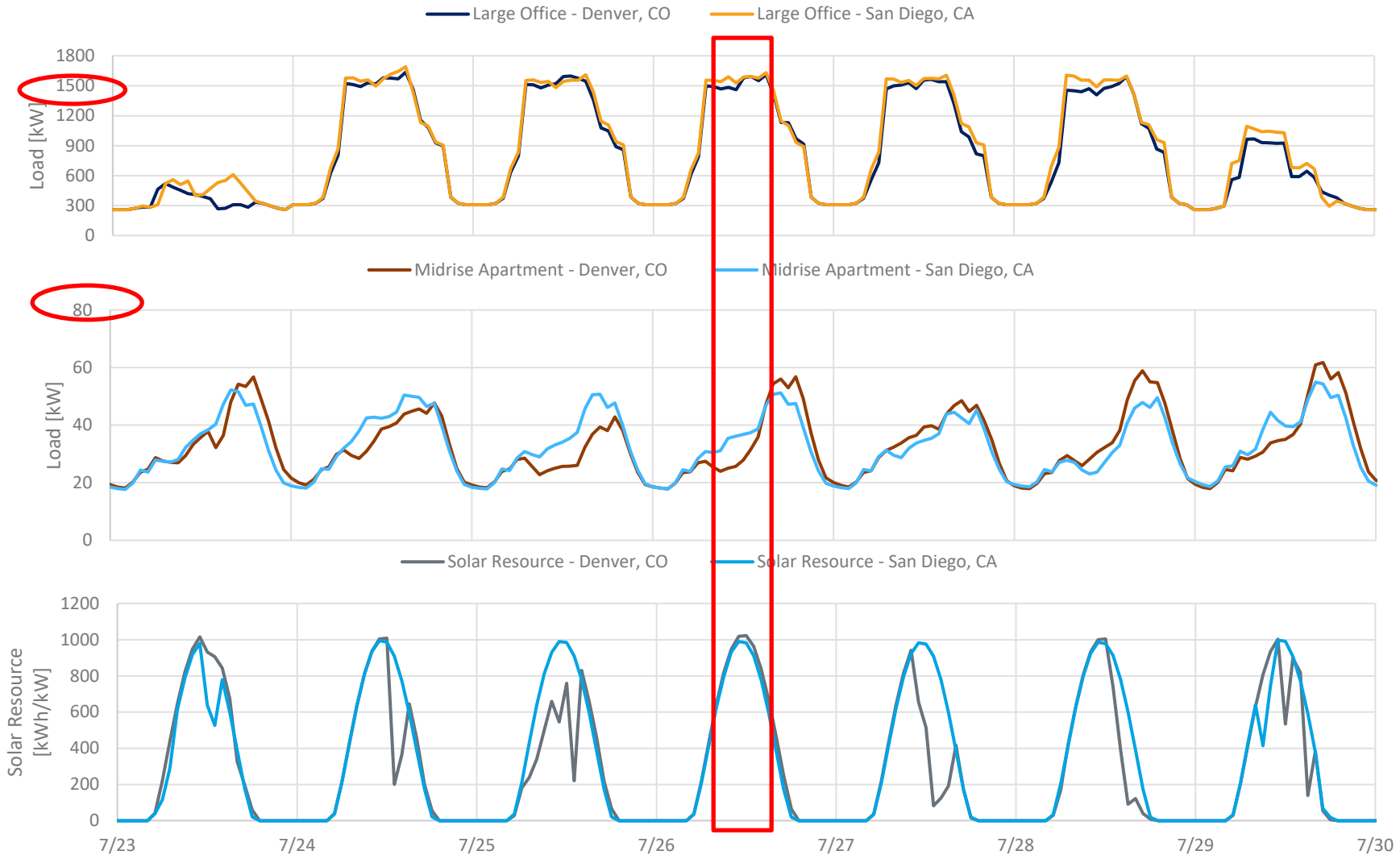
- Using your laptop (preferred), tablet, or cell, go to the REopt Lite webtool: https://reopt.nrel.gov/tool/
  - Choose your focus: select “financial”
  - Enter your site data (see information sheet on your table)
  - Write down your results

- Each table has a different set of inputs and should expect different outputs
- You can work together with someone at you table, or alone
- If you get stuck, raise your hand. Emma and Kathleen will be walking around the room to answer questions
- We will go through the results at the end. If you finish early, complete resilience section

# Financial Results

| | Location | Electric rate structure | Net metering | Building/ load type | PV size | Battery size | NPV [$] | 1-hr outage Survivability | 12-hr outage Survivability |
|---|---|---|---|---|---|---|---|---|---|
| **1** | Denver | Flat | 2,000 kW | Large office | 0 kW | 0 kW / 0 kWh | $0 | 0% | 0% |
| **2** | Denver | Demand | 2,000 kW | Large office | 2,000 kW | 18 kW / 24 kWh | $ 189k | 30% | ~0% |
| **3** | Denver | Flat | 2,000 kW | Midrise apartment | 0 kW | 0 kW / 0 kWh | $0 | 0% | 0% |
| **4** | Denver | Demand | 2,000 kW | Midrise apartment | 41 kW | 0 kW / 0 kWh | $ 1k | 24% | 0% |
| **5** | San Diego | Flat | 10,000 kW | Large office | 4,654 kW | 0 kW / 0 kWh | $ 3,339k | 39% | 1% |
| **6** | San Diego | Demand | 10,000 kW | Large office | 4,654 kW | 137 kW / 181 kWh | $3,864k | 49% | 2% |
| **7** | San Diego | Flat | 10,000 kW | Midrise apartment | 174 kW | 0 kW / 0 kWh | $ 124k | 39% | ~0% |
| **8** | San Diego | Demand | 10,000 kW | Midrise apartment | 174 kW | 1 kW / 2 kWh | $ 130k | 40% | ~0% |

# Load Profile, Solar Resource, & Utility Rate Comparison




## Utility Rate

| Location | Rate structure | Energy charges [$/kWh] | Demand charges [$/kW] |
|---|---|---|---|
| Denver | Flat rate | $0.0958 | $0 |
| Denver | Demand rate | $0.0958 | $15 |
| San Diego | Flat rate | $0.1525 | $0 |
| San Diego | Demand rate | $0.1525 | $18 |

## Net Metering Limit

| Location | Net metering limit |
|---|---|
| Denver | 2,000 kW |
| San Diego | 10,000 kW |

# Resources and Contact Information

- REopt Lite: https://reopt.nrel.gov/tool
  - Tool
  - Help manual
- REopt Website: https://reopt.nrel.gov/tool
  - Analysis services
  - Case studies
- Send tool feedback & ask a question: reopt@nrel.gov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**kathleen.krah@nrel.gov**

# Q&A

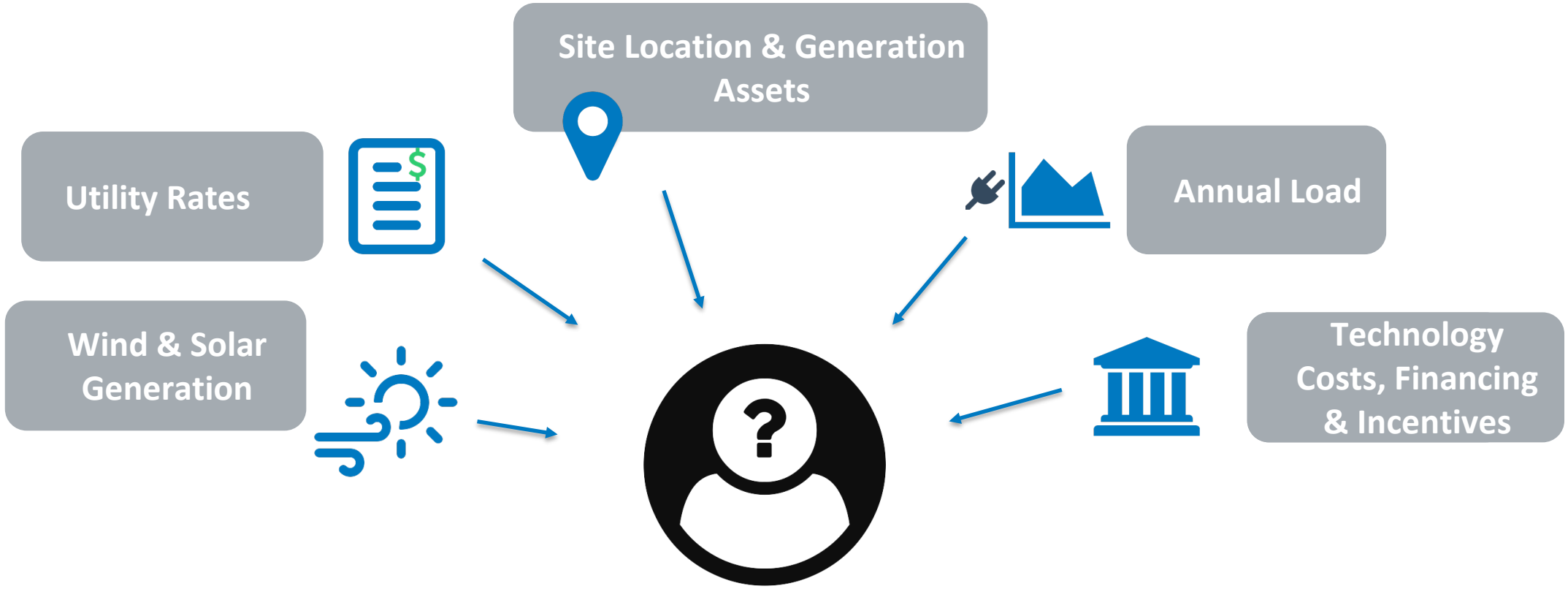
www.nrel.gov

# Appendix

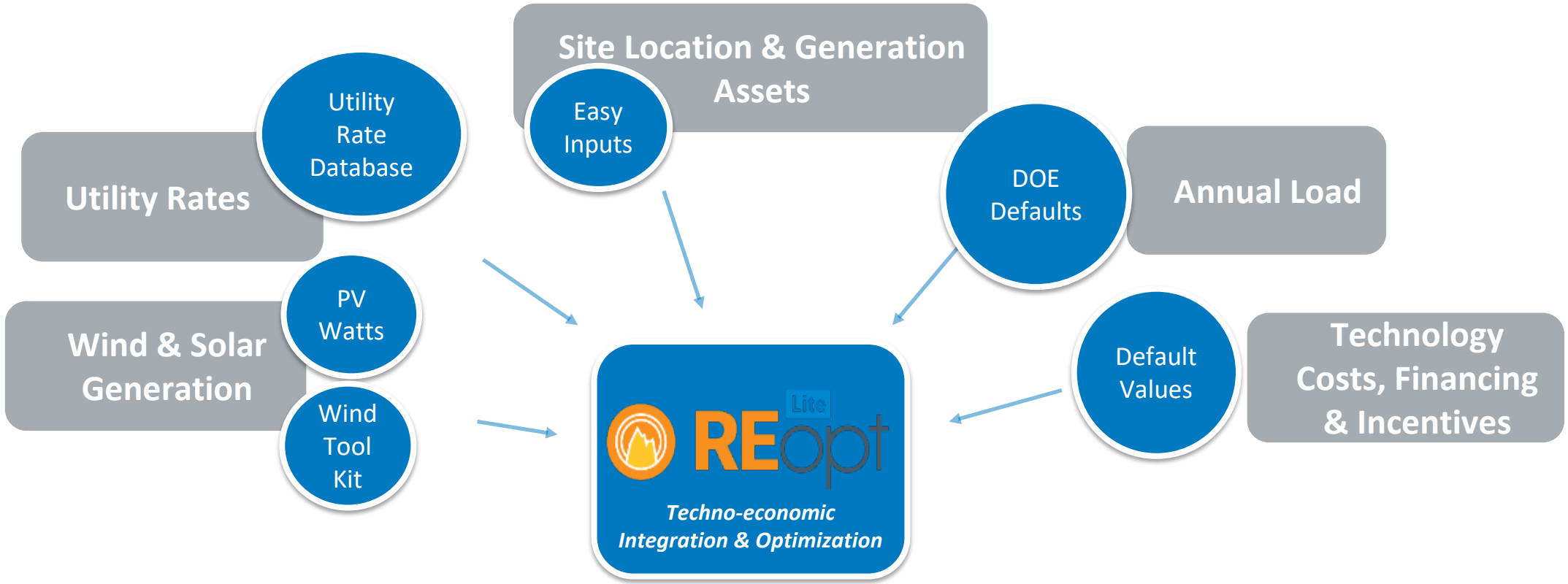
# Resilience Results

| | Location | Electric rate structure | Net metering | Building/ load type | Analysis focus | PV size | Battery size | NPV [$] | 1-hr outage Survivability | 12-hr outage Survivability |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Denver | Flat | 2,000 kW | Large office | Financial | 0 kW | 0 kW / 0 kWh | $0 | 0% | 0% |
| | | | | | **Resiliency** | **2,000 kW** | **337 kW / 3,197 kWh** | **- $ 1,895k** | **99%** | **88%** |
| 2 | Denver | Demand | 2,000 kW | Large office | Financial | 2,000 kW | 18 kW / 24 kWh | $ 189k | 30% | ~0% |
| | | | | | **Resiliency** | **2,000 kW** | **495 kW / 3,197 kWh** | **- $ 1,069k** | **100%** | **98%** |
| 3 | Denver | Flat | 2,000 kW | Midrise apartment | Financial | 0 kW | 0 kW / 0 kWh | $0 | 0% | 0% |
| | | | | | **Resiliency** | **179 kW** | **20 kW / 191 kWh** | **- $ 114k** | **~100%** | **~100%** |
| 4 | Denver | Demand | 2,000 kW | Midrise apartment | Financial | 41 kW | 0 kW / 0 kWh | $ 1k | 24% | 0% |
| | | | | | **Resiliency** | **179 kW** | **23 kW / 191 kWh** | **- $ 80k** | **100%** | **99%** |
| 5 | San Diego | Flat | 10,000 kW | Large office | Financial | 4,654 kW | 0 kW / 0 kWh | $ 3,339k | 39% | 1% |
| | | | | | **Resiliency** | **4,629 kW** | **380 kW / 2,648 kWh** | **$ 1,670k** | **99%** | **93%** |
| 6 | San Diego | Demand | 10,000 kW | Large office | Financial | 4,654 kW | 137 kW / 181 kWh | $3,864k | 49% | 2% |
| | | | | | **Resiliency** | **4,629 kW** | **603 kW / 2,648 kWh** | **$ 2,992k** | **100%** | **96%** |
| 7 | San Diego | Flat | 10,000 kW | Midrise apartment | Financial | 174 kW | 0 kW / 0 kWh | $ 124k | 39% | ~0% |
| | | | | | **Resiliency** | **173 kW** | **15 kW / 140 kWh** | **$42k** | **~100%** | **98%** |
| 8 | San Diego | Demand | 10,000 kW | Midrise apartment | Financial | 174 kW | 1 kW / 2 kWh | $ 130k | 40% | ~0% |
| | | | | | **Resiliency** | **173 kW** | **26 kW / 140 kWh** | **$ 80k** | **100%** | **88%** |

# New system decisions are complex…



# … REopt Lite is here to help



# Summary Results Include System Sizes & Savings

## Results for Your Site

These results from REopt Lite summarize the economic viability of PV and battery storage at your site. You can edit your inputs to see how changes to your energy strategies affect the results.

Edit Inputs

REopt Lite

### Your recommended solar installation size

781 kW
PV size

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

### Your recommended battery power and capacity

131 kW
battery power

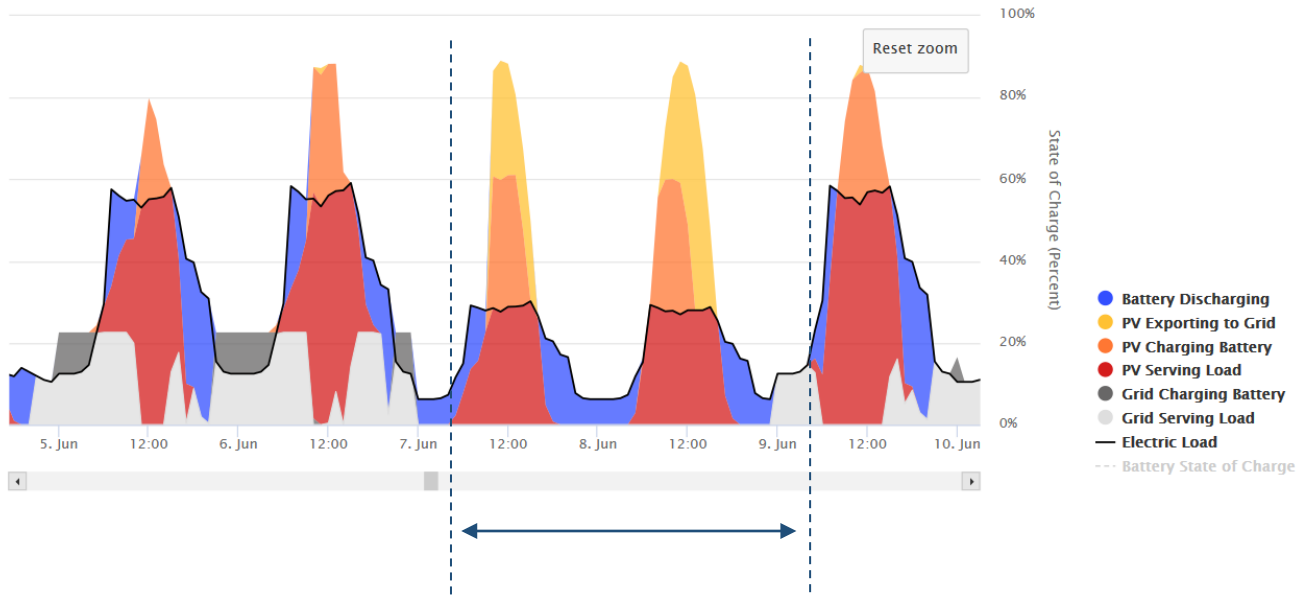
556 kWh
battery capacity

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

### Your potential life cycle savings (20 years)

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

$439,275




Outage occurring June 6-7
Critical load 50% of typical load

# Will PV Work for Your Site?

**Solar Resource**

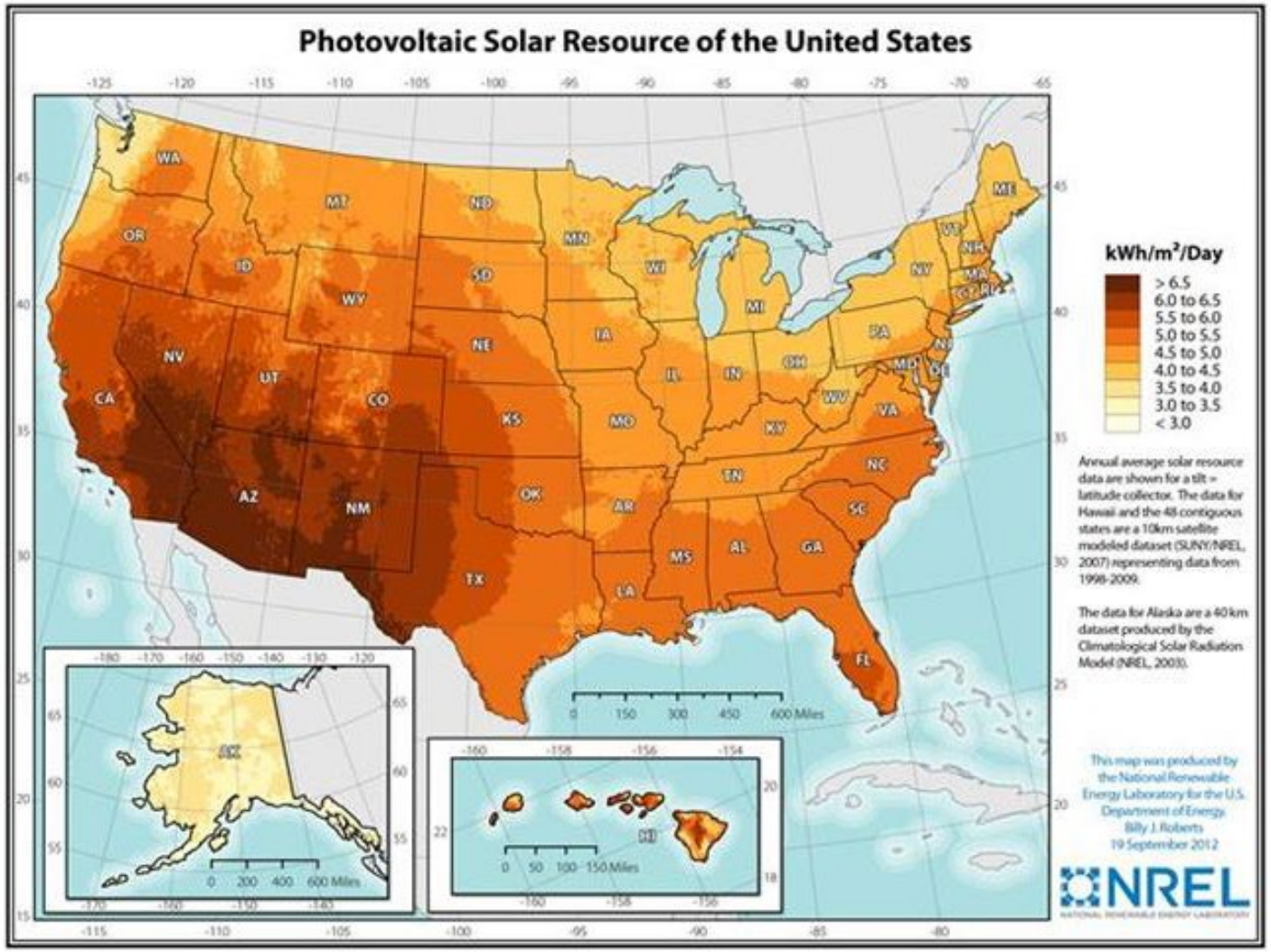
**PV Costs & Incentives**

**Space Available**

**Utility Cost & Consumption**

**Financial Parameters**

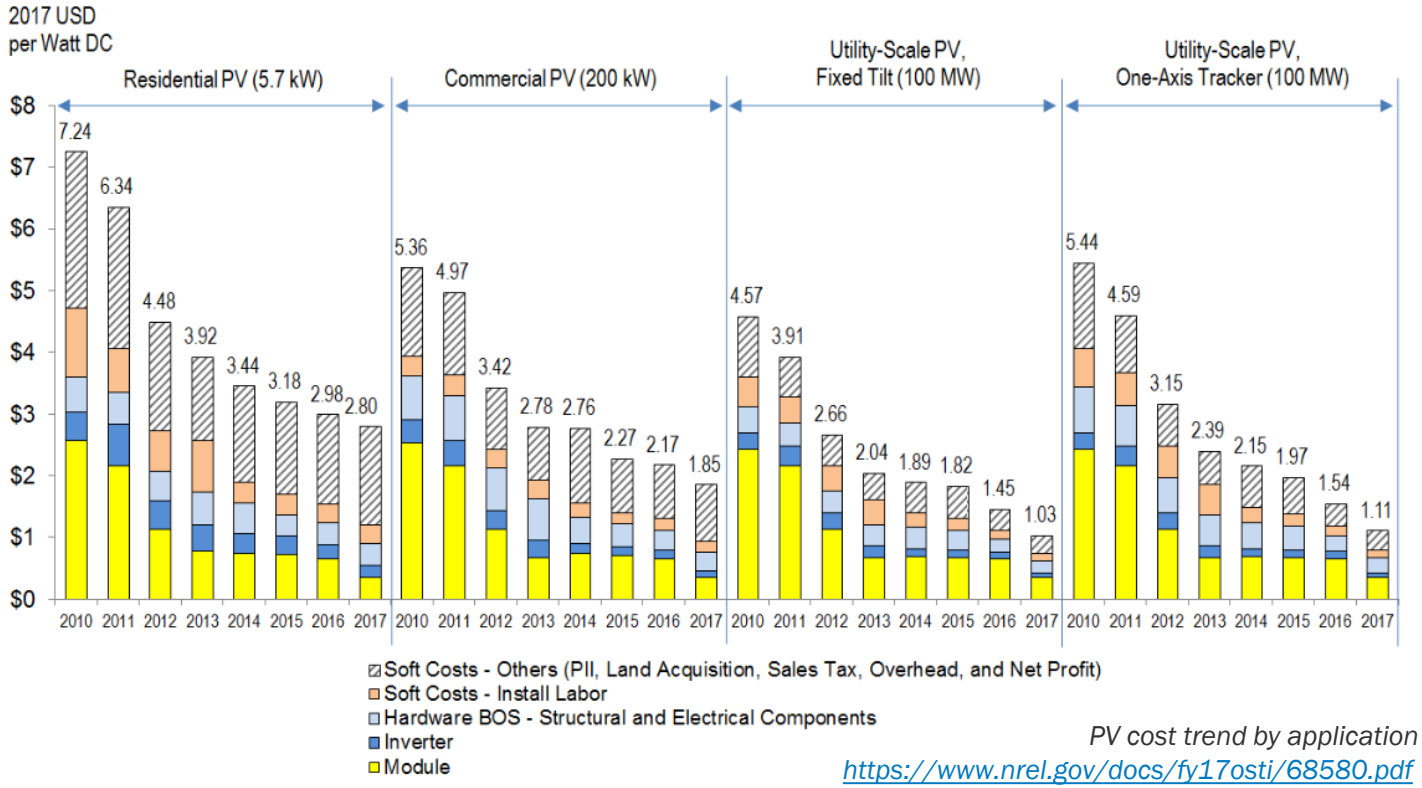
# Solar Resource across the U.S.




- Solar resource across the continental U.S. varies by a factor of 2

- Solar resource in Golden, CO: 5.53 kWh/m$^2$/day
- Phoenix, AZ: 6.57 kWh/m$^2$/day
- Buffalo, NY: 3.99 kWh/m$^2$/day

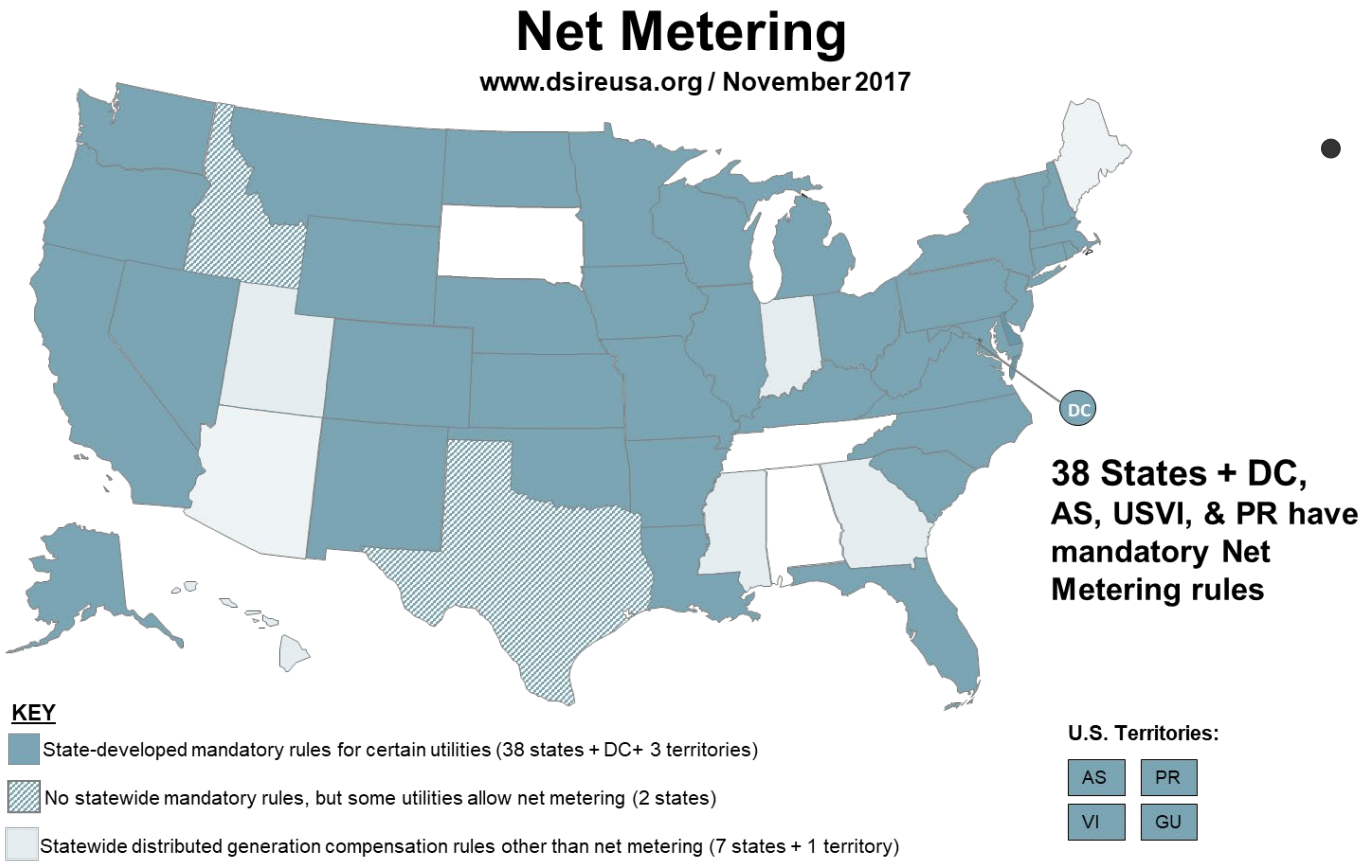
# PV Cost




*PV cost trend by application*
*https://www.nrel.gov/docs/fy17osti/68580.pdf*

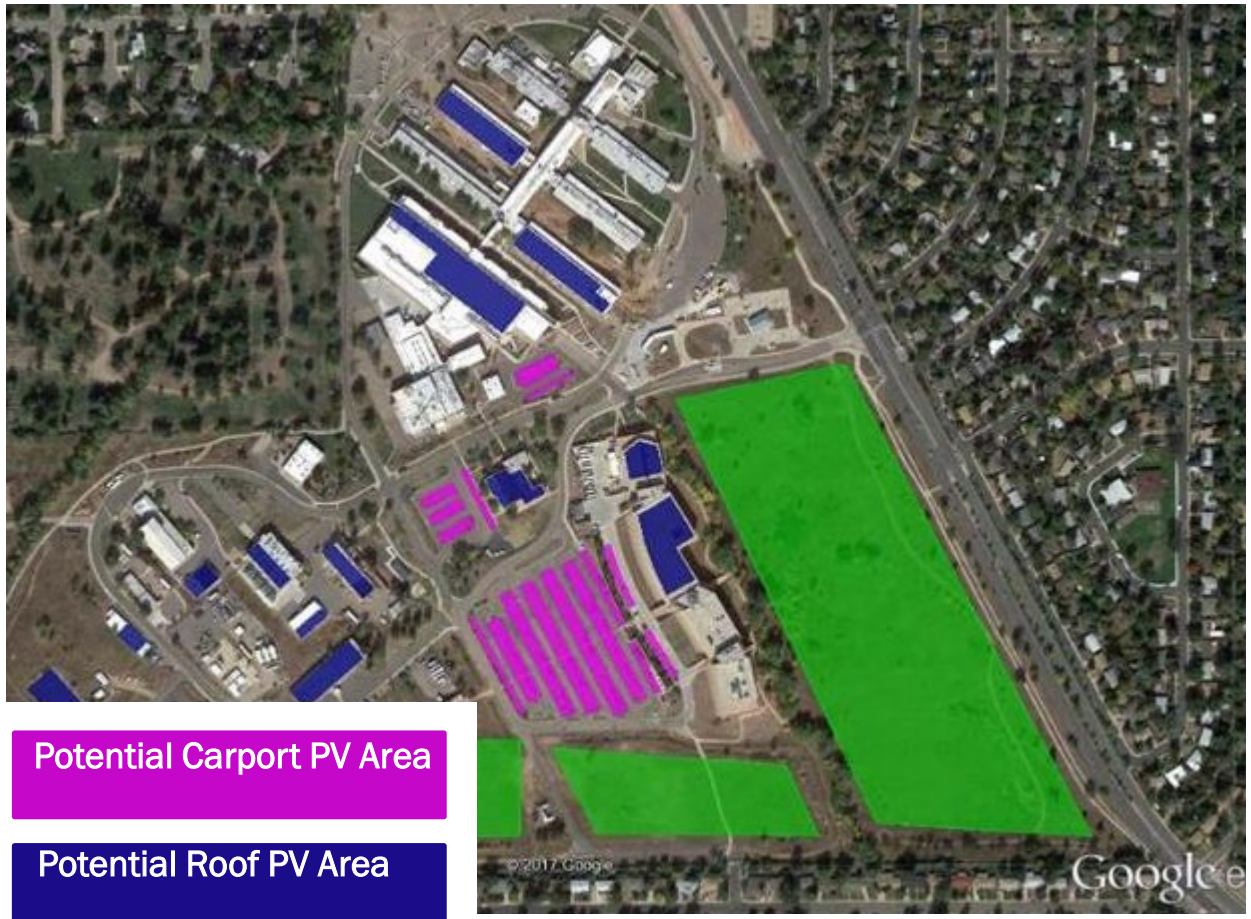
- Consider total installed system cost (soft cost, BOS, inverter, module)
- Costs vary by size, location, and installer
- Cost reduction across all segments over past 8 years

# Incentives




- Incentives can help lower the total cost of a PV system
- Common incentives include:
  - Capacity: Based on the total installed size of the system
  - Production: Based on electricity production
  - Net metering: Credit if generation exceeds load

# Space Available for PV




- Where you install the PV system impacts:
  - Packing density
  - System cost
  - The tilt and orientation
  - The viewshed of your site

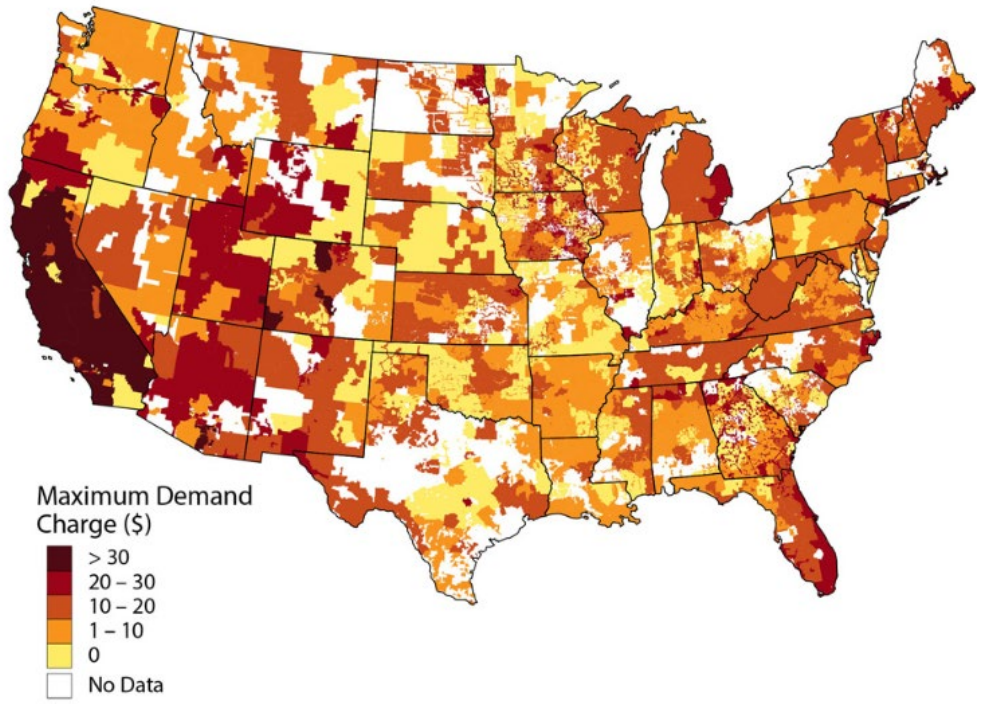
- Typical packing density:
  - Ground: 5 acres/MW
  - Roof/carport: 10 Wdc/ $ft^2$

# Utility Cost and Structure

| Component | How It's Billed | How PV Can Help |
|---|---|---|
| **Energy Charges** | Amount of kWh consumed | Reduce the kWh purchased (can vary by time of day) |
| **Demand Charges** | Based on highest demand (kW) of the month | Reduce demand if PV production coincides with monthly peak |
| **Fixed Charges** | Fixed cost per month | PV cannot offset these |

Other types of charges include:

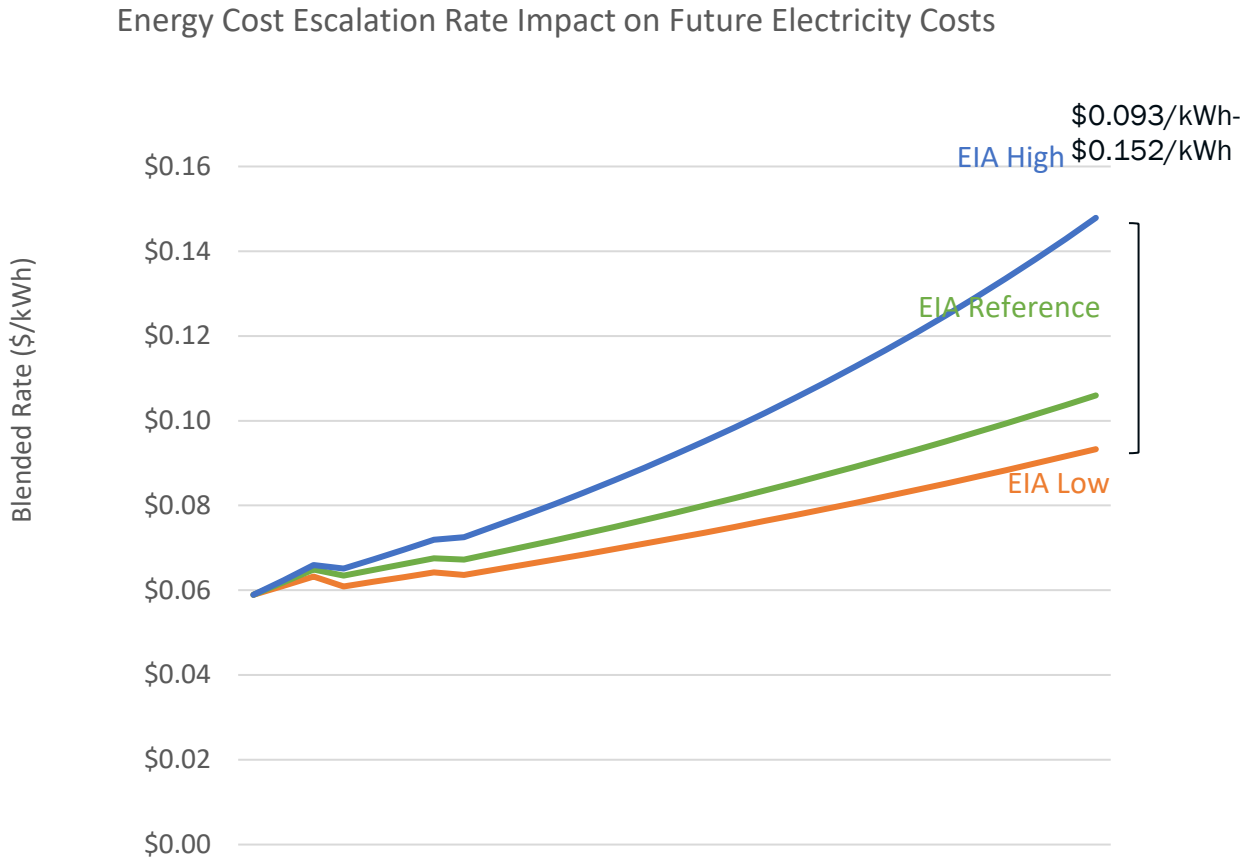
- Minimum charge
- Departing load charge
- Standby charge




*Maximum demand charge rates by utility service territory*
*https://www.nrel.gov/docs/fy17osti/68963.pdf*

# Financial Parameters

| | Parameter | Impacts |
|---|---|---|
| **Inflation Rate** | General expected inflation rate | Future O&M costs |
| **Utility Cost Escalation Rate** | How electricity costs are expected to change | Costs that PV is offsetting |
| **Discount Rate** | Cost of money | Financing costs |



# Resources

- Where can I view my solar resource?
  - NSRDB Viewer: https://maps.nrel.gov/nsrdb-viewer/
- Where can I find information about installed PV costs?
  - Annual Technology Baseline: https://atb.nrel.gov/
- Where can I find information about PV incentives?
  - DSIRE: http://www.dsireusa.org/
- Where can I find information about how much PV I can install?
  - Google Project Sunroof: https://www.google.com/get/sunroof#p=0
- Where can I find information about my utility rate?
  - Utility Rate Database: https://openei.org/wiki/Utility_Rate_Database
- Where can I find information about my financial parameters?
  - EIA: https://www.eia.gov/outlooks/aeo/

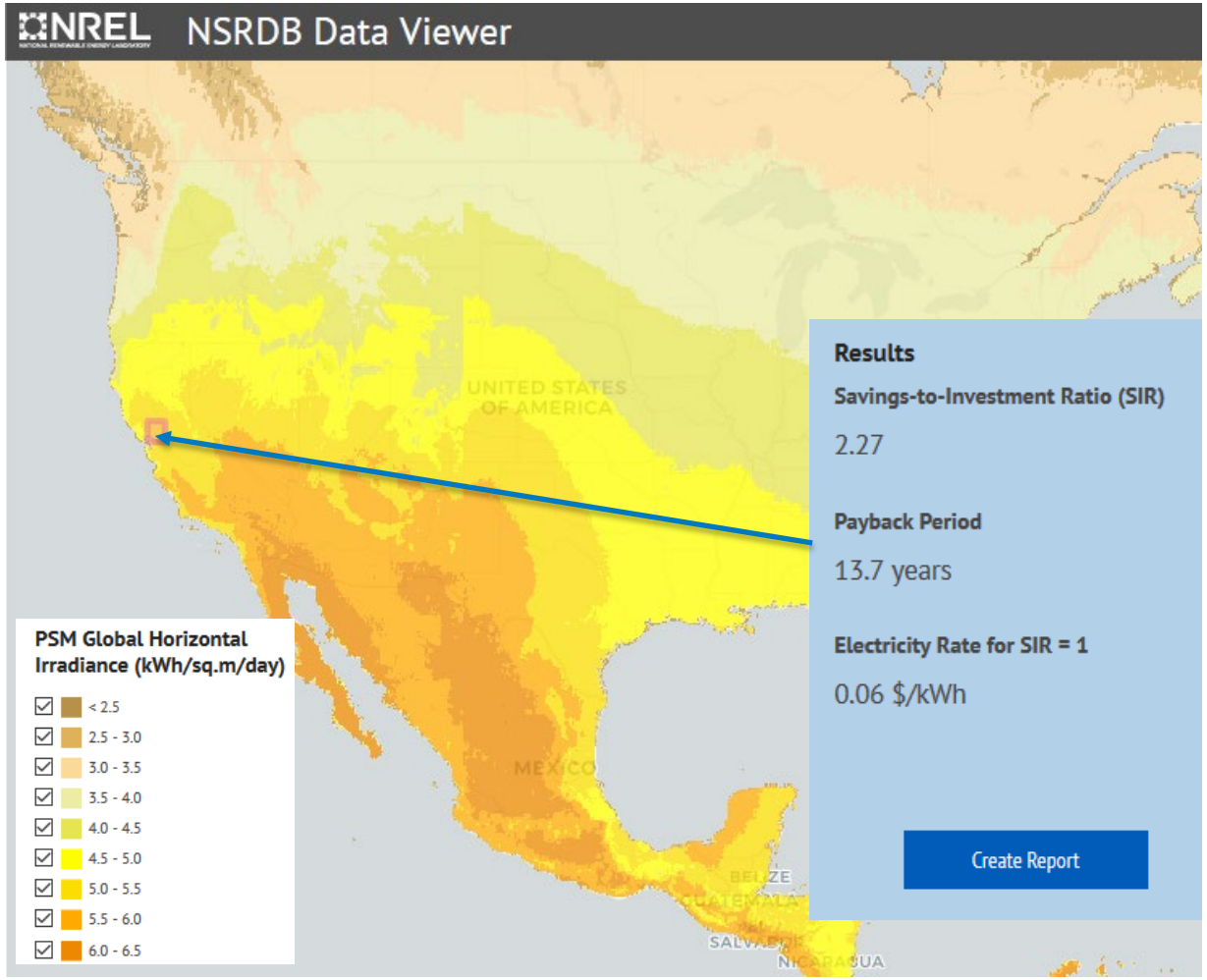
# Tools That You Can Use

- PV modeling tools take into account the factors that impact project potential
- Publicly available tools can be used to gauge initial potential, optimize system sizing & refine project economics

| | Expertise and Effort needed | Required Inputs | Key Outputs |
|---|---|---|---|
| **FEMP DG Screening Tool** | Low | • Location | • Map interface with geospatial layers<br>• High-level economics |
| **PVWatts Calculator** | Low | • Location<br>• System configuration | • PV energy generation (no economics) |
| **REopt Lite Web Tool** | Medium | • Location<br>• Energy Consumption<br>• Rate tariff | • Optimized system size and dispatch<br>• High-level economics |
| **System Advisor Model (SAM)** | High | • Energy Consumption<br>• Rate tariff<br>• Detailed system configuration<br>• Financing inputs | • Detailed technology performance<br>• Detailed economic modeling |

# FEMP DG Screening Tool

- Leverages interactive resource maps and data layers for simple user experience
- Allows user to click anywhere on the map for high-level metrics including:
  - Savings to investment ratio (SIR)
  - Payback period
  - Electricity rate required for SIR of 1
- Generates summary report

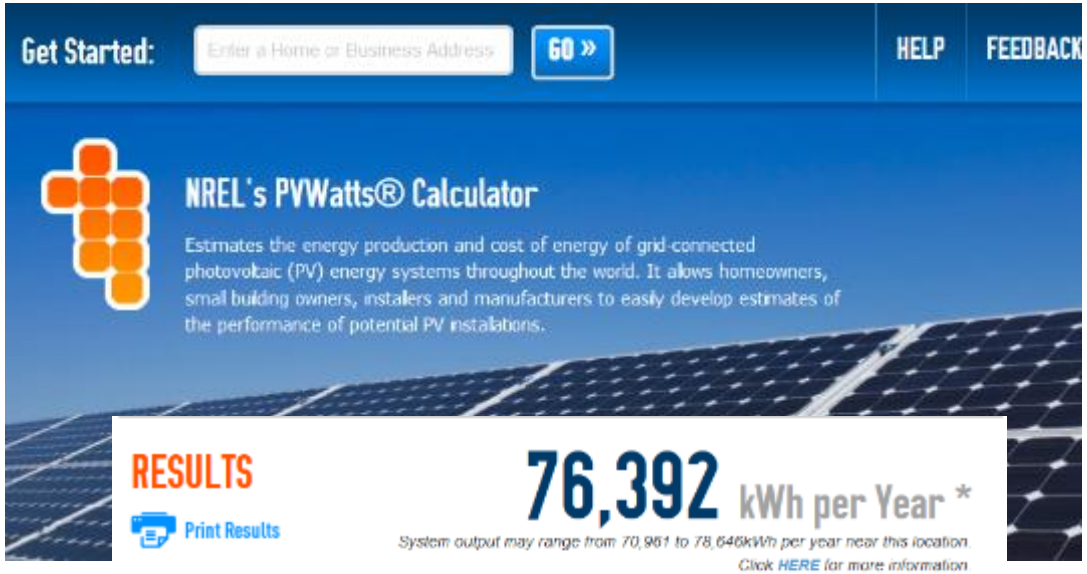



https://maps.nrel.gov/femp/

# PVWatts

- PVWatts uses solar resource data and energy production models to estimate energy production from PV systems in a given location
- Users enter their location and PV system size in a simple interface
- Estimates annual and hourly energy production

http://pvwatts.nrel.gov/




RESULTS

Print Results

**76,392** kWh per Year *

*System output may range from 70,961 to 78,646kWh per year near this location.*

*Click HERE for more information.*

| Month | Solar Radiation ( kWh / m² / day ) | AC Energy ( kWh ) | Energy Value ( $ ) |
|---|---|---|---|
| January | 3.57 | 4,666 | 516 |
| February | 4.21 | 4,881 | 539 |
| March | 5.61 | 7,108 | 785 |
| April | 6.15 | 7,342 | 811 |
| May | 6.46 | 7,791 | 861 |
| June | 6.74 | 7,671 | 848 |
| July | 6.60 | 7,578 | 837 |
| August | 6.44 | 7,397 | 817 |
| September | 5.99 | 6,791 | 750 |
| October | 4.99 | 6,044 | 668 |
| November | 3.80 | 4,692 | 518 |
| December | 3.38 | 4,431 | 490 |
| Annual | 5.33 | 76,392 | $ 8,440 |

# REopt Lite Web Tool

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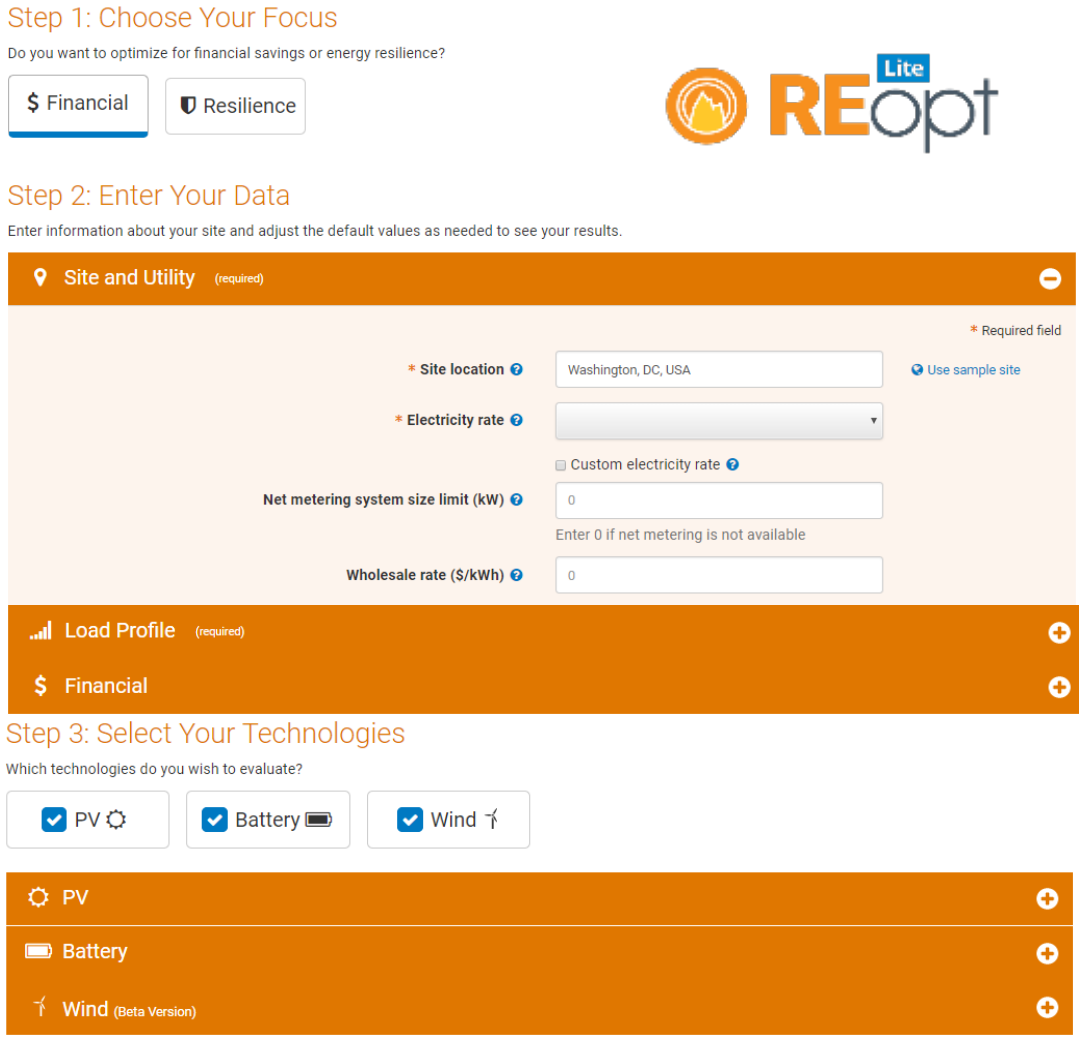
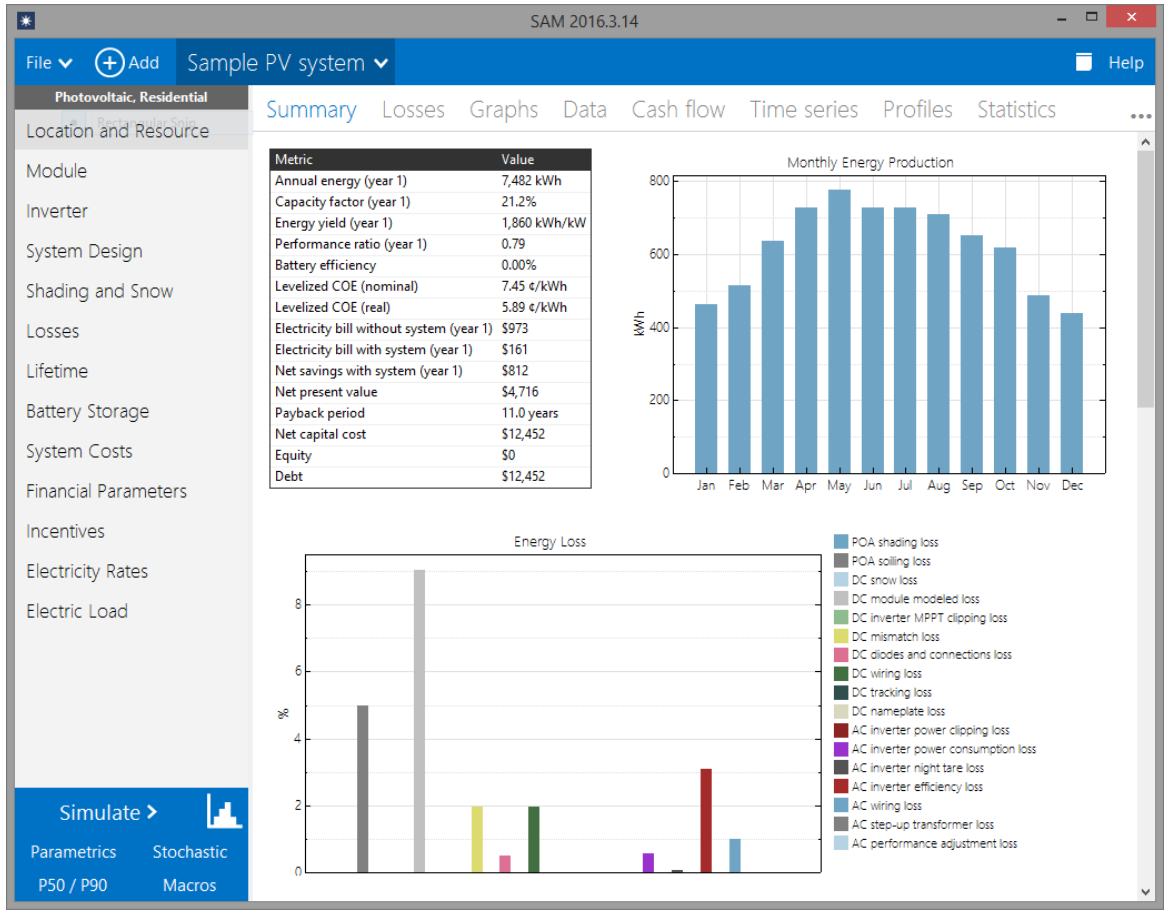


# System Advisor Model (SAM)

- Platform combines detailed performance and financial models to estimate cost of energy
- Energy Performance:
  - Photovoltaics, detailed & PVWatts
  - Battery storage
  - Wind
  - Geothermal
  - Biomass
  - Solar water heating
- Financials
  - Behind-the-meter (residential & commercial)
  - Power purchase agreements (single owner & equity flips)
  - Simple LCOE calculator

**http://sam.nrel.gov/download**



# Microgrid Ready PV

- If there are future microgrid plans at a site, consider microgrid ready PV
- Microgrid ready PV: the practice of including low or no-cost measures when installing a PV system that will facilitate the integration of that PV system into a microgrid at a later point
- Microgrid ready PV includes:
  - Inverters capable of operating in both grid-interactive and microgrid modes
  - Inverters capable of responding to commands from a microgrid controller
  - Reserved space near the PV system for microgrid and equipment expansions
- Check out FEMP's factsheet on Microgrid-Ready Solar PV – Planning for Resiliency (https://www.nrel.gov/docs/fy18osti/70122.pdf)

Quiz tip: Microgrid ready PV includes inverters capable of operating in both grid-interactive and microgrid modes, inverters capable of responding to commands from a microgrid controller, and reserving space near the PV system for microgrid and equipment expansions

# Why Distributed Energy for Resilience

- Distributed energy resources (DERs) include renewable energy (RE) technologies, storage, and combined heat and power (CHP)
- DERs can provide revenue streams and savings while grid connected
  - Savings may allow for the incorporation of additional microgrid components
- When integrated into a microgrid, DERs can increase survival time during a grid outage when fuel supplies are limited