
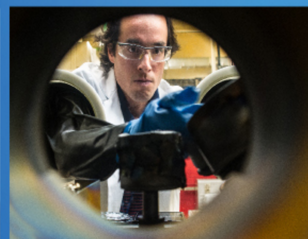


Campus Energy Approach, REopt Overview, and Solar for Universities

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International Institute for Sustainable Laboratories

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Agenda

Topic	Time
Campus Energy Approach	20 min.
REopt Tool	20 min.
Universities Using Solar Campus Solar Trends REopt University Screenings Campus Case Studies	30 min.
Q&A Session	20 min.

Speakers and Moderator

Speakers

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Moderator

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Campus Energy Approach

Learning Objectives

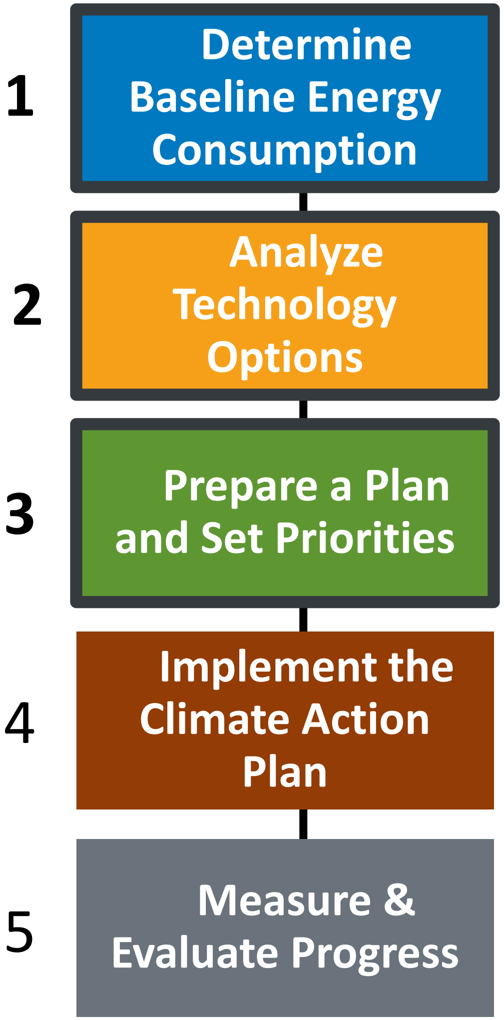
1. A framework for reducing energy use on research campuses

2. Reaching net zero electricity with renewable energy

3. Using the REopt web tool to evaluate the economics of solar and storage

4. Renewable energy project at universities

Climate Neutral Research Campuses



Focus of this presentation: 1-3

Research campuses consume more energy per square foot than most facilities. They also have greater opportunities to reduce energy consumption, implement renewable energy systems, reduce greenhouse gas emissions, and set an example of climate neutrality.

The NREL Climate Neutral Research Campuses web site provides research campuses a five-step process to develop and implement climate action plans.

- Determine Baseline Energy Consumption
- Analyze Technology Options
- Prepare a Plan and Set Priorities
- Implement the Climate Action Plan
- Measure & Evaluate Progress

See: https://www.nrel.gov/tech_deployment/climate_neutral/

Climate Neutral Research Campuses Website


NREL
NATIONAL RENEWABLE ENERGY LABORATORY

NREL HOME

ABOUT NREL | ENERGY ANALYSIS | SCIENCE & TECHNOLOGY | TECHNOLOGY TRANSFER | APPLYING TECHNOLOGIES

Applying Technologies

Climate Neutral Research Campuses

More Search Options SEARCH
Site Map

Determine Baseline Energy Consumption
Analyze Technology Options
Plan & Prioritize
Implement the Climate Action Plan
Measure & Evaluate Progress
Climate Action Planning Tool
Working with Us

Climate Neutral Research Campuses

Research campuses consume more energy per square foot than most facilities. They also have greater opportunities to reduce energy consumption, implement renewable energy systems, reduce greenhouse gas emissions, and set an example of climate neutrality.

This Web site provides research campuses a five-step process to develop and implement climate action plans.

1. Determine Baseline Energy Consumption
2. Analyze Technology Options
3. Prepare a Plan and Set Priorities
4. Implement the Climate Action Plan
5. Measure & Evaluate Progress

The process follows a logical hierarchy of actions to evaluate options by energy sector and set specific targets. It encompasses every energy system on campus, recognizing that campus-wide measures have greater potential for reducing carbon emissions. Use the Climate Action Planning Tool to determine which technology options will have the most impact on your campus.

The National Renewable Energy Laboratory (NREL) developed this Web site with support from Labs21—a joint venture of the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) and the U.S. Environmental Protection Agency.

Technology Options

Develop a portfolio of measures across the campus.

Labs21 Approach

Climate Action Planning Tool for Research Campuses

https://www.nrel.gov/tech_deployment/climate_neutral/

1. Determine Baseline Energy Consumption

Determine current energy consumption → Determine resulting greenhouse gas emissions → Break down emissions by sector

<u>Scope 1:</u> Direct combustion of fuels at your site

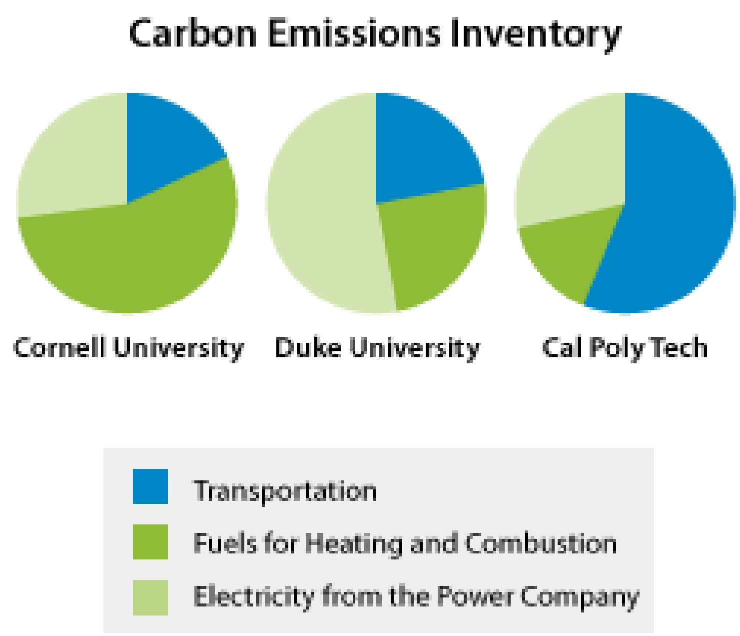
- Carbon emissions from direct combustion readily translate from fuel consumption data using standard engineering formulas.

<u>Scope 2:</u> Indirect impact from purchased electricity.

- Carbon emissions from electricity consumption can be obtained for your utility company, region, and state from the U.S. Environmental Protection Agency's eGRID

<u>Scope 3:</u> Transportation impacts from commuters and business travel.

- Can be derived from surveys of commuter and business travel patterns.



2. Analyze Technology Options

People and Policy

Formulate policies that have a long-term effect on energy consumption and identify human behaviors that lower energy use and greenhouse gas emissions.

Buildings

Take a whole-building approach when evaluating campus buildings. Also, remember energy efficiency comes first. Maximize energy efficiency in both existing and new buildings before doing anything else.

Transportation

Reduce vehicle miles traveled, switch your fleets to alternative fuels, and offer transportation alternatives that reduce occupant dependency on single-passenger vehicle

Energy Sources

Optimize the energy supply based on carbon fuels at the central power plant, and then add renewable energy systems wherever practicable.

Carbon Offsets and Renewable Energy Certificates

Buy carbon offsets and green power as the last step in an overall strategy to meet long-term carbon reduction targets. You can also purchase offsets as a way to "top off" progress

Buildings: Key Elements of a Smart Lab

Key Element	Approaches to Overcome Barriers
Optimized ventilation and exhaust systems	Partner with industrial hygiene to determine lowest safe ventilation rate for each lab space and exhaust stack discharge velocity
Optimized fume hoods	Partner with IH and lab staff to determine fume hood number, size, and containment requirements
Continuous commissioning	Use building control system and tools to optimize lab mechanical systems operations
Energy-efficient lighting	Implement energy-efficient lighting technologies and controls
Variable air volume	Upgrade constant air volume systems to variable air volume
Minimized system pressure drops	Minimized system pressure drops and set duct static pressure to lowest adequate level
Lab staff is engaged in sustainable practices	Provide sustainable best practices to lab staff

Energy Sources: Renewable Energy on Campus

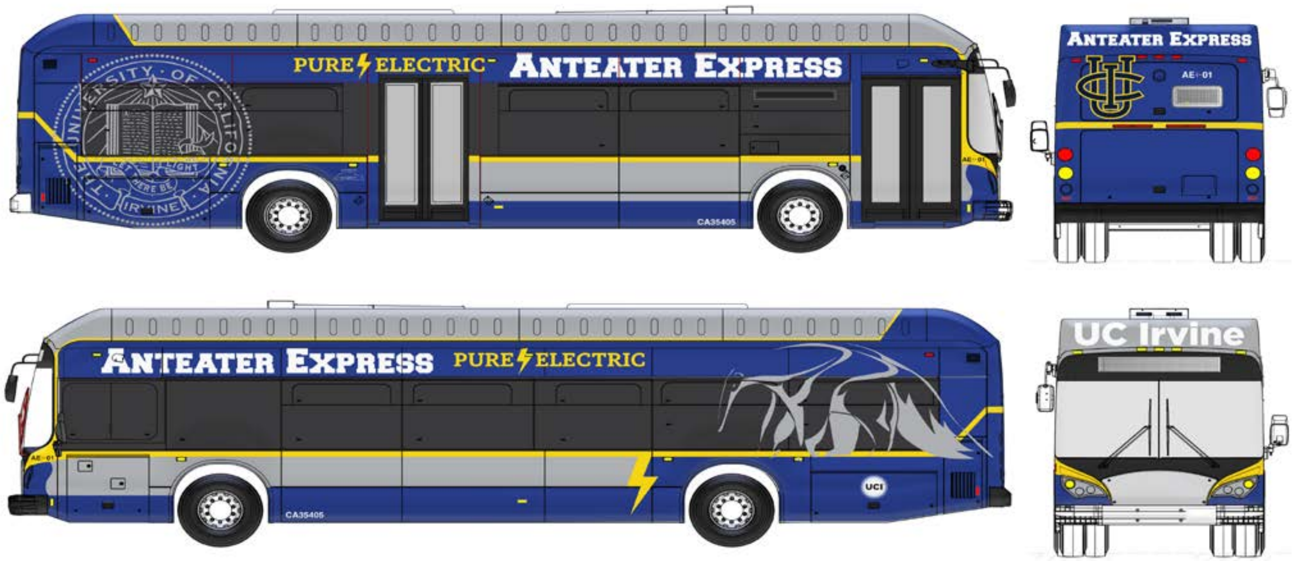
- Consider available area:
  - Vacant land
  - Parking lots
  - Roofs (with 20 year plus life and able to accommodate 2-4 lb./SF solar weight)
  - Shading
- Calculate energy use and cost, preferably by building
- Determine potential electrical interconnection points
- Research interconnection rules

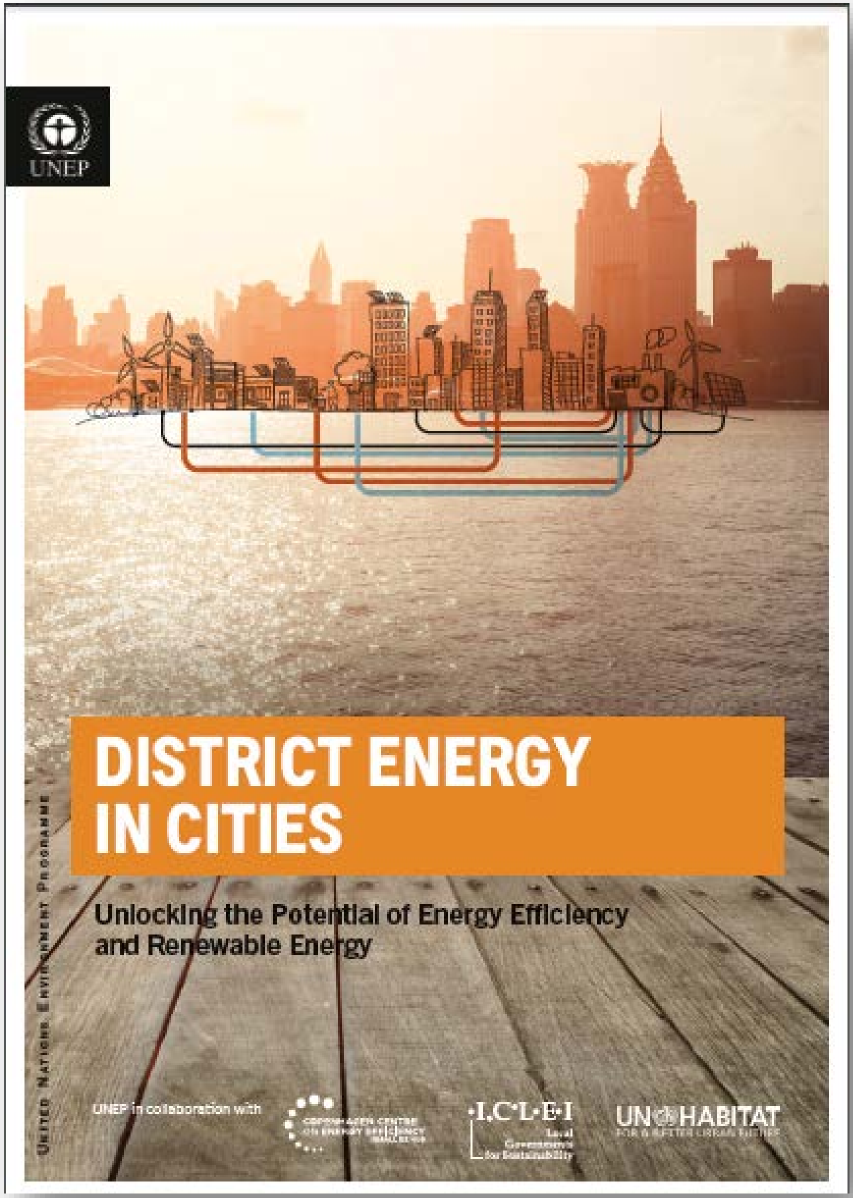
Energy Sources: Available Area for RE on Campus

Potential Roof PV Area	Potential Carport PV Area	Potential Ground PV Area
140,456 ft^2	118,722 ft^2	897,083 ft^2

Transportation: Switch to Electric Transportation

- Electric transportation reduces fossil fuel use
- Smart vehicle charging can be used for load leveling, demand control, and mitigating TOU rates
- UC Irvine adding 20 electric buses in 2017-18

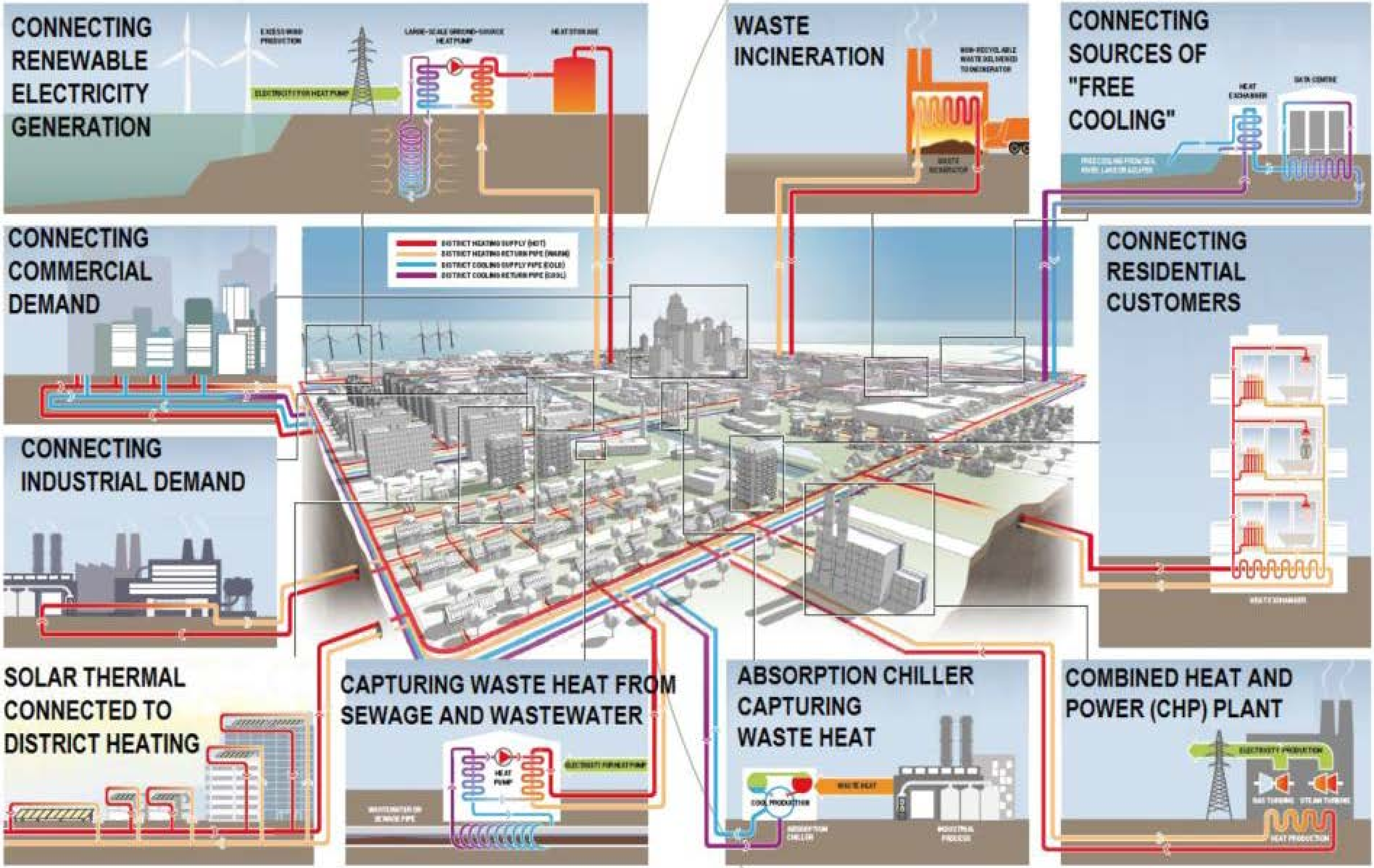




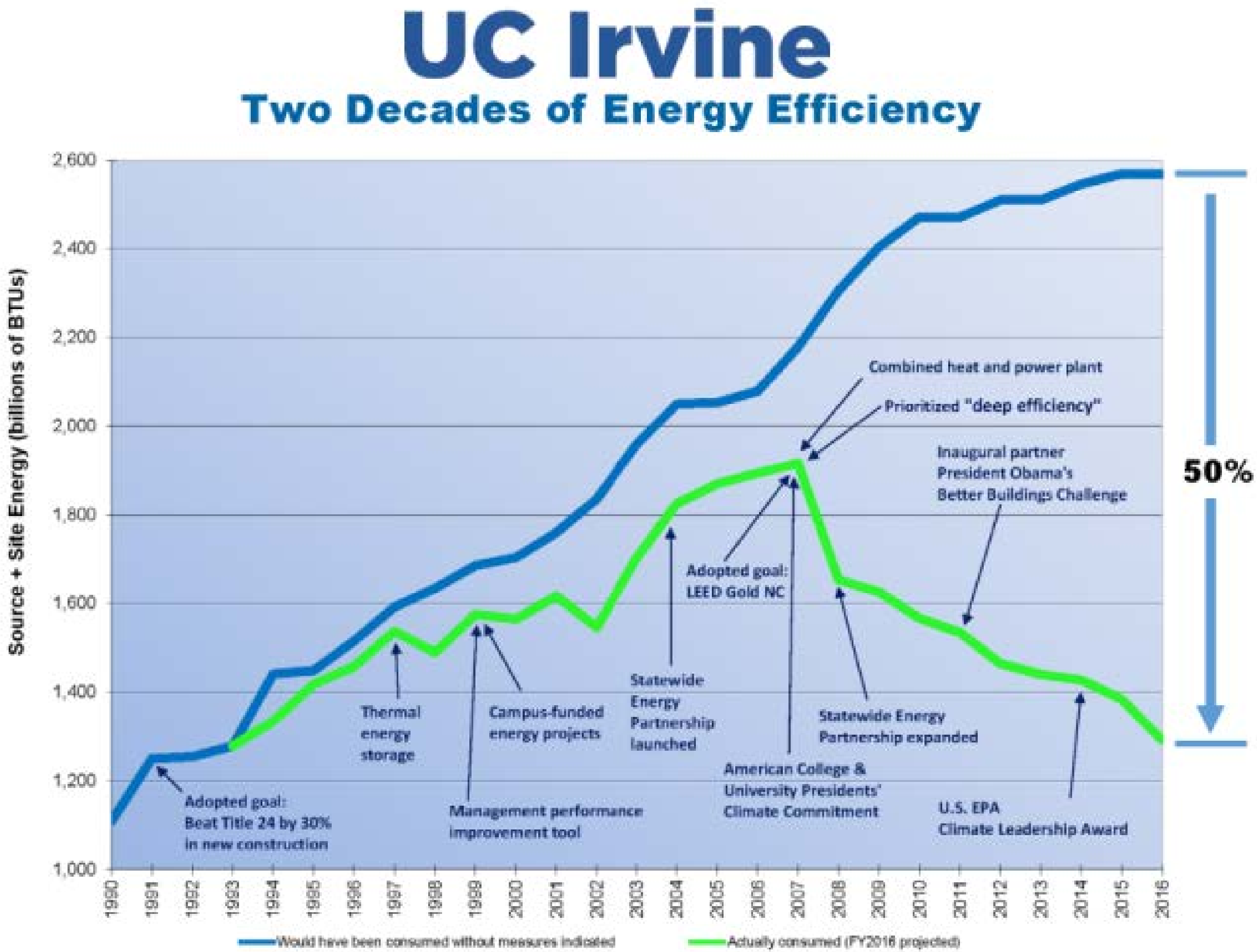
UNEP District Energy

http://staging.unep.org/energy/districtenergyincities

WHAT IS DISTRICT ENERGY?

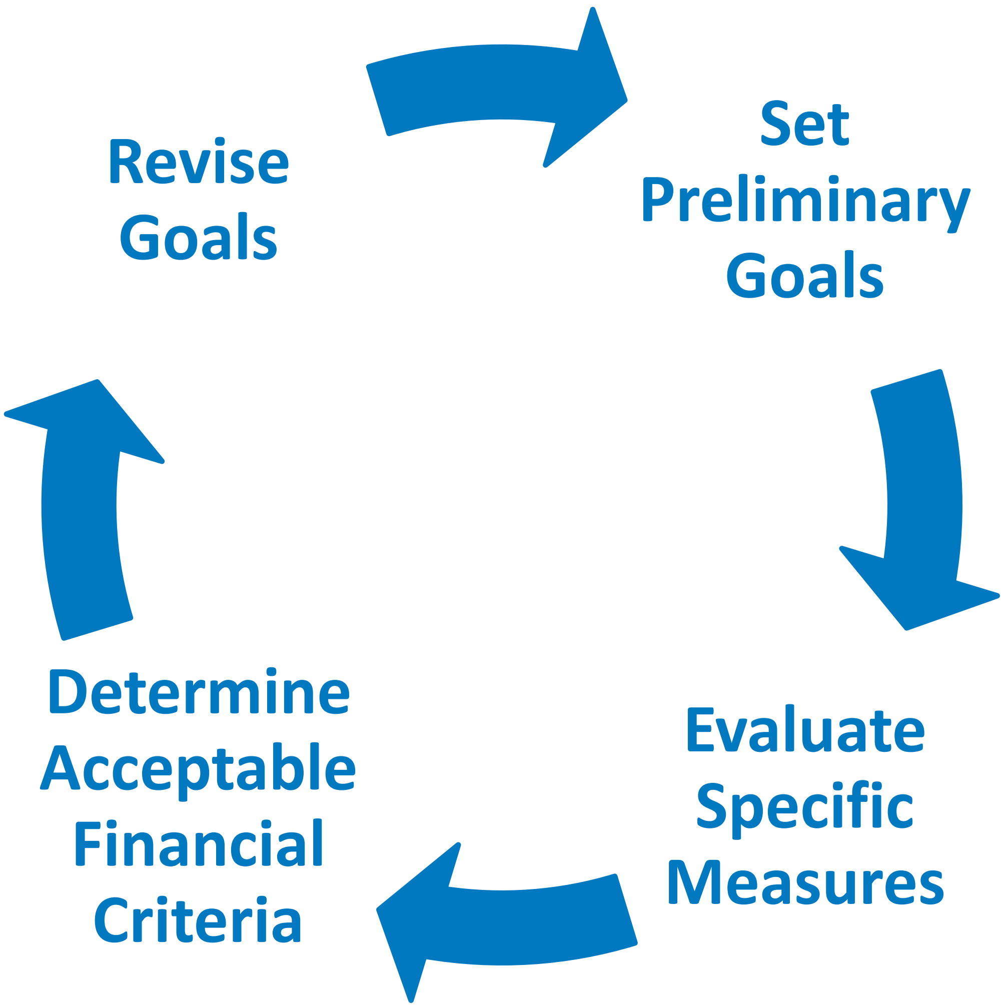


UC Irvine Smart Labs and CHP with Thermal Energy Storage



www.ehs.uci.edu/programs/energy/

3. Prepare a Plan and Set Priorities



REopt Model & Web Tool

REopt: Decision Support Throughout the Energy Planning Process

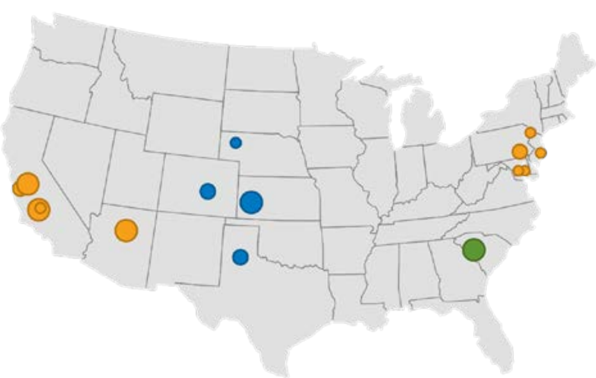
Optimization • Integration • Automation

Master Planning → Economic Dispatch → Resiliency Analysis

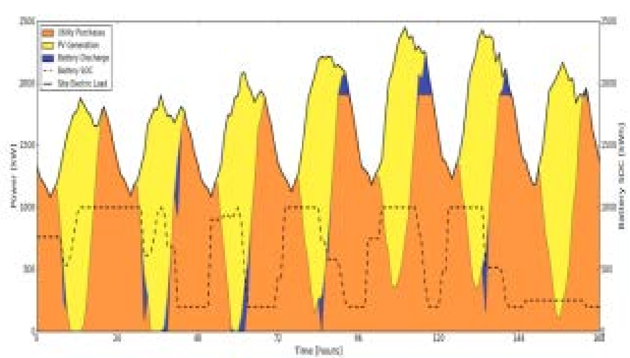
Master Planning
- Portfolio prioritization
- Cost to meet goals

Economic Dispatch
- Technology types & sizes
- Optimal operating strategies

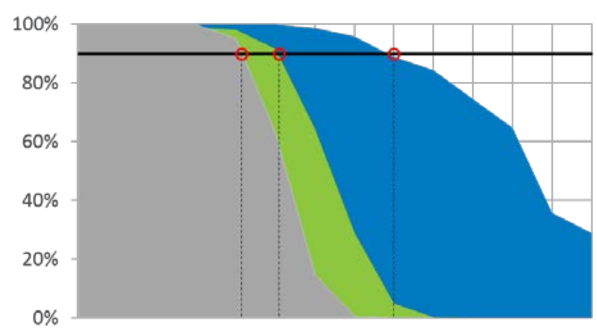
Resiliency Analysis
- Microgrid dispatch
- Energy security evaluation



Cost-effective RE at Army bases

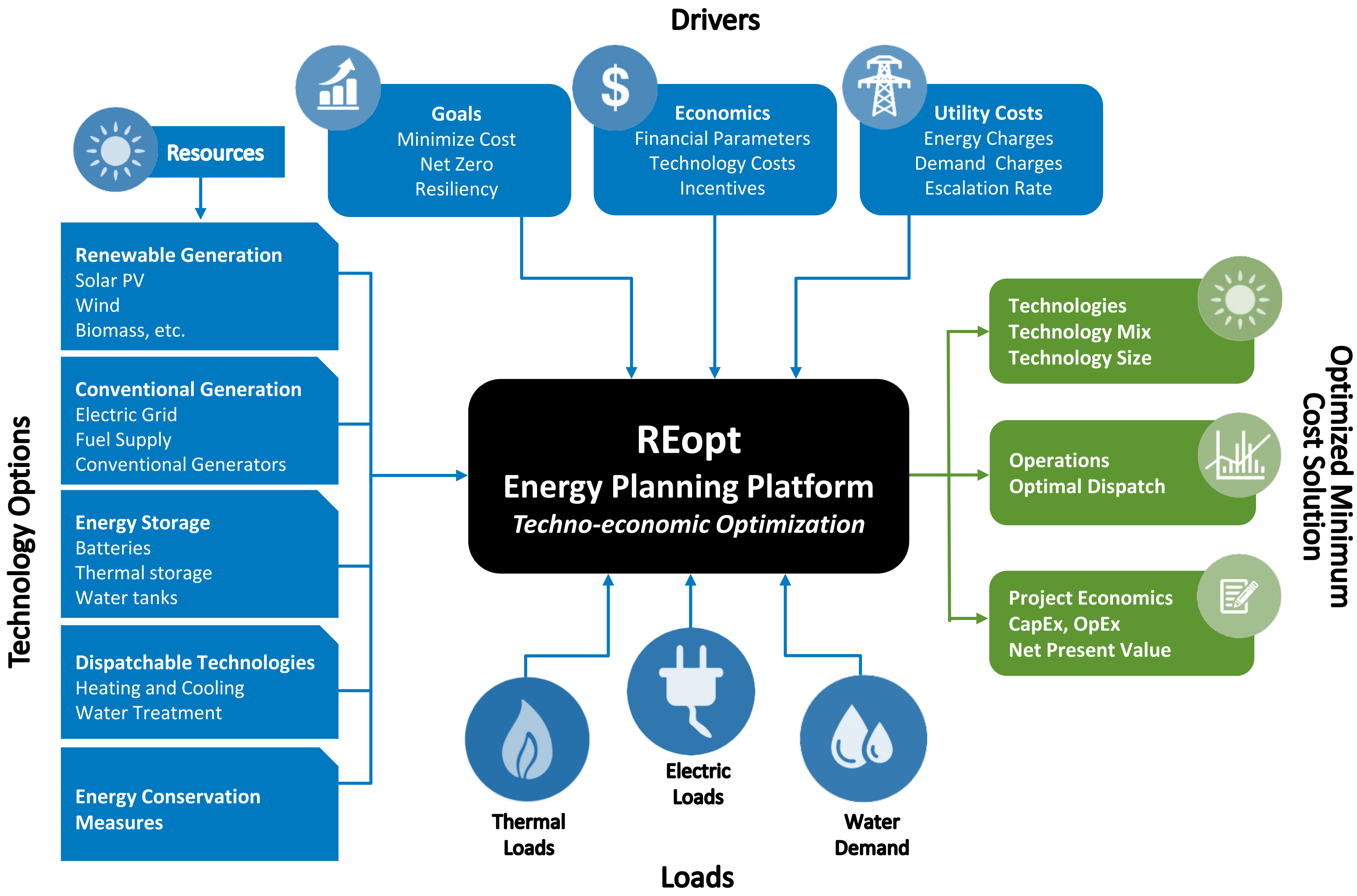


Cost-optimal Operating Strategy



Extending Resiliency with RE

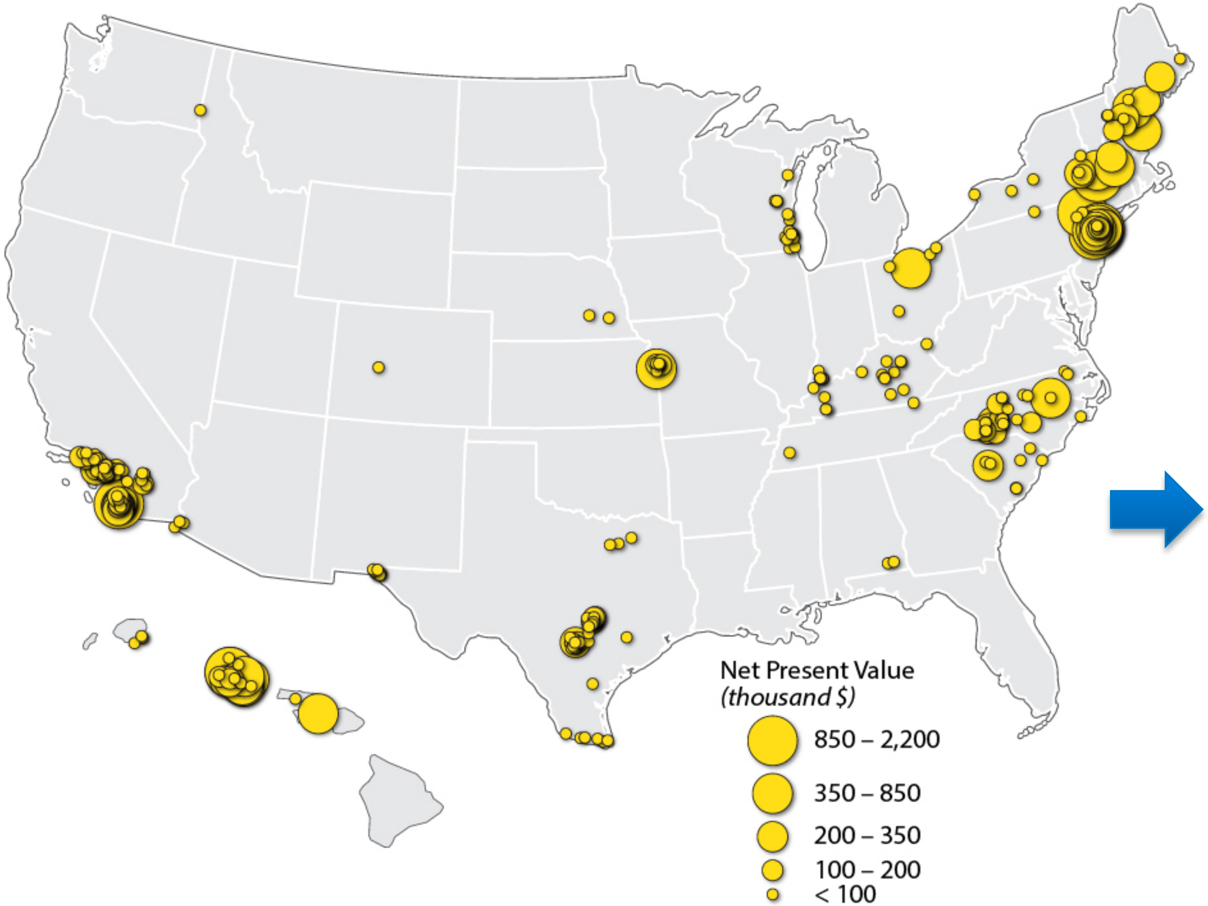
REopt Inputs and Output



Project Example: Identifying & Prioritizing Projects across a Portfolio

REopt portfolio screening can help:

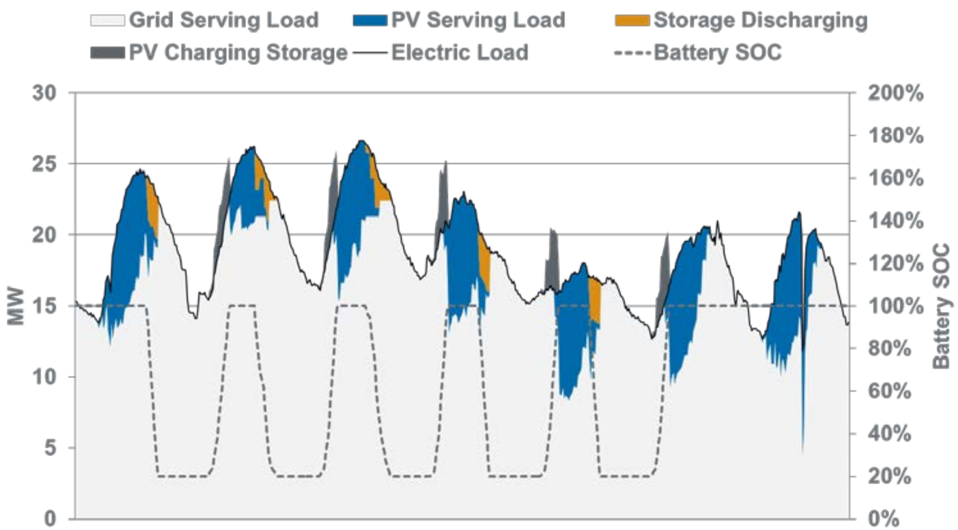
- Identify & prioritize cost-effective projects to minimize lifecycle cost of energy or achieve net zero
- Estimate cost of meeting renewable energy goals



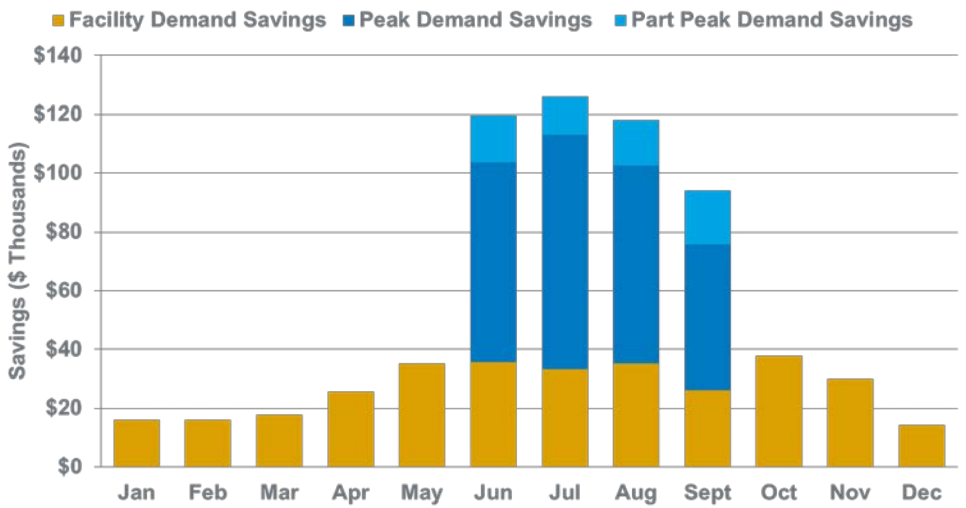
Sites Evaluated	696
Cost-Effective PV	306
Size	38.79 MW
NPV	$37 million
RE Generation	64.7 GWh
RE Penetration	10.5 %

Project Example: PV + Battery Sizing in Southern CA

- Determine economically optimal PV + storage system size & dispatch using:
  - 15-minute electric load
  - Southern California Edison utility tariff TOU-8
- Results show 12.4 MW PV + 2.4 MW:3.7 MWh storage can provide $19.3 million NPV
- Battery is only economical when paired with PV at this site due to wide peaks
- Optimal battery dispatch strategy reduces all three demand charges



Optimal Dispatch for Week in July

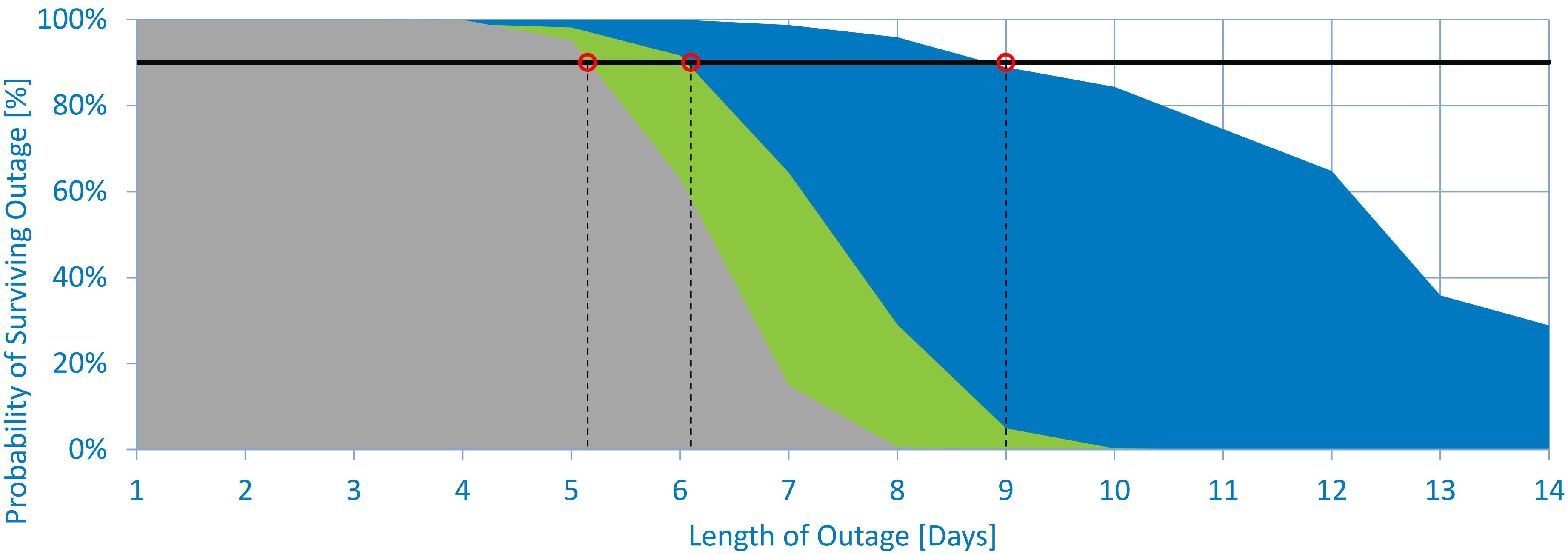


Savings from Demand Reduction

Project Example: Using RE to Extend Survivability

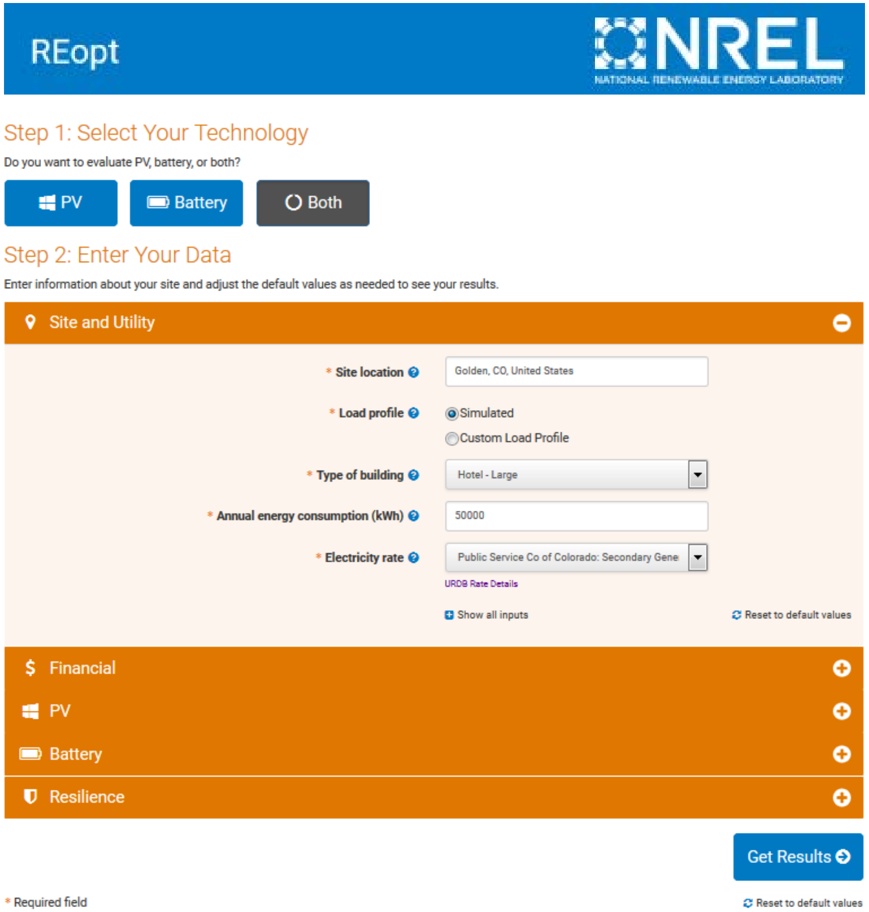
NREL evaluated thousands of random grid outages and durations throughout the year and compared number of hours the site could survive with a diesel generator and fixed fuel supply vs. generator augmented with PV and battery

	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**	**$19.5 million**	**6 days**
3. Proposed system	**2.5 MW**	**2 MW**	**500 kWh**	**$20 .1million**	**9 days**



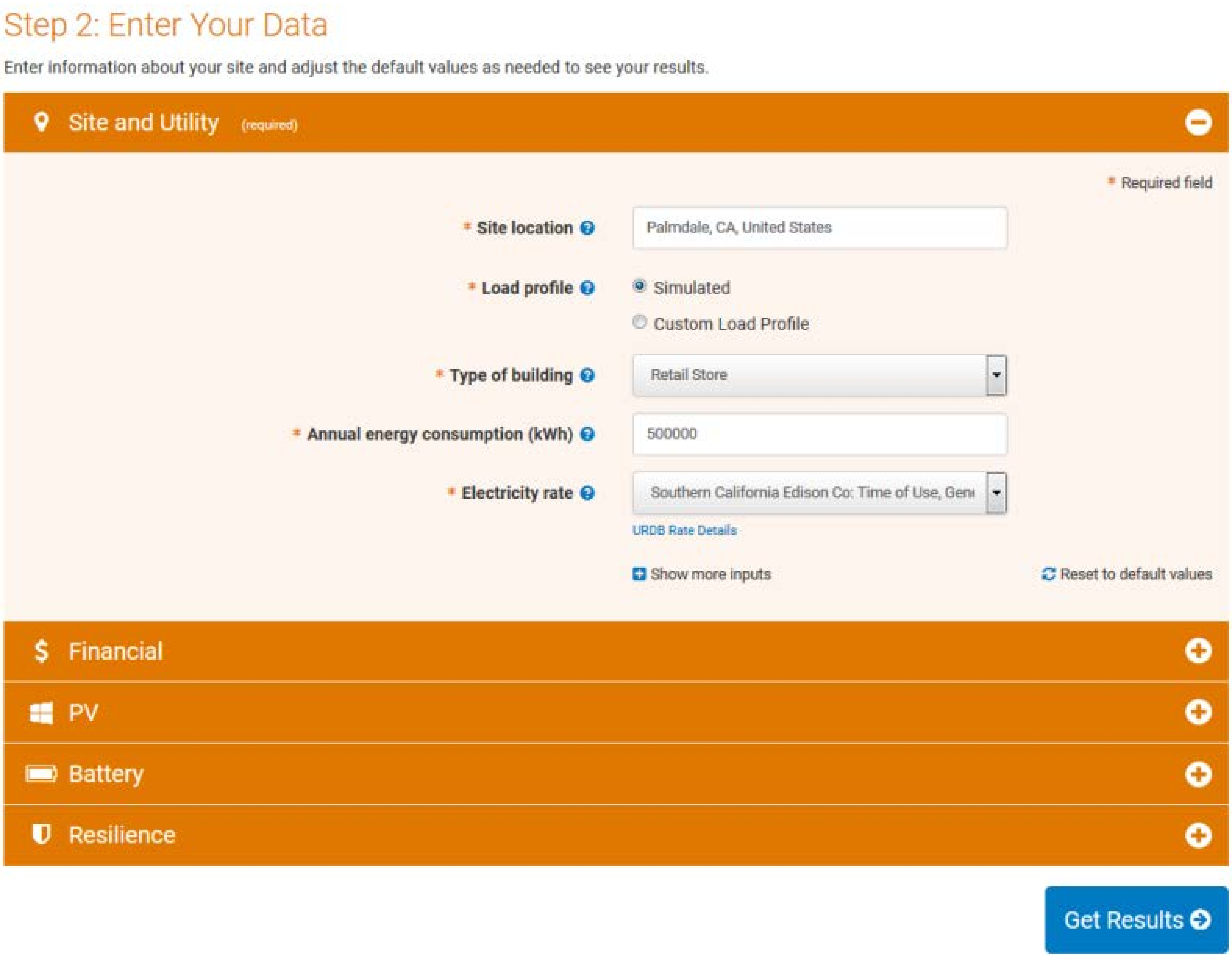
REopt Lite Web Tool

- Publicly available web version of REopt launched September 2017
- Evaluates the economics of grid-connected PV and battery storage at a site
- Allows users to identify system sizes & dispatch strategy that minimize life cycle cost of energy

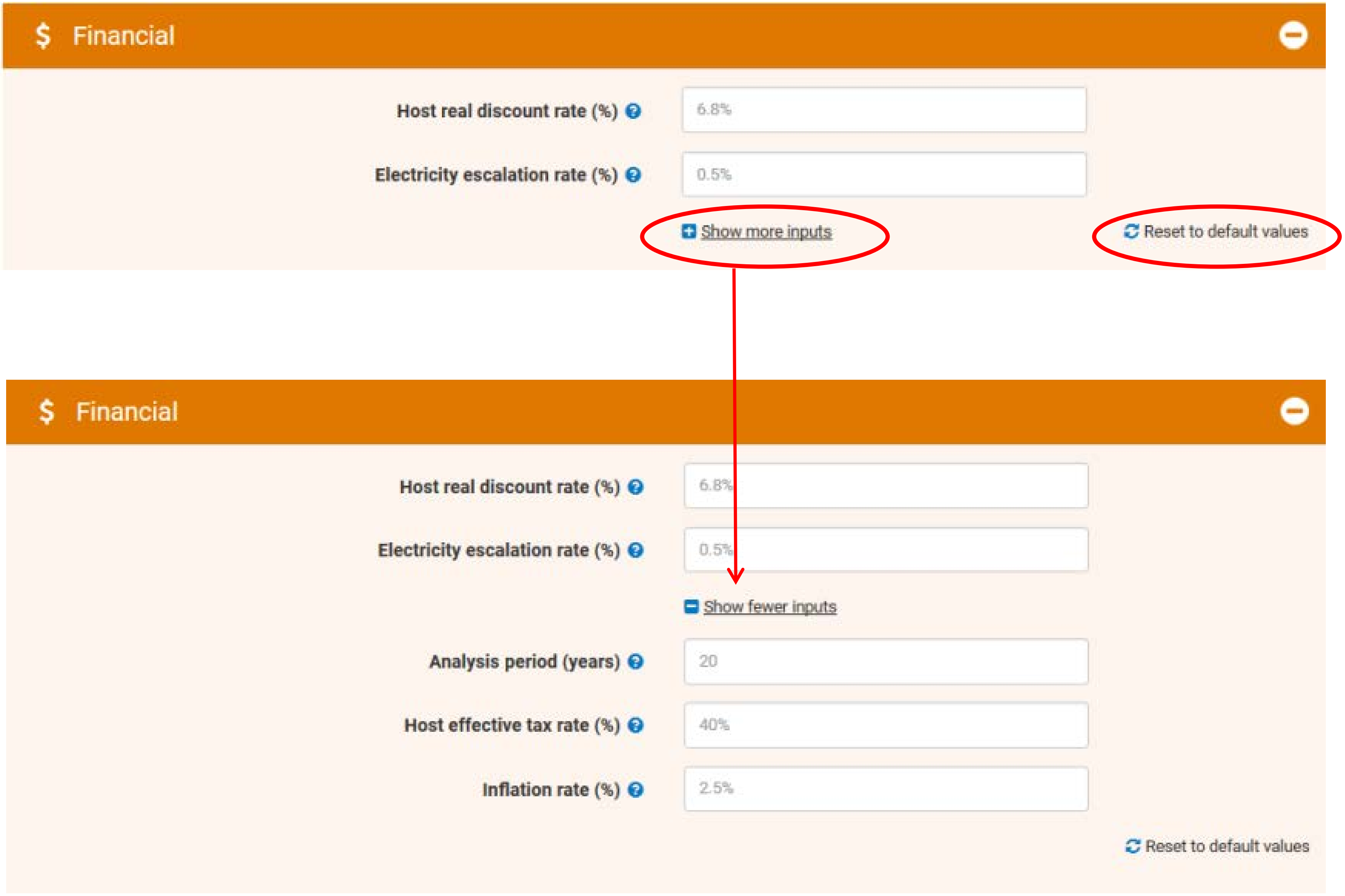


https://reopt.nrel.gov/tool.html

Five Required Site Specific Inputs



Additional Inputs Can Be Edited, Or Left As Defaults



Results Summary Includes System Sizes and 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

296 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

17 kW
battery power

26 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.

$102,771

Results Output – Economics Summary

Results Comparison

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

	Business As Usual	Optimal Case	Difference
System Size, Energy Production, and System Cost			
PV Size	0 kW	296 kW	296 kW
Annualized PV Energy Production	0 kWh	514,500 kWh	514,500 kWh
Battery Power	0 kW	17 kW	17 kW
Battery Capacity	0 kWh	26 kWh	26 kWh
DG System Cost (Net CAPEX + O&M)	$0	$303,869	$303,869
Energy Supplied From Grid in Year 1	1,000,000 kWh	510,113 kWh	489,887 kWh
Year 1 Utility Cost — Before Tax			
Utility Energy Cost	$87,053	$43,384	$43,669
Utility Demand Cost	$43,481	$31,092	$12,389
Utility Fixed Cost	$3,264	$3,264	$0
Utility Minimum Cost Adder	$0	$0	$0
Life Cycle Utility Cost — After Tax			
Utility Energy Cost	$631,470	$314,702	$316,768
Utility Demand Cost	$315,409	$225,537	$89,872
Utility Fixed Cost	$23,676	$23,676	$0
Utility Minimum Cost Adder	$0	$0	$0

Simple Resiliency Evaluation

Simple Resiliency Inputs

Resilience

Outage start

Outage duration (hours)

Critical load factor: 50%

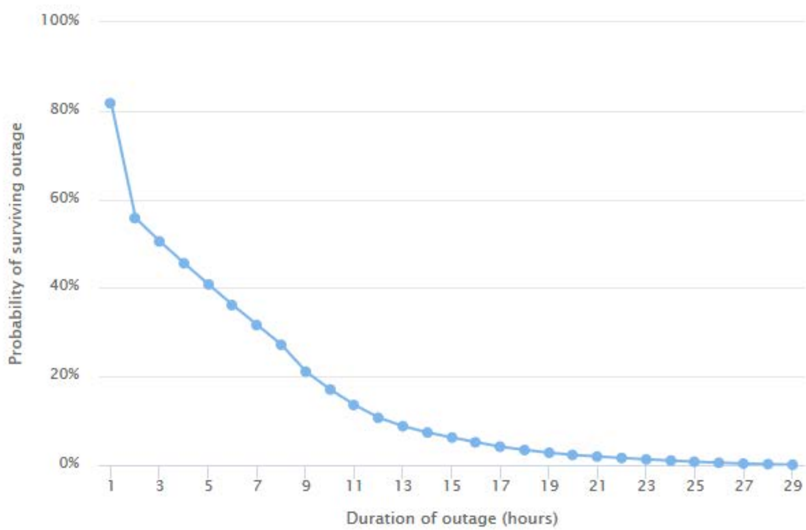
Reset to default values

Simple Resiliency Outputs

Outage Simulation

Evaluate the amount of time that your system can survive grid outages.

	Optimal Case
Average Resiliency (hours)	5 hours
Minimum Resiliency (hours)	0 hours
Maximum Resiliency (hours)	29 hours



Robust Resiliency Analysis Feature Is FY18 Priority

University Solar Case Studies

Campus Solar Trends

University Solar Installation Trends

About

400

universities and colleges have adopted solar

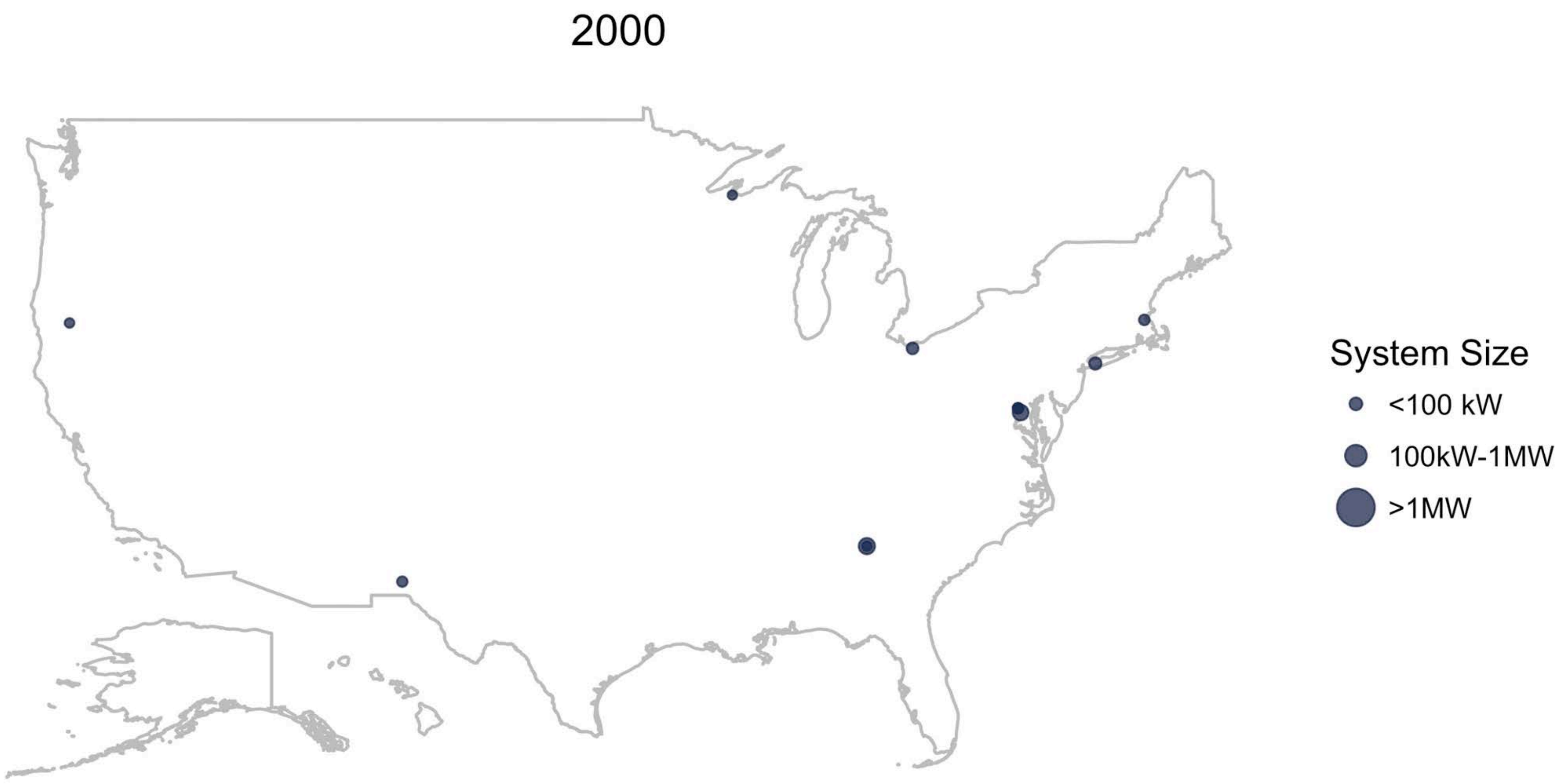
with about

650 MW

of installed capacity*

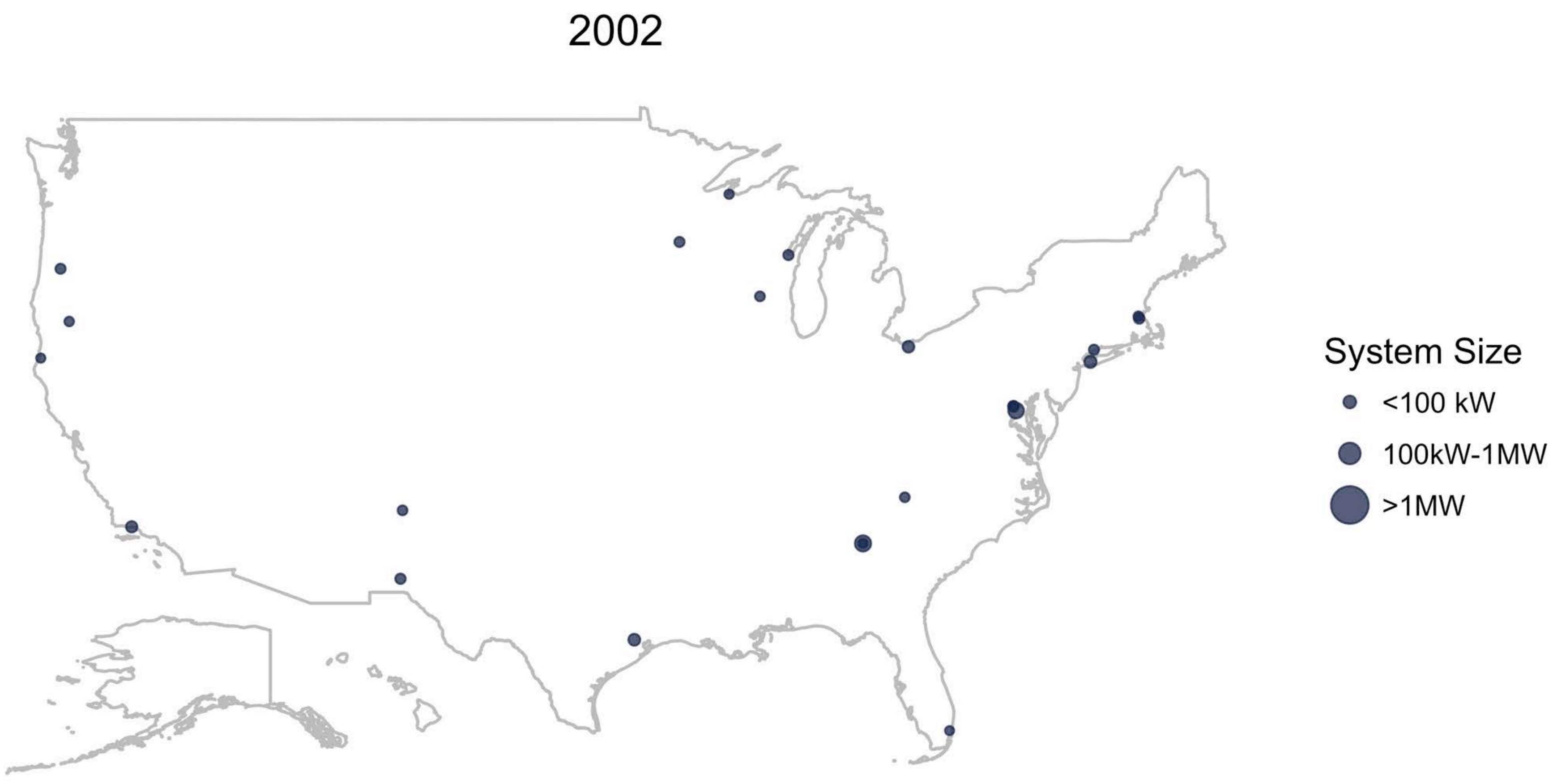
* This installed capacity includes collaborative projects where universities do not own the entire system

University PV Adoption



Based on data from: AASHE, BNEF, SN

University PV Adoption



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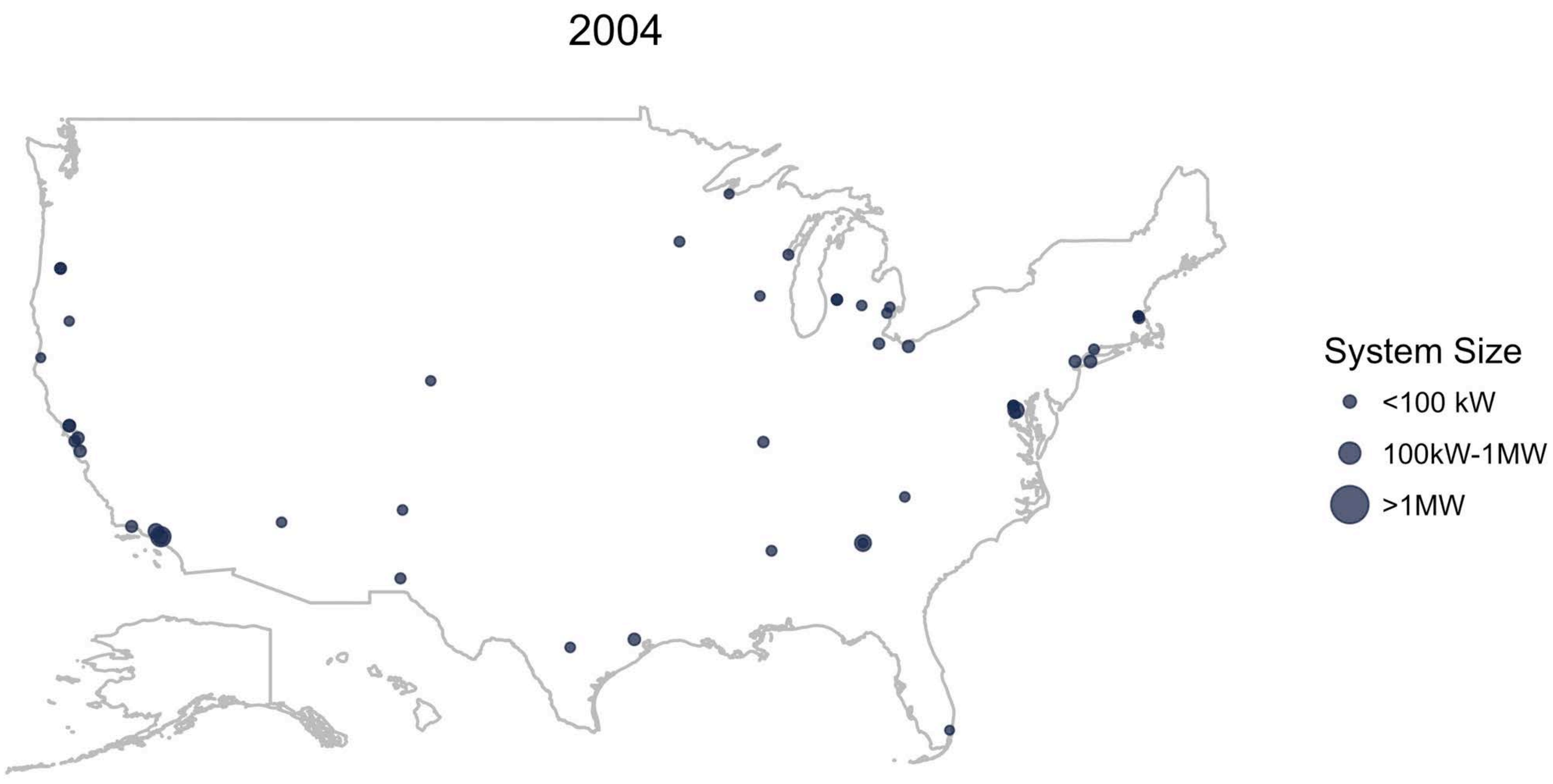

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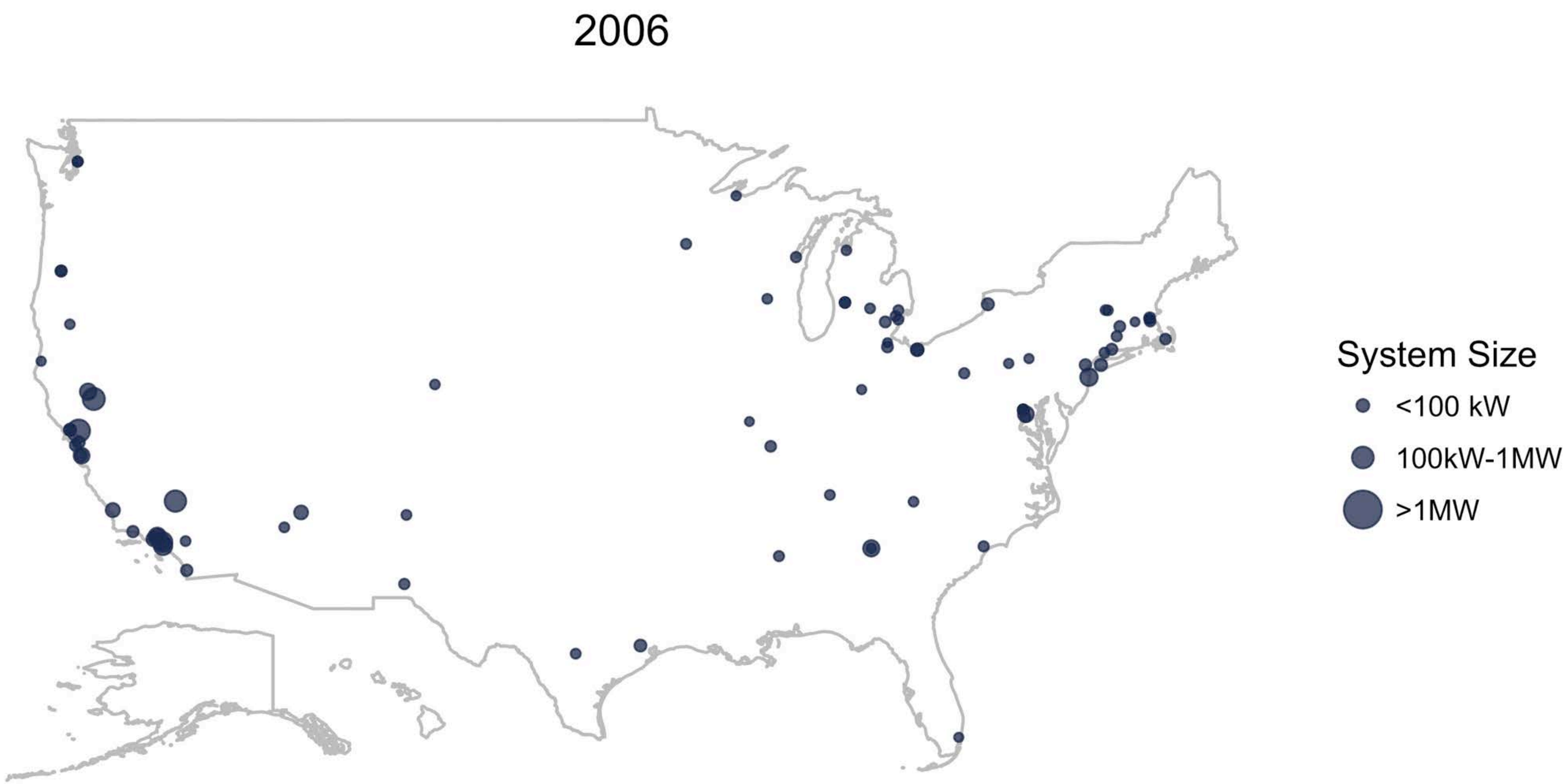

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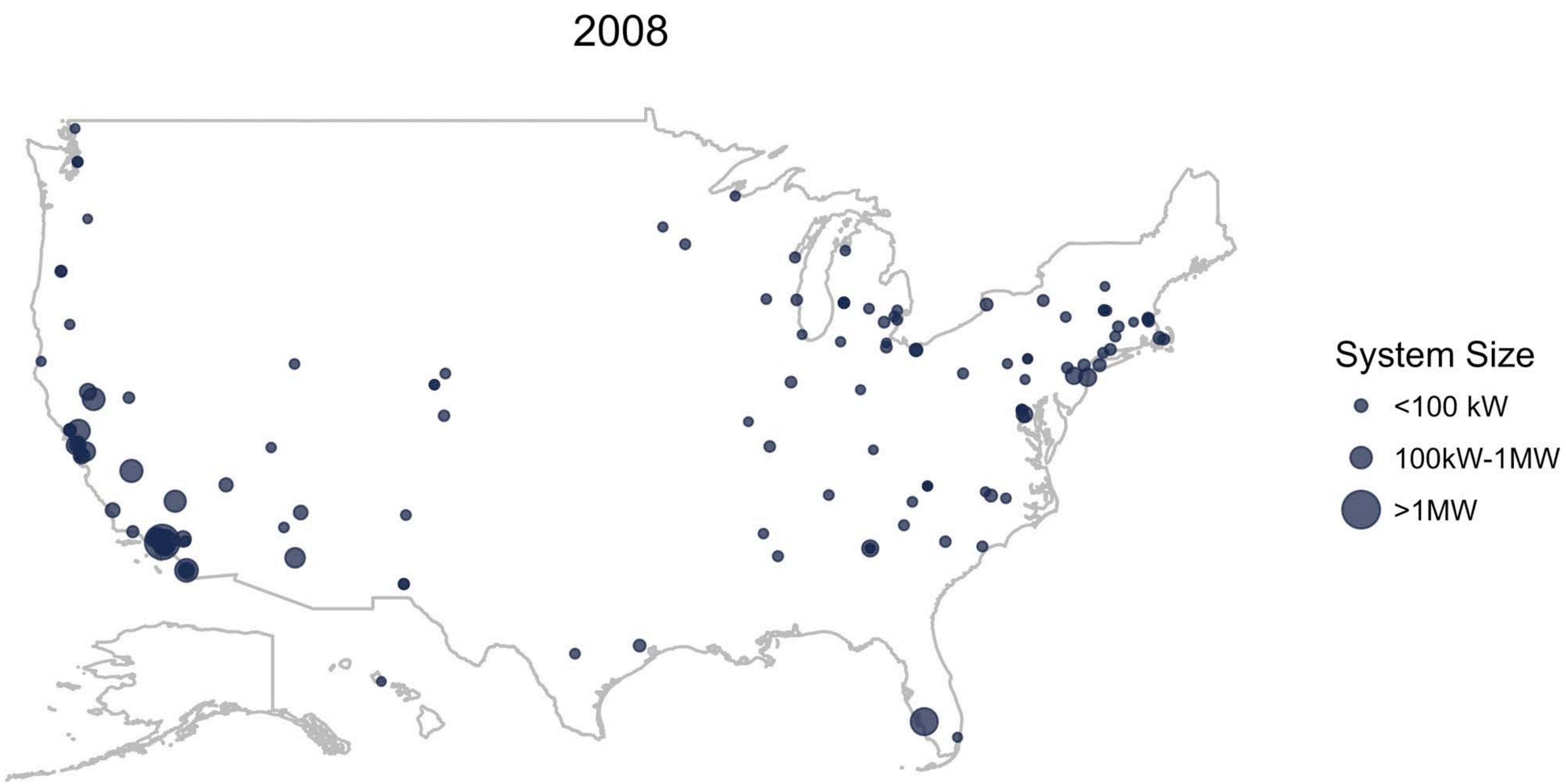

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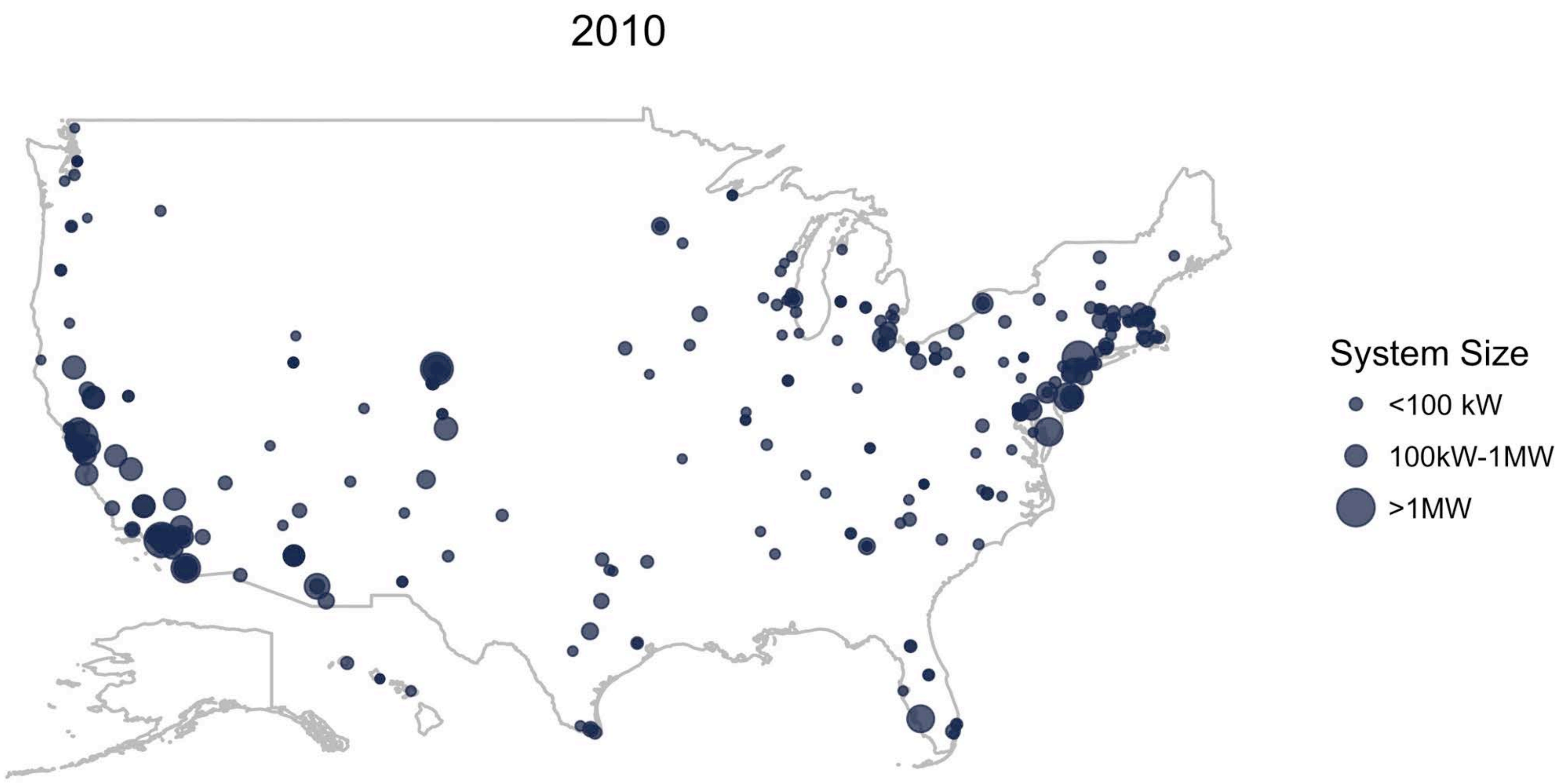

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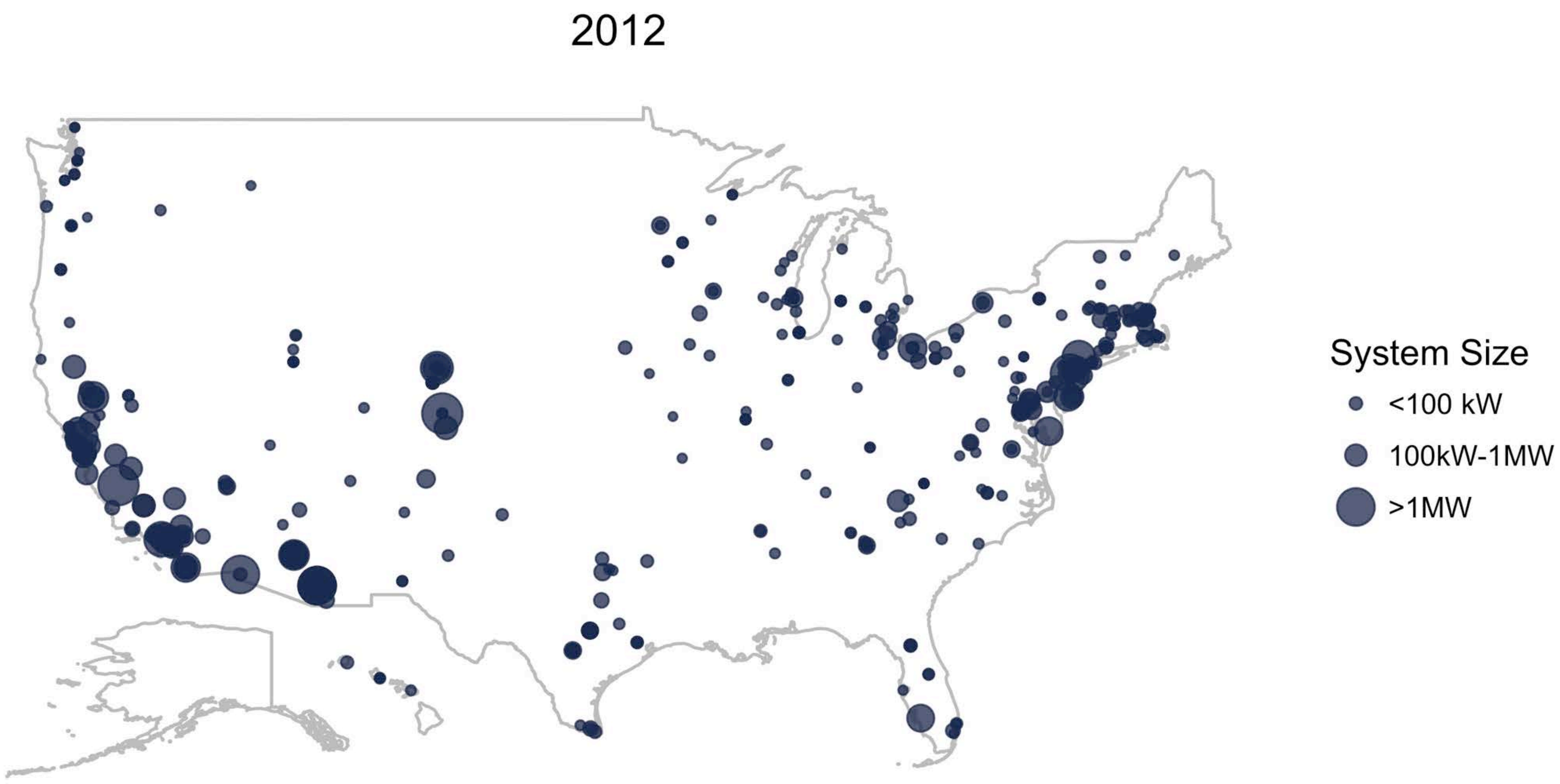

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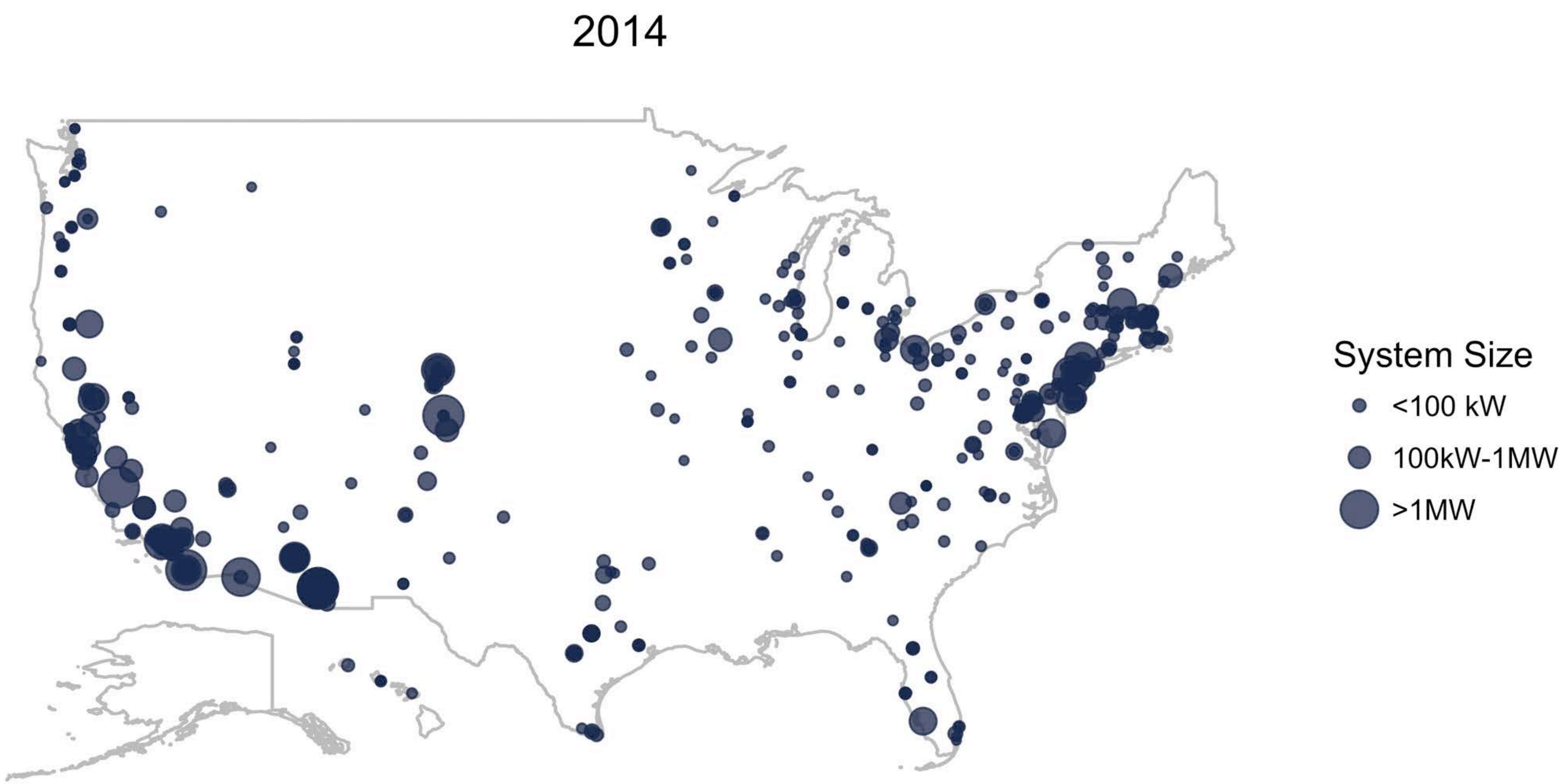

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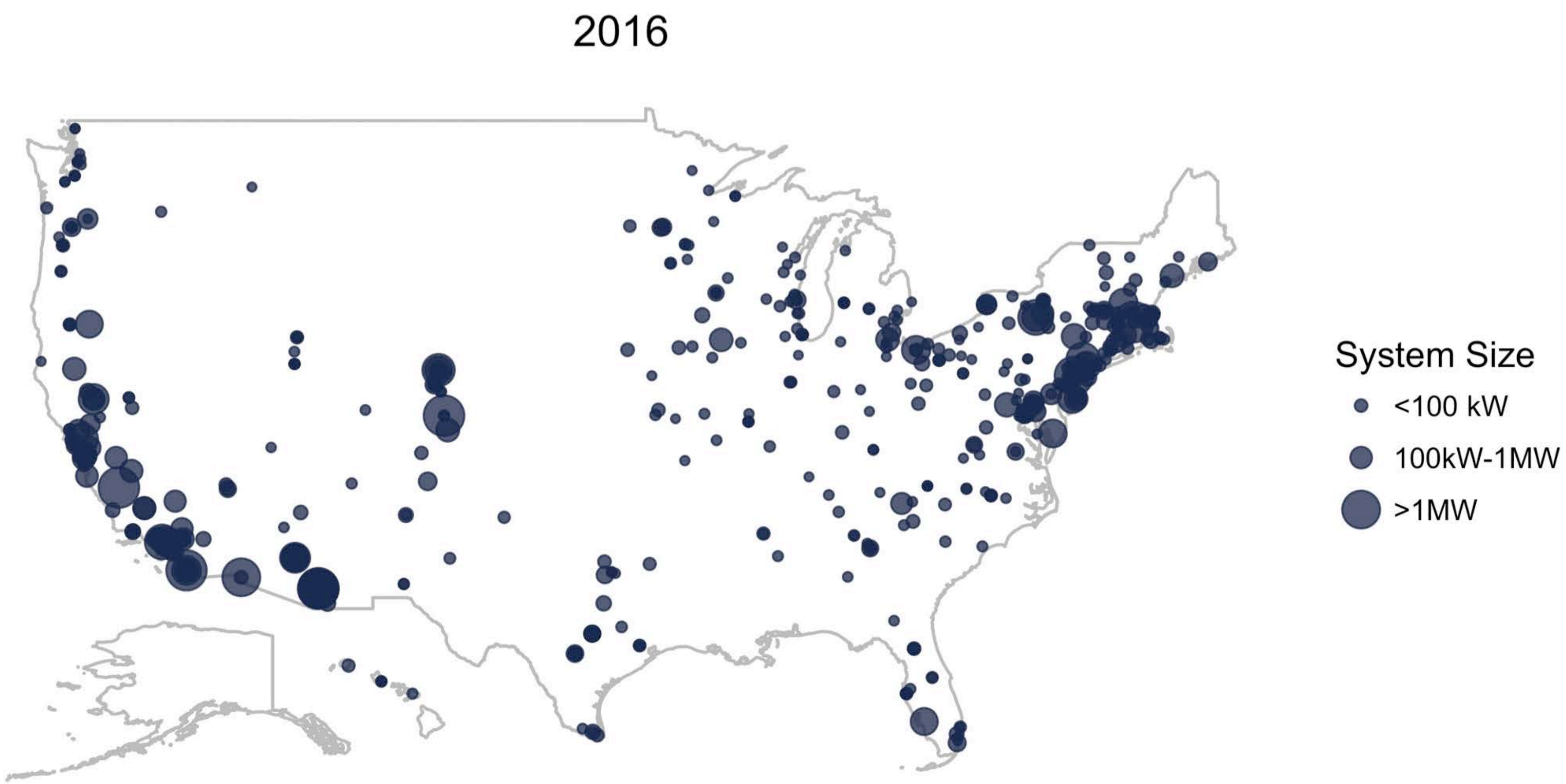
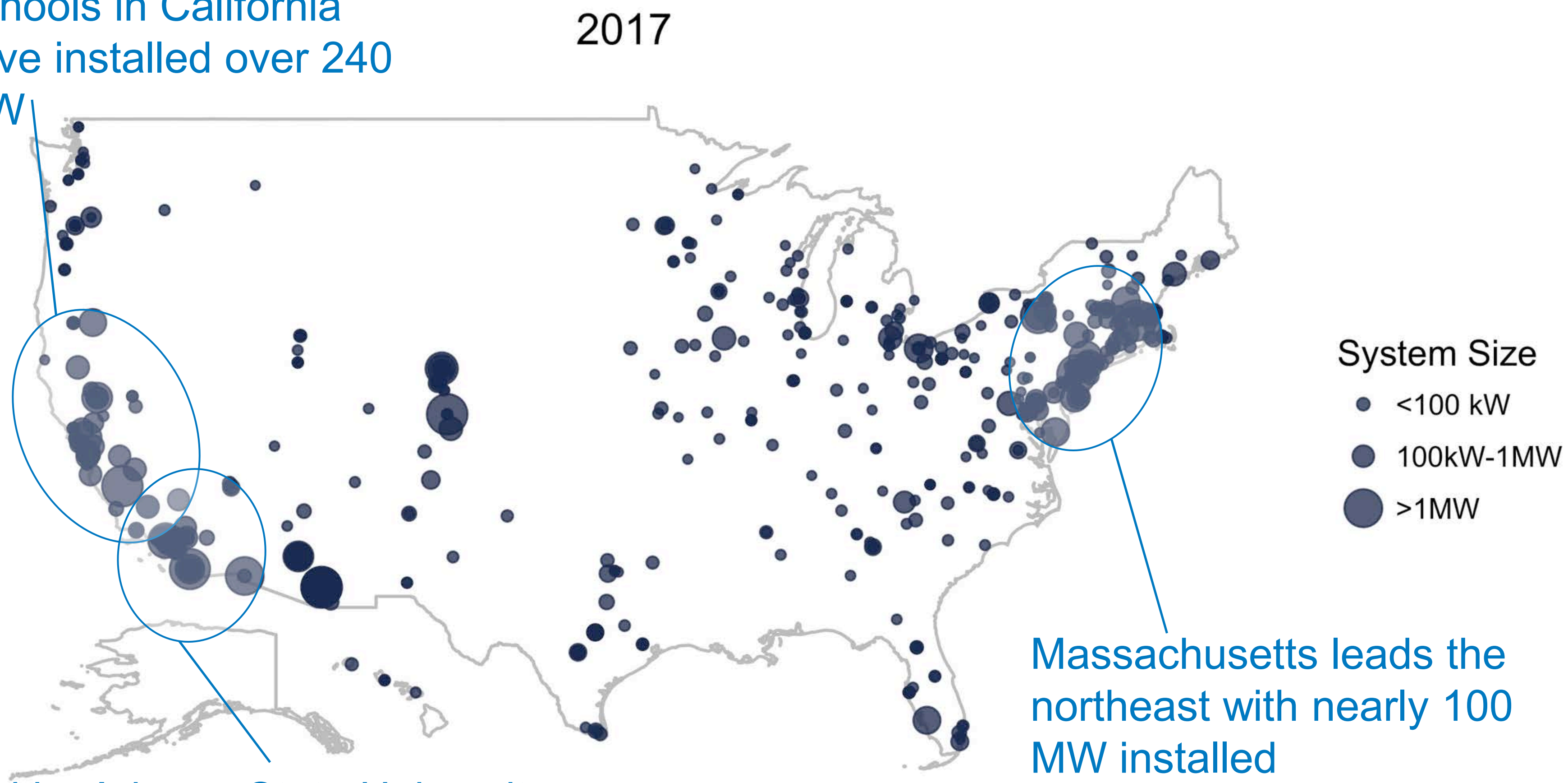
University PV Adoption



Based on data from: AASHE, BNEF, SN

University PV Adoption

Schools in California have installed over 240 MW



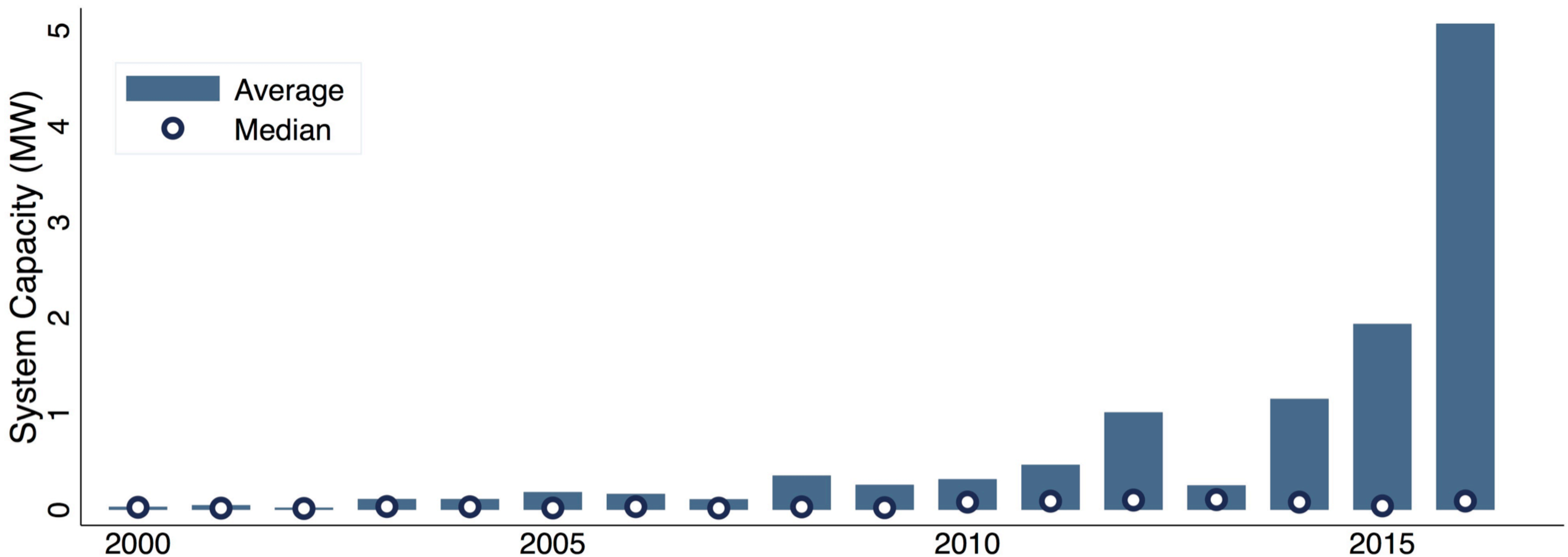
Led by Arizona State University and the University of Arizona, schools in AZ have installed over 70 MW

Massachusetts leads the northeast with nearly 100 MW installed

Close to 700 MW has been installed through early 2017

Average System Sizes Are Increasing

- The average system is around 940 kW, or around 60 kW at the median
- Universities began deploying larger systems around 2010, average system size for systems installed after 2010 is 1,300 kW



Average and Median System Sizes (2000-2016)

Campus Case Studies

Colorado State University (CSU) Solar Case Study

- Case study documents the approaches CSU took to installing 6.7 MW of solar PV capacity between 2009-2015

- Report includes discussion of decision-making process, campus engagement strategies, and relationships with state, local, and utility partners.

Top: 5.3 MW solar PV array at Christman Field at CSU's Foothills Campus. Bottom: Rooftop PV system on the Recreation Center at CSU's main campus in Fort Collins, CO. Photos courtesy CSU

http://www.nrel.gov/docs/fy17osti/67540.pdf

Arizona State University (ASU) Solar Case Study

- ASU has the most solar of any single university in the US
  - 24.1 MW on site
  - 28.8 MW off site

https://cfo.asu.edu/solar

University of California – Solar Supply

Off-Campus

- UC entered in to two agreement for the long-term supply of wholesale renewable energy
  - Agreements executed 2014
- Five Points Solar Park
  - 60 MW
  - Fresno County
  - Commercial operation – fall 2016
- Giffen Solar Park
  - 20 MW
  - Fresno County
  - Commercial operation – summer 2017
- Total expected production over 200,000 MWh per year

Slide courtesy of the University of California

Five Points Solar Park 60 MW PV

Slide courtesy of the University of California

University of California – Solar Supply

On Campus

- As part of the UC system's efforts to reduce its system-wide carbon footprint, each UC campus has installed on-site renewable generation
  - System-wide, the campuses are home to more than 36 MW of solar power systems that produce more than 52 million kWh of renewable electricity
  - More are planned as economics and site availability dictate

Slide courtesy of the University of California

UC Davis on campus solar project

Slide courtesy of the University of California

UC Irvine on Campus Solar Project

Slide courtesy of the University of California

REopt University Screenings

Study Overview

- In support of the U.S. Department of Energy's SunShot initiative, NREL provided Solar PV + storage screenings to universities seeking to go solar.
- Using the REopt model, NREL conducted initial techno-economic assessment of solar PV feasibility at selected universities in FY16 and 17.
- NREL provided each university with customized results, including the cost-effectiveness of solar PV, recommended system size, estimated capital cost to implement the technology, and estimated life cycle cost savings.

REopt : http://www.nrel.gov/tech_deployment/tools_reopt.html
University Assistance : http://www.nrel.gov/technical-assistance/universities.html

15 Universities Selected

Beloit College
Beloit, WI; 8.9 GWh/year

Fairleigh Dickenson University
Hackensack, NJ; 24 GWh/year

Georgia Tech
Atlanta, GA; 316 GWh/year

Lake Superior College
Duluth, MN; 5 GWh/year

Lane Community College
Eugene, OR; 12 GWh/year

Luther College
Decorah, IA; 14 GWh/year

Northern Arizona University
Flagstaff, AZ; 64 GWh/year

Milwaukee Area Technical College
Milwaukee, WI; 29 GWh/year

South Central College
North Mankato, MN; 2.25 GWh/year

Thomas College
Waterville, ME; 2.9 GWh/year

Tuskegee University
Tuskegee, AL; 26 GWh/year

University of California—Riverside
Riverside, CA; 113 GWh/year

University of Colorado–Colorado Springs
Colorado Springs, CO; 23 GWh/year

University of Minnesota—Duluth
Duluth, MN; 40 GWh/year

Washington and Lee University
Lexington, VA; 16 GWh/year

Summary of Screening Results

	Solar PV	Battery Storage
Universities Evaluated	15	5
Projects Recommended	10	5
Combined Project Size	29.2 MW	1.5 MW:4.9 MWh
Energy Generated	42.3 GWh	n/a
Base Case Life Cycle Cost	$514 million in electricity costs (life cycle cost of electricity over 25 years)	
Net Present Value (PV + Storage)	**$8.1 million in electricity cost savings** (savings achieved over 25 years by adding PV + storage)	

- PV projects recommended ranged from 19 kW to 16 MW
- PV appeared cost effective at 10 of the 15 universities evaluated
  - A high electricity rate was also a selection criteria; thus the rate of cost-effective PV projects may be higher for these 15 universities than in general
- Many of these projects were limited by the land and roof area suitable for RE projects

Case Study: Luther College

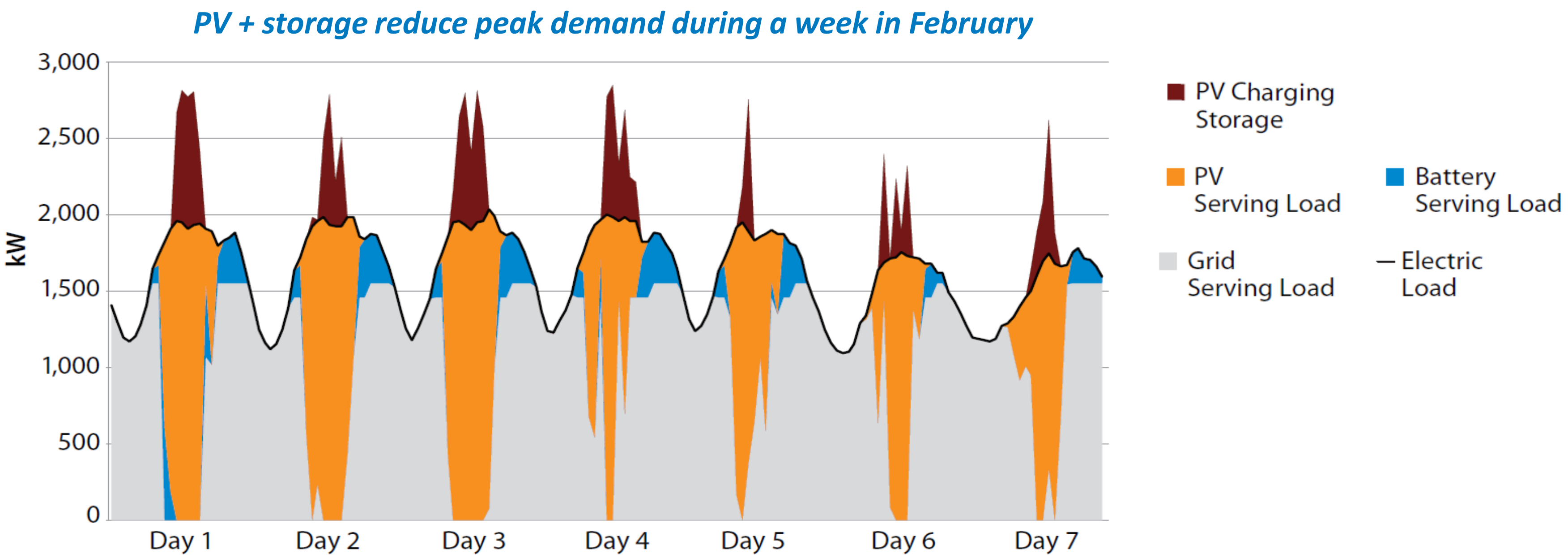
- Luther College in Decorah, Iowa, installed a PV system last year, and is interested in installing **additional PV** at an **area that can host up to 3 MW**.
- They also want to consider a **battery** to **lower demand** charges and **limit electricity export** to the grid.
- The site's utility bill consists of an **energy charge** of about $0.05/kWh and a **demand charge** which varies based on season and time of day and ranges between $8–$23/kW.

Case Study: Luther College

Technologies Evaluated	Business as Usual	Add PV	Add PV and Battery Storage
Additional PV Size	n/a	3 MW	3 MW
Battery Size	n/a	n/a	0.58 MW:3.2 MWh
Total Cost	n/a	$5.6 million	$7.8 million
Annual Energy Costs	$487,000	$269,000 ($218,000 savings)	$292,000 ($195,000 savings)
Annual Demand Costs	$679,000	$652,000 ($28,000 savings)	$522,000 ($157,000 savings)
Life Cycle Cost	$29.0 million	$27.1 million	$25.6 million
Net Present Value	**n/a**	**$1.9 million**	**$3.4 million**

- NREL compared the business as usual case with two alternate scenarios where the university would install additional PV, or PV and batteries
- 3 MW of PV would reduce the life cycle cost of energy from $29.0 million to $27.1 million ($1.9 million NPV); the majority of annual savings is from reduced energy costs
- 3 MW of PV + 0.58 MW:3.2 MWh battery would reduce energy costs from $29.0 million to $25.6 million ($3.4 million NPV); light decrease in energy savings but significant increase in demand savings

Case Study: Luther College



- The PV system charges the battery during hours when PV produces more energy than the site load
- The battery meets the load in the evenings when the PV system is no longer generating electricity but the load is still high
- Two different plateaus can be seen in the grid purchases; the demand charges are higher during the middle of the day and lower in the evening; to optimize the total energy costs the model is dispatching the battery to push demand lower during the higher cost hours

Resources for Universities

- REopt Website: https://reopt.nrel.gov/
- University Assistance Website: http://www.nrel.gov/technical-assistance/universities.html
- NREL Brochure "Using Power Purchase Agreements for Solar Deployment at Universities" http://www.nrel.gov/docs/gen/fy16/65567.pdf
- IREC's Solar Power Purchase Agreements: A Toolkit for Local Governments (Includes an annotated model PPA) http://www.irecusa.org/publications/solar-power-purchase-agreements-a-toolkit-for-local-governments/
- Archived webinar: https://vimeo.com/125871846
- Example PPAs: Standard Commercial PPA version 1.1 (Developed by a working group of financial professionals) https://financere.nrel.gov/finance/content/solar-securitization-and-solar-access-public-capital-sapc-working-group#standard_contracts
- New York K-Solar PPA Template http://www.p12.nysed.gov/facplan/documents/K-SolarPPATemplatePerformanceWarrantyandPurchaserCreditAgreement.pdf
- IREC: Sample PPA (Word version) http://www.irecusa.org/wp-content/uploads/2015/04/Final_Clean_PPA_Template.docx

QUESTIONS?

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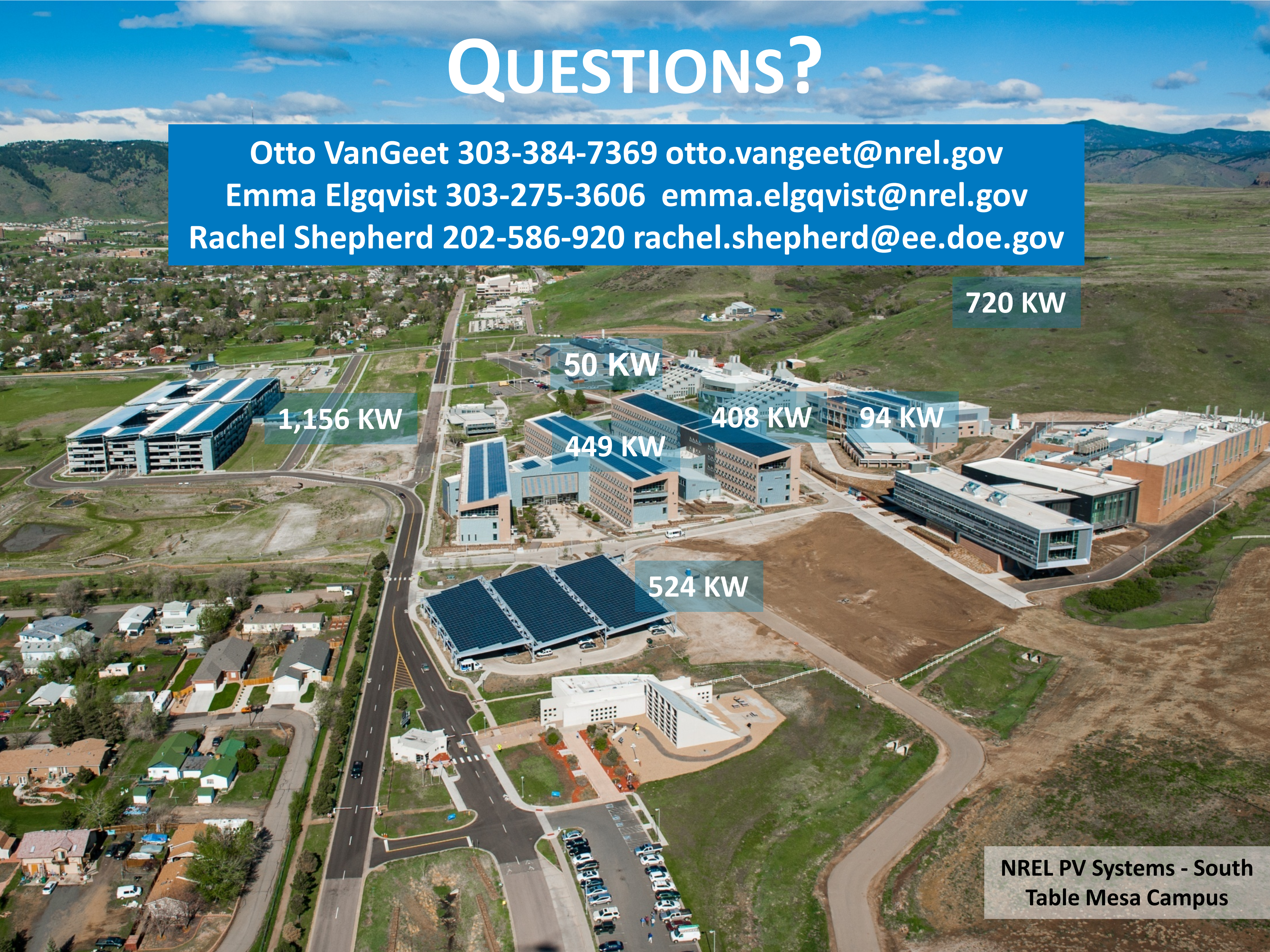

NREL PV Systems - South Table Mesa Campus