Campus Energy Approach, REopt Overview, and Solar for Universities
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International Institute for Sustainable Laboratories
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<thead>
<tr>
<th>Topic</th>
<th>Time</th>
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<tr>
<td>Campus Energy Approach</td>
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<tr>
<td>REopt Tool</td>
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<td>Universities Using Solar</td>
<td>30 min.</td>
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<td>REopt University Screenings</td>
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<td>Q&amp;A Session</td>
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**Agenda**
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

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

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

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. Plan & Prioritize
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.

https://www.nrel.gov/tech_deployment/climate_neutral/
1. Determine Baseline Energy Consumption

**Determining current energy consumption**

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

**Scope 1: Direct combustion of fuels at your site**

**Scope 2: 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.

**Scope 3: 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

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

• Consider available area:
  o Vacant land
  o Parking lots
  o Roofs (with 20 year plus life and able to accommodate 2-4 lb./SF solar weight)
  o 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: 140,456 ft²

Potential Carport PV Area: 118,722 ft²

Potential Ground PV Area: 897,083 ft²
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
District Energy

http://staging.unep.org/energy/districtenergyincities
WHAT IS DISTRICT ENERGY?

- Connecting Renewable Electricity Generation
- Waste Incineration
- Connecting Sources of "Free Cooling"
- Connecting Commercial Demand
- Connecting Residential Customers
- Connecting Industrial Demand
- Capturing Waste Heat from Sewage and Wastewater
- Absorption Chiller Capturing Waste Heat
- Solar Thermal Connected to District Heating
- Combined Heat and Power (CHP) Plant
UC Irvine Smart Labs and CHP with Thermal Energy Storage

www.ehs.uci.edu/programs/energy/
3. Prepare a Plan and Set Priorities

Set Preliminary Goals

Evaluate Specific Measures

Determine Acceptable Financial Criteria

Revise Goals
REopt Model & Web Tool
REopt: Decision Support Throughout the Energy Planning Process

Optimization • Integration • Automation

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

Drivers
- Goals
  - Minimize Cost
  - Net Zero
  - Resiliency
- Economics
  - Financial Parameters
  - Technology Costs
  - Incentives
- Utility Costs
  - Energy Charges
  - Demand Charges
  - Escalation Rate

Goals
- Minimize Cost
- Net Zero
- Resiliency

Economics
- Financial Parameters
- Technology Costs
- Incentives

Utility Costs
- Energy Charges
- Demand Charges
- Escalation Rate

REopt
Energy Planning Platform
Techno-economic Optimization

Technology Options
- Renewable Generation
  - Solar PV
  - Wind
  - Biomass, etc.
- Conventional Generation
  - Electric Grid
  - Fuel Supply
  - Conventional Generators
- Energy Storage
  - Batteries
  - Thermal storage
  - Water tanks
- Dispatchable Technologies
  - Heating and Cooling
  - Water Treatment
- Energy Conservation Measures

Optimized Minimum Cost Solution
- Technologies
  - Technology Mix
  - Technology Size
- Operations
  - Optimal Dispatch
- Project Economics
  - CapEx, OpEx
  - Net Present Value

Loads
- Thermal Loads
- Electric Loads
- Water Demand
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

Project Example: Identifying & Prioritizing Projects across a Portfolio

Sites Evaluated: 696
Cost-Effective PV: 306
Size: 38.79 MW
NPV: $37 million
RE Generation: 64.7 GWh
RE Penetration: 10.5 %
• Determine economically optimal PV + storage system size & dispatch using:
  o 15-minute electric load
  o 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
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 storage.

<table>
<thead>
<tr>
<th></th>
<th>Generator</th>
<th>Solar PV</th>
<th>Storage</th>
<th>Lifecycle Cost</th>
<th>Outage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Base case</td>
<td>2.5 MW</td>
<td>-</td>
<td>-</td>
<td>$20 million</td>
<td>5 days</td>
</tr>
<tr>
<td>2. Lowest cost solution</td>
<td>2.5 MW</td>
<td>625 kW</td>
<td>175 kWh</td>
<td>$19.5 million</td>
<td>6 days</td>
</tr>
<tr>
<td>3. Proposed system</td>
<td>2.5 MW</td>
<td>2 MW</td>
<td>500 kWh</td>
<td>$20.1 million</td>
<td>9 days</td>
</tr>
</tbody>
</table>

![Graph showing the probability of surviving outages with different systems over varying lengths of outage.](image-url)
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

- Site location: Palmdale, CA, United States
- Load profile: Simulated
- Type of building: Retail Store
- Annual energy consumption (kWh): 500000
- Electricity rate: Southern California Edison Co: Time of Use, Gen

Financial

PV

Battery

Resilience

Get Results
Additional Inputs Can Be Edited, Or Left As Defaults
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.

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)

$102,771

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.
Results Comparison

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

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

Simple Resiliency Inputs

![Resilience Input Form]

Simple Resiliency Outputs

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

<table>
<thead>
<tr>
<th>Optimal Case</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Resiliency (hours)</td>
<td>5 hours</td>
</tr>
<tr>
<td>Minimum Resiliency (hours)</td>
<td>0 hours</td>
</tr>
<tr>
<td>Maximum Resiliency (hours)</td>
<td>29 hours</td>
</tr>
</tbody>
</table>

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

System Size
- <100 kW
- 100kW-1MW
- >1MW
University PV Adoption

Based on data from: AASHE, BNEF, SN
University PV Adoption

2004

Based on data from: AASHE, BNEF, SN
University PV Adoption

Based on data from: AASHE, BNEF, SN

System Size
- <100 kW
- 100kW-1MW
- >1MW

2006
University PV Adoption

Based on data from: AASHE, BNEF, SN
University PV Adoption

2010

Based on data from: AASHE, BNEF, SN
University PV Adoption

2012

Based on data from: AASHE, BNEF, SN
University PV Adoption

Based on data from: AASHE, BNEF, SN

System Size
- <100 kW
- 100kW-1MW
- >1MW
University PV Adoption

2016

Based on data from: AASHE, BNEF, SN
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.
• 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
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.

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
Off-Campus

• UC entered in to two agreement for the long-term supply of wholesale renewable energy
  o Agreements executed 2014

• Five Points Solar Park
  o 60 MW
  o Fresno County
  o Commercial operation – fall 2016

• Giffen Solar Park
  o 20 MW
  o Fresno County
  o Commercial operation – summer 2017

• Total expected production over 200,000 MWh per year
Five Points Solar Park 60 MW PV

*Slide courtesy of the University of California*
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
  o 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
  o More are planned as economics and site availability dictate
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
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.

University Assistance: [http://www.nrel.gov/technical-assistance/universities.html](http://www.nrel.gov/technical-assistance/universities.html)
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.
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

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

- 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/](https://reopt.nrel.gov/)
- University Assistance Website: [http://www.nrel.gov/technical-assistance/universities.html](http://www.nrel.gov/technical-assistance/universities.html)
- Archived webinar: [https://vimeo.com/125871846](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](https://financere.nrel.gov/finance/content/solar-securitization-and-solar-access-public-capital-sapc-working-group#standard_contracts)
QUESTIONS?

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