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U.S. DEPARTMENT OF ENERGY

How Distributed Energy Resources Can Improve Resilience in Public Buildings: Three Case Studies and a Step-by-Step Guide

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Overview

States, local governments, and other public organizations face a range of priorities when it comes to powering their buildings. These priorities can include saving money, ensuring resilience, and increasingly, meeting energy efficiency and renewable energy goals or targets. Targeted, cost-effective investments in energy efficiency have demonstrated success in supporting each of these priorities.[1] Efficiency improvements can also provide added benefits when combined with another emerging strategy for critical public facilities: onsite generation – and storage when needed – as part of a microgrid system with the ability to “island” from the grid and power critical operations during a grid outage. Publicly available tools from the U.S. Department of Energy (DOE)’s National Laboratories can help energy managers and other decision-makers explore options to meet their unique energy needs while saving energy and money.

Purpose of this Document

DOE offers two tools that provide high-level assessments of the size and potential cost of onsite energy systems that can power critical facilities, both during grid outages as well as during normal operations. These tools are: 1) the Distributed Energy Resources Customer Adoption Model (DER-CAM), developed by the Lawrence Berkeley National Laboratory (LBNL), and 2) the REopt Lite web tool, which offers a subset of features from the Renewable Energy Integration and Optimization model (REopt) developed by the National Renewable Energy Laboratory (NREL). While each tool has distinctive features (see Table 2), both of them can help facility managers assess how power can be maintained during grid outages using a variety of distributed energy resources (DERs), such as energy efficiency, energy storage, onsite renewable energy, and combined heat and power.

This guide demonstrates completed analysis on potential energy investments at existing facilities managed by three partners in DOE’s Better Buildings Challenge,[2] including North Carolina; Hillsboro, Oregon; and Alachua County Public Schools in Florida. Prior to considering resilience investments, each partner has achieved significant energy and cost savings by taking actions to meet energy efficiency targets through the Better Buildings Challenge. The results presented here are intended to illustrate how DER-CAM and REopt Lite can be used to assess different approaches toward enhancing energy resilience at critical public facilities. Aspects of these cases also highlight the opportunity for improved energy efficiency to lower energy costs during normal operations and when making resilience investments.

Two appendices include step-by-step guidance and considerations for how to conduct new analysis in REopt Lite and DER-CAM. The appendices are written for new users of each tool that want to conduct resilience analysis for their own buildings similar to the cases presented in this guide. The appendices complement existing user manuals and training tutorial videos, which are included for reference.

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[1] For more information, see https://www.energy.gov/sites/prod/files/2019/06/f64/EEDG-Resilience.PDF and https://aceee.org/blog/2019/07/going-clean-how-energy-efficiency

[2] The Better Buildings Challenge is a U.S. Department of Energy initiative where leading states, cities, school districts and other organizations commit to improving the energy efficiency of their portfolio of buildings by at least 20% over 10 years. For more information, see: https://betterbuildingsinitiative.energy.gov/challenge

Microgrids and Distributed Energy Resources for Resilience in Critical Infrastructure

In communities across the United States, public buildings, such as hospitals, police departments, fire stations, and other facilities, provide critical services that require continued operations during natural disasters or malicious attacks that disable the electric grid. In many areas, schools or other large public buildings serve as emergency shelters for prolonged recovery periods. While onsite diesel generators have historically powered a majority these sites,[3] other DER options can support a microgrid[4] system to provide the dual benefits of both backup power during an emergency and efficient, onsite energy that reduces utility bills year-round. A key factor in minimizing the cost of a microgrid system is the magnitude of the energy needed at the site during a grid outage.[5] As illustrated in Figure 1, energy efficiency improvements can reduce the amount of utility-purchased energy that is needed during a typical day. Reducing the overall electricity demand of a building also reduces the energy needed to maintain critical functions, such as lighting, during a grid outage. This lower electricity demand also means lower initial cost for DER investments. Whether efficiency is incorporated during building construction or as part of a retrofit, making energy efficiency improvements first can be an effective strategy to reduce the overall costs of meeting resilience goals with onsite generation and storage technologies.[6]

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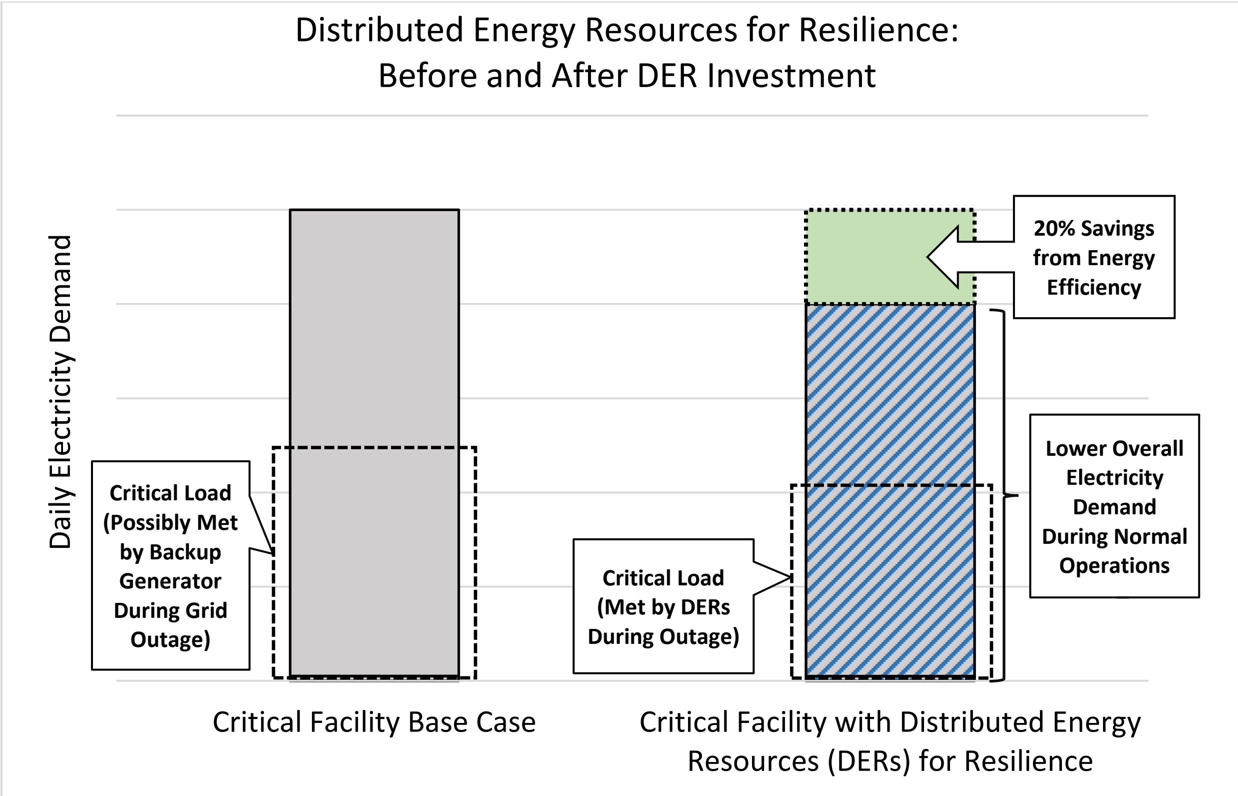
[3] Nearly 85% of backup generators used by commercial buildings and critical facilities are powered by diesel and 10% are powered by natural gas. For more information on current onsite and electric power backup capabilities at critical facilities, see https://publications.anl.gov/anlpubs/2016/05/127089.pdf.

[4] DOE's Office of Electricity describes microgrids as "localized grids that can disconnect from the traditional grid to operate autonomously." This can include a single customer microgrid or more complex designs that serve multiple customers. For more information on how microgrids work, see https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/role-microgrids-helping.

[5] See Chapter VI of Marqusee et al., available here: https://noblis.org/wp-content/uploads/2017/11/Power-Begins-at-Home-Noblis-Website-Version-15.pdf.

[6] For more information and examples, see https://www.energy.gov/sites/prod/files/2019/06/f64/EEDG-Resilience.PDF

Figure 1: Comparison of Electric Usage Before and After DER Investment



Before DER investments, a facility's electricity demand is met by the grid during normal operations, and during a grid outage, may be met by a backup generator (left.) After DER investments (right), energy efficiency improvements (in green) reduce the amount of total electricity demand, lowering energy costs. During normal operations, the facility's electricity needs are met by a combination of grid-purchased electricity and onsite generation, further lowering utility bills. During a grid outage, DERs can meet critical loads, which may now require less electricity as a result of the energy efficiency improvements.

Additional Potential Value to Facilities

Energy efficiency and other DERs can bring further value to public facilities in addition to the energy and cost savings mentioned above, and oftentimes, these additional benefits can improve the value proposition of potential DER investments. Previous research illustrates that including the resilience value of a proposed DER investment can be a key factor in determining whether a project is economically viable.[7] However, there is no consensus best practice for valuing the resilience benefits of DERs,[8] and existing methods require data and research that were outside the scope of this analysis. Other value streams can

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[7] See https://www.nrel.gov/docs/fy18osti/70679.pdf and https://www.cleanegroup.org/ceg-resources/resource/resilient-southeast/.
[8] For a recent report describing current methods for valuing the resilience benefits of DERs, see: https://pubs.naruc.org/pub/531AD059-9CC0-BAF6-127B-99BCB5F02198.

also be considered for investments in microgrids with DERs; DER technologies can receive incentives as part of a program administered by federal, state, or local governments or the local utility. In addition, microgrid systems can provide ancillary grid services, such as voltage regulation or frequency stability, and can serve as alternatives to grid infrastructure upgrades.[9] Determining the value of these grid services is a difficult process, where benefits vary based on the physical location and utility systems' distributed energy needs.[10] Depending on the utility, microgrid systems can participate in demand response programs through building load control.[11] Jurisdictions may also consider factoring in the value of meeting energy efficiency and renewable energy targets or other energy policies beyond those considered here. Table 1 illustrates other ways that energy efficiency can pair with onsite generation to achieve multiple benefits.

Table 1: Energy Efficiency and Onsite Generation: Benefits During Normal Operations and Energy Disruptions

	Energy Efficiency	Efficiency with Onsite Generation/Storage
During normal grid operations and fuel supply	Lower costs for total energy required Reduced likelihood of demand spikes that can lead to outages Support energy efficiency and/or renewable energy targets or goals Greater comfort, higher indoor air quality	Deeper cost savings - reduced demand charges and energy purchased from grid Further reduced likelihood of outages due to demand spikes Further support energy efficiency and/or renewable energy targets or goals
Additional value during a grid outage or fuel shortage event	Passive survivability	Continuity of energy services

Energy efficiency can provide a range of resilience benefits, both with and without other DERs – including "passive survivability," or the ability for buildings to maintain habitable conditions during a power outage. This table is adapted from the Efficiency-Resilience Nexus Fact Sheet; access the resource for further description of these benefits.

Understanding a site's energy use and operational performance is critical to assessing options for improving resilience during energy interruptions. States, local governments, and other public organizations

[9] A list of potential microgrid revenue streams is available at: https://www.sciencedirect.com/science/article/pii/S1040619019301265?via%3Dihub.

[10] https://www.energy.gov/sites/prod/files/2014/12/f19/AdvancedMicrogrid_Integration-Interoperability_March2014.pdf.

[11] While current opportunities exist for buildings to deliver services back to the electric grid, DOE's Building Technologies Office is currently conducting additional research to improve the capabilities of Grid-interactive Efficient Buildings in the future. For more information, visit https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings.

should track and manage energy consumption data to effectively assess energy solutions that promote resilience.[12]

DOE Tools to Assess Options for Distributed Energy Resources and Resilience

DOE has supported the development of two publicly available tools, DER-CAM and REopt Lite, which provide high-level assessments of the size and cost of onsite DERs and the ability to power critical loads during specified outage periods. These tools also estimate the optimal combination of energy efficiency, renewable energy, and energy storage to reduce the system costs and provide energy savings. The table below summarizes the respective capabilities and key differences between the two tools. One specific benefit of DER-CAM is the range of different DER technologies that can be considered by users. However, it requires downloading software and can take time to learn before being able to perform analysis. REopt Lite has a more focused set of DER technologies but is available as a web interface with fewer inputs required to be entered by the user. This may make it preferable for users interested specifically in the technologies listed below and looking for a quicker set of results. For users that want to assign a specific value of lost load, both REopt Lite and DER-CAM have the ability to include this value as an analysis input, as explained in the appendices.

[12] More information on data management is available in this summary of DOE's forthcoming Energy Data Management Guide, available at https://www.energy.gov/sites/prod/files/2018/03/f49/WIP-DataGuidev3.pdf.

Table 2: Comparison of REopt Lite and DER-CAM

Model	REopt Lite	DER-CAM
Unit of analysis	Single building or co-located campus of buildings	Single building or co-located campus of buildings
Onsite technologies included	Solar photovoltaic (PV), battery storage, wind (combined heat and power – forthcoming)	Solar photovoltaic (PV), battery storage, thermal storage, combined heat and power, efficiency improvements, flexible load, wind, biofuels, fuel cells
User interface	Website with fields to input – analysis can be performed in 5-10 minutes	Software must be downloaded; input prompts are divided in sections of tool – learning how to use the tool and running analysis takes practice
Resilience metrics – scope and outputs	Able to assess optimal system to power critical loads during user-specified outage periods; will report size of system needed to meet exact outage defined by the user and the probability of withstanding outages at other times of year. Avoided outage cost scenarios ($/kilowatt hour (kwh)) can be compared with optimization results.	Able to assess optimal system to power critical loads during user-specified outage periods; allows user to designate monetary value of lost load in $/kilowatt hour, then reports size of new system to minimize all costs, including lost load during an outage.
Energy use data inputs	Users can input hourly consumption data for their typical and/or critical electric loads. If hourly usage data is not available, users can input monthly or annual energy consumption and select a building type (e.g., elementary schools, hospitals) to estimate energy load patterns.	Users can input hourly interval data for electricity use during 3 "types" of days (i.e., average weekday, weekend, peak day) in each month of the year, then all days in that month are assigned to one of the day "types." Default load shapes for different types of buildings (e.g., elementary schools, hospitals) are also available.

Note: For example case studies using REopt Lite, see Valuing the Resilience Provided by Solar and Battery Energy Storage Systems. For examples of completed feasibility studies using DER-CAM, see New Jersey Township Microgrid Program.

Case Studies: Better Buildings Challenge Partners Explore Opportunities for Resilience

The following case studies showcase three partners in the Better Buildings Challenge (BBC) that have committed to improving the energy efficiency of their portfolio of buildings by at least 20% over 10 years. As a part of their voluntary commitment as BBC partners, each state, local government, and K-12 school district tracks their energy consumption data to monitor progress toward their savings goals. This data was leveraged to conduct resilience analyses in DER-CAM and REopt Lite.

No explicit monetary value of resilience (also called the value of lost load) was assigned or included in the financial analysis of the following cases presented. Instead, these cases look at strategies that could be used to meet energy needs during a simulated outage of a specific length and explore the other impacts (i.e., initial cost and annual generation) of installing the required technologies. While these cases consider incentives such as available net metering, other value streams not considered by this analysis could improve a project's value proposition to facilities.[13] Comparing costs and impacts across a building fleet, as demonstrated below, can highlight which sites may be the most cost-effective prospects for a microgrid relative to other existing critical facilities.

North Carolina

North Carolina joined the Better Buildings Challenge in 2009 and is a goal achiever, having reduced the energy intensity of state buildings by 21%.[14] In 2018, their Governor issued Executive Order 80 that called for even deeper reductions in both state building energy consumption and state greenhouse gas emissions to 40% below 2002-2003 levels. As the state government develops a plan to meet these goals, they must also address growing concerns at several government-managed facilities about the prospect of prolonged grid outages caused by hurricanes and related flooding. North Carolina identified eight critical facilities to assess microgrid technologies that could allow the facilities to "island," or operate during a grid outage.

Based on North Carolina's specific interest in solar PV and battery storage, the REopt Lite tool was used to analyze six out of the eight critical facilities[15] to determine the optimal size and performance of a system necessary to provide power for up to 48 hours during a grid outage. This analysis indicated that a combination of solar PV and energy storage could power critical loads – modeled as 50% of normal load – at each facility during the entire simulated outage. Over the course of a year, the same solar PV and storage systems could generate enough power to provide 66% to 100% of the facility's annual electricity consumption – reducing reliance on the grid and supporting the state's energy goals.

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[13] See "Additional Potential Value to Facilities" on page 3.
[14] For information on the progress of North Carolina and other Better Buildings Challenge Partners, see http://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/DOE_BBI_2018_Progress_Report_051018.pdf
[15] Based on their functions, each of these facilities was assessed as a medium-sized office building. For more information on simulated building types, see the appendices.

Table 3.1: Solar + Storage for Resilience Analysis for Six North Carolina Facilities Using REopt Lite

Modeled Results for Meeting 50% of Building Load During a 2-day (48-hour) Grid Outage					
North Carolina Facilities	Battery Storage Size (kWh)	Solar PV System Size (kW)	Annual Solar PV Production (kWh)	Solar PV Production As % of Annual Electricity Consumption	Net Increase in Total Energy Costs Over 20 years[16]
NC Facility #1	307	283	353,357	84%	51%
NC Facility #2	73	58	72,068	73%	25%
NC Facility #3	134	106	132,283	73%	25%
NC Facility #4	322	431	529,494	97%	13%
NC Facility #5	1,027	530	667,487	100%	36%
NC Facility #6	669	568	700,464	66%	19%

For one site of specific interest to North Carolina, the REopt Lite tool was also used to explore how a smaller, lower cost microgrid system with solar PV and storage could be used to support the same outage length, if the state first identified incremental energy efficiency measures to reduce the critical load. Table 3.2 illustrates how the initial cost of a resilient solar PV and storage system is significantly lower if energy efficiency measures are used to reduce the site's energy needs.

[16] Net increase listed in this column combines the reduction in utility costs for the site with the cost of installing and maintaining the microgrid system. This calculation includes cost reductions from the federal investment tax credit (ITC), as well as net metering compensation available to each site. However, it does not include other value streams that may be considered make the project economics more favorable. A description of potential revenue sources for microgrids is available at: https://www.sciencedirect.com/science/article/pii/S1040619019301265?via%3Dihub

Table 3.2: Solar + Storage and Energy Efficiency Analysis for One North Carolina Facility Using REopt Lite

Modeled Results for Meeting 50% of Building Load During a 2-day (48-hour) Grid Outage					
NC Facility and Electricity Usage Scenario	Battery Storage Size (kWh)	PV System Size (kW)	Annual PV Production (kWh)	Solar PV Production As % of Electricity Consumption	Installed Cost
NC Facility #6 - Business as Usual (BAU)	669	568	700,464	66%	$1,170,960
NC Facility #6 - 10% More Efficient	602	511	630,418	66%	$1,053,895 (~$117,065 less than BAU)
NC Facility #6 - 20% More Efficient	535	454	560,372	66%	$936,797 (~$234,163 less than BAU)
NC Facility #6 - 40% More Efficient	401	341	420,280	66%	$702,660 (~$468,300 less than BAU)

Efficiency improvements at the scale of the state's 40% goal are ambitious, but achievable. Case studies featuring state, local, and federal government building retrofits implemented with energy savings performance contracts (ESPCs) indicate achieved energy savings as high as 60%.[17]

For two additional North Carolina facilities, with higher annual electric consumption as well as more significant energy needs for space and water heating, DER-CAM was used to explore a broader range of technologies that could provide power for an electric grid outage of up to four days. For each of these sites, DER-CAM selected a microgrid system that consisted of combined heat and power (CHP), solar PV, and thermal storage (which helped meet cooling needs at a lower cost than battery storage). During normal operations, the microgrid could operate in a way that could reduce the costs for utility-purchased electricity by an amount greater than the cost of installing and operating the system – a resilience investment that can effectively pay for itself over time.

[17] ESPC is a contract vehicle that allows efficiency investments to be made with no upfront cost, and be paid for as energy bill savings are realized. More detail on savings performance is available at https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/stateanlocalgovprojectperformancebenchmarks.pdf. More information on ESPC can be found at https://betterbuildingssolutioncenter.energy.gov/sites/default/files/FL1709_WIP_ESPC%20Fact%20Sheet_FINAL%20VERSION_Jan%202018.pdf

Table 3.3: DERs for Resilience Analysis for Two North Carolina Facilities Using DER-CAM

Modeled Results for Meeting 50% of Building Load During a 4-day (96-hour) Grid Outage				
NC Facility	PV System Size (kW)	CHP Capacity (kW)	Thermal Storage Capacity (kwh)	Net Increase in Total Energy Costs Over 20 Years[18]
NC Facility #7	222	250 (microturbine)	1,332	-14%
NC Facility #8	1,011	250 (internal combustion engine)	2,943	-3%

In these scenarios, a combination of solar PV and energy storage can power critical loads while reducing electricity purchased from the utility, and pursuing energy efficiency first to reduce energy needs can lower the cost of that initial investment by as much as nearly $200,000 at a single site. For two facilities with higher electric consumption and significant energy and cooling needs, a combination of solar PV, CHP, and thermal storage reduced the cost of utility-purchased electricity. Future analysis could consider additional value streams that may improve the total value to North Carolina in meeting its energy goals.

Hillsboro, Oregon

Hillsboro, Oregon joined the Better Buildings Challenge in 2009 and, as of 2018, has exceeded its goal by reducing the energy intensity of its public buildings by 26%.[19] During this time, as a result of facility energy efficiency upgrades and other steps, Hillsboro has reduced greenhouse gas emissions from city operations electricity, natural gas, and fleet fuels by 30%.[20] Hillsboro also received the SolSmart Gold designation, as a community that has effectively removed barriers to local solar energy development;[21] established a community Environmental Sustainability Plan with a goal of reaching 75% "green power"[22] purchased by 2035; and according to the EPA is the country's leading "green power" city by share of its total power

[18] This calculation combines the reduction in utility costs for the site with the cost of installing and maintaining the microgrid system. This includes cost reductions from net metering compensation available to each site. However, it does not include the federal investment tax credit (ITC) and other value streams that may be available to make the project economics more favorable. DER-CAM does include the capability to incorporate the ITC and additional revenue streams, as described in its supporting documentation. A description of potential revenue sources for microgrids is available at: https://www.sciencedirect.com/science/article/pii/S1040619019301265?via%3Dihub

[19] https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/DOE_BBI_2018_Progress_Report_051018.pdf

[20] Other steps taken by the city to reduce greenhouse gas emissions include renewable power purchases and generation, greener practices in new facility construction, incentives to encourage alternative employee commutes, increased alternative fuel vehicles and infrastructure, and advanced technology to reduce water use. For more information, visit https://www.hillsboro-oregon.gov/home/showdocument?id=11263

[21] SolSmart is led by The Solar Foundation and the International City/County Management Association (ICMA) and is funded by the U.S. Department of Energy Solar Energy Technologies Office. More information on SolSmart is available at https://www.solsmart.org/

[22] The EPA's Green Power Partnership program defines green power as "as a subset of renewable energy that encompasses those renewable resources and technologies that provide the highest environmental benefit." Participants may choose from a range of green power products to meet this target, including purchasing renewable energy certificates. For more information, see https://www.epa.gov/sites/production/files/2016-01/documents/gpp_partnership_reqs.pdf

usage.[23] As Hillsboro develops initiatives and programs to continue to lead and meet these goals, city officials recognize the growing concerns of grid outages due to earthquakes and other threats.[24]

Hillsboro identified eight community sites that provide critical services and/or have the potential to be used as gathering places in the event of a natural disaster that leads to a widespread grid outage. Driven by their own unique set of energy and environmental goals, Hillsboro was most interested in understanding how CHP, solar PV, and storage technologies could be used to power critical loads at these facilities at different times of the year. Because Hillsboro's interests included CHP, DOE worked with LBNL to use DER-CAM to assess the size and performance of systems that could provide critical power services at each Hillsboro site. For each facility, DER-CAM simulated a year in which a 24-hour grid outage occurred in each season (four total outages each year). Results below show the system needs for serving 25% of normal electricity usage to maintain critical operations during each outage. Based on natural gas usage and heating demand, Hillsboro Facilities 1 and 2 were found to be good options for CHP, while Hillsboro Facilities 3 through 8 had lower overall energy demand and were better fits with solar PV and storage.

Table 4: DERs for Resilience Analysis for Eight Hillsboro Facilities Using DER-CAM

Modeled Results for Meeting 25% of Building Load During Four, Seasonal (24-hour) Grid Outages with Battery Storage and Solar PV					
Hillsboro, Oregon Facilities	CHP Capacity (kW)	Battery Storage Size (kWh)	Solar PV System Capacity (kW)	Solar PV Production As % of Electricity Consumption	Net Increase in Total Energy Costs Over 20 years 25
Hillsboro Facility #1	75	--	349	99.8%	0.6%
Hillsboro Facility #2	75	--	378	99.8%	-30%
Hillsboro Facility #3	--	512	269	>100%	105%
Hillsboro Facility #4	--	179	101	>100%	71%
Hillsboro Facility #5	--	935	119	>100%	62%
Hillsboro Facility #6	--	299	157	>100%	85%
Hillsboro Facility #7	--	1835	965	>100%	91%
Hillsboro Facility #8	--	619	325	>100%	90%

[23] Based on EPA's Green Power Community Rankings. For more information, see https://www.epa.gov/greenpower/green-power-communities and https://www.hillsboro-oregon.gov/Home/Components/News/News/7932/44
[24] https://www.hillsboro-oregon.gov/city-services-overview/emergency-management/prepare-now-/hazard-specific-information
[25] This calculation combines the reduction in utility costs for the site with the cost of installing and maintaining the microgrid system. This includes cost reductions from net metering compensation available to each site. However, it does not include the federal investment tax credit (ITC) and other value streams that may be available to make the project economics more favorable. A description of potential revenue sources for microgrids is available at: https://www.sciencedirect.com/science/article/pii/S1040619019301265?via%3Dihub

For the sites where solar PV plus storage was selected (Hillsboro Facilities #3-8), the analysis resulted in solar PV array sizes that were simulated to generate more electricity than each site could use during normal annual operations, making each site a potential net-exporter. A key driver of these results is the simulation of an outage during the winter months, when each KW of solar PV capacity will produce less per day than during the rest of the year. This requirement increases the relative size of the onsite capacity needed to produce the same amount of power during an outage. This information empowers Hillsboro to consider a range of next steps. First, these results underscore the high value of improving the efficiency of equipment that will be needed during winter outages, such as heating and lighting. Reducing critical energy needs during winter outages will have a direct impact on how much solar PV capacity is projected to continue operations. There may also be other opportunities to improve the cost-effectiveness of these resilience investments through providing grid services during normal operations. As with the other cases presented in this document, the analysis did not include the potential for additional local incentives or compensation from battery storage or other grid services provided from the microgrid that may be available to the city, which could improve the estimated cost impacts. With these results as a starting point, Hillsboro plans to work with their utility and other stakeholders to consider these results and additional options to determine what will be most feasible to meet their energy goals at these sites.

Alachua County Public Schools, Florida

Alachua County Public Schools (ACPS) in Florida is a top-rated school system[26] that educates more than 27,000 students and employs more than 4,000 people across a combined floor space of more than 4 million square feet. In addition to being selected as a 2013 Top Performer District by the Environmental Protection Agency, ACPS also earned the 2015 Florida Green School District Award, Gold Level and received the 2016 U.S. Department of Education's Green Ribbon Schools District Sustainability Award.[27] As a partner in the Better Buildings Challenge, ACPS has achieved a 9% reduction in the energy intensity of its buildings and is committed to a 20% reduction by 2023.[28]

For many of its facilities, ACPS must address another energy goal: ensuring a continued power supply in the wake of natural disasters, when many of the district's schools serve as community emergency shelters. While diesel generators have historically supplied backup power, the district is interested in using onsite solar PV and storage to meet resilience objectives. Based on the extensive use of local schools as shelters during recent hurricane seasons, ACPS wanted to explore onsite generation systems that could maintain critical operations for up to five days.

Both DER-CAM and REopt Lite were used to help ACPS consider its options at 11 of its schools, all of which serve as emergency shelters. First, to understand options for an integrated systems with solar PV, battery storage and thermal (ice) storage, DER-CAM was used to assess an effective combination of all three to meet critical load – modeled as 30% of normal load – for five consecutive days in August. The results and respective sizes of these systems are shown in the table below.

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[26] ACPS received an "A" grade from the Florida Department of Education in 2019. For more information, see http://www.fldoe.org/accountability/accountability-reporting/school-grades/

[27] https://betterbuildingsinitiative.energy.gov/partners/alachua-county-public-schools

[28] https://betterbuildingsinitiative.energy.gov/energy-data/Alachua%20County%20Public%20Schools

Table 5.1: DERs for Resilience Analysis for Eleven ACPS Facilities Using DER-CAM

Modeled Results for Meeting 30% of Building Load During a 5-day Grid Outage			
Alachua County Public School (ACPS) Facility	Solar PV (kW)	Battery Storage (kWh)	Thermal Storage (kWh equivalent)
ACPS Facility #1	138	69	164
ACPS Facility #2	270	142	2,964
ACPS Facility #3	165	87	1,806
ACPS Facility #4	321	169	3,651
ACPS Facility #5	277	98	3,632
ACPS Facility #6	354	125	560
ACPS Facility #7	177	89	1,923
ACPS Facility #8	132	67	1,373
ACPS Facility #9	114	60	1,259
ACPS Facility #10	226	80	2,964
ACPS Facility #11	117	59	1,519

ACPS also wanted to consider a staged approach to these resilience investments, by first installing the required solar PV systems identified by DER-CAM, then later making investments in the storage technologies needed for surviving an outage. To provide more streamlined information about potential investments in solar PV only, REopt Lite was used to assess the financial impacts of installing solar PV at a size that could allow for a more resilient system with future storage investments. For all but one site (ACPS Facility #10, which had a negative net present value until between 20 and 21 years of operation), the projected utility cost savings for solar PV indicated that investing in “storage ready” solar first could pay for itself within the ACPS goal payback period of 20 years and allow each school to generate a significant share of its electricity needs, even before installing storage technologies.

Table 5.2: Financial Payback Analysis of Solar PV System for 11 ACPS Facilities Using REopt Lite

Impacts of a Solar-Only System Sized to Meet Building Load During 5-day Grid Outage (when combined with future storage investments)				
Alachua County Public School (ACPS) Facility	Solar PV (kW)	20-Year Savings (Net Present Value)	Payback Period (Years)	Solar PV Production as % of Electricity Consumption
ACPS Facility #1	138	$8,753	**18.9**	**25%**
ACPS Facility #2	270	$88,812	**14.9**	**24%**
ACPS Facility #3	165	$39,797	**16.0**	**25%**
ACPS Facility #4	321	$77,784	**16.0**	**25%**
ACPS Facility #5	277	$57,834	**16.5**	**26%**
ACPS Facility #6	354	$13,607	**19.4**	**27%**
ACPS Facility #7	177	$26,456	**17.3**	**23%**
ACPS Facility #8	132	$23,067	**16.9**	**24%**
ACPS Facility #9	114	$19,701	**16.9**	**23%**
ACPS Facility #10	226	-$5,955	**20.5**	**27%**
ACPS Facility #11	117	$705	**19.9**	**25%**

For some school districts, investing in multiple DERs all at once may not be possible. For ACPS, which has already achieved significant cost savings through energy efficiency, this analysis indicates that installing solar PV under current conditions can reduce energy costs, while also enabling future investment in storage technologies to improve resilience for their communities.

Conclusion

The case studies presented in this guide demonstrate how a state, local government, and other public organizations can use DER technologies to meet a range of energy goals. Investing in DERs at critical facilities can strengthen resilience, lower annual energy costs, and help achieve targets for energy efficiency and renewable energy generation. Energy efficiency has the potential to drive down investment costs in other DERs to meet a resilience goal. At one site, an energy-efficient scenario lowered the required investment cost of solar PV and storage for resilience by nearly $470,000.

Two free tools, REopt Lite and DER-CAM, can help stakeholders around the country explore how energy efficiency scenarios combined with other DERs can meet resilience needs at their critical facilities. The appendices to this guide provide details on how REopt Lite and DER-CAM can be used to assess options for critical infrastructure in communities across the United States.

Additional Resources

In addition to REopt Lite and DER-CAM, other resources are available for states, local governments, and other public organizations on various aspects of resilience and the energy technologies that can help make a community more resilient. For a broader range of information, consider the resources below:

Better Buildings Distributed Generation for Resilience Planning Guide: This guide provides information and resources on how distributed generation, with a focus on CHP, can help communities meet resilience goals and ensure critical infrastructure remains operational regardless of external events. If used in combination with a surveying of critical infrastructure at a regional level, this guide also provides tools and analysis capabilities to help decision makers, policy makers, utilities, and organizations determine if DG is a good fit to support resilience goals for critical infrastructure in their specific jurisdiction, territory, or organization.

Interruption Cost Estimate (ICE) Calculator: This tool is designed for electric reliability planners at utilities, government organizations, or other entities that are interested in estimating interruption costs and/or the benefits associated with reliability improvements.

NREL Resilience Roadmap: This resource offers comprehensive guidance for federal, state, and local entities to effectively convene at the regional level to create a resilience plan. Steps in the Roadmap include “Intergovernmental Preparation and Coordination,” “Planning and Strategy Development,” and “Plan Adoption, Implementation and Evaluation.”

Resilient Power Project Toolkit: This toolkit includes information and resources designed to provide the tools and background information to gain a better understanding of resilient power systems and how to approach the planning and development of a resilient power installation. Resources include descriptions and links to key reports, guides, and webinars.

SolarResilient Tool: This tool estimates the required rating and physical size of grid-connected photovoltaic (PV) and battery energy storage to provide power for extended periods during a large scale grid power outage.

Assessing Your Buildings: Introduction and Step-by-Step Guide to Resilience Tools

This section provides a high-level overview for state and local governments and K-12 school districts interested in conducting similar analyses on their own public facilities using two publicly available analysis tools: REopt Lite and DER-CAM. Each tool can be used for assessing the potential for DERs at public facilities, either to meet resilience goals or for other priorities such as cost reduction or deployment of energy efficiency or renewable energy. REopt Lite analysis focuses on a targeted set of DER technologies and can be completed over a web interface quickly with fewer inputs. DER-CAM considers a range of different technologies in a downloadable software that can take additional time to learn. For more detailed information on these tools, refer to the collection of resources found in the Tutorial Movies and Manual for the Full DER-CAM Web Service and the REopt Lite Web Tool User Manual.

Both tools assume a base level of understanding of different DERs. For information on different distributed generation technologies and how to assess which may be best for your energy and resilience needs, it may be useful to review the Better Buildings Distributed Generation for Resilience Guide.

Appendix A: Renewable Energy Integration and Optimization Lite (REopt Lite) Tool

Before you start…

Gather Information

- For each building or campus your organization would like to analyze, the following information is needed:
- Building address
- Building utility tariff (can be found on the site's utility bill)
- Annual energy consumption or interval data (electric and natural gas, if applicable)
- One or more specific goals for your site. It is also important to know your specific goal:
- Are you trying to minimize energy bills with the most cost-effective technology?
- Are you trying to meet a certain amount of your energy demand with clean energy?
- Are you trying to prepare to withstand a grid outage of a certain length?

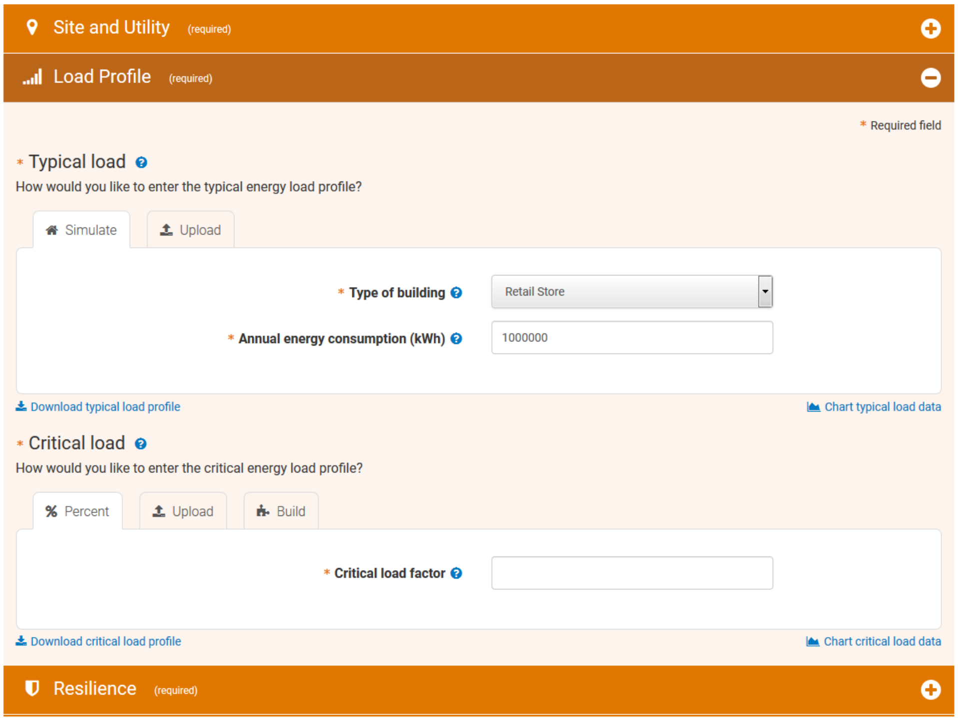
Step One: Specify your goal

First, specify whether your primary goal is "Financial", or maximizing the financial benefits of grid-connected PV, wind, and battery storage at a site; or if your primary goal is "Resilience", or identifying system sizes and battery dispatch strategies to meet a specific, simulated grid outage at the lowest possible cost. Note that if you choose "Resilience," the model will still work to meet critical loads during an outage at the lowest cost and will report out the financial impacts of the recommended investment. Conversely, if "financial" is selected, the results reported will still include information on the resilience benefits that could be provided by the optimized system.

Step Two: Enter your building site and utility data

Enter the basic information about your site, including address, electricity rate, available land acres, load profile, building type, and net metering information if applicable. Under the "Site and Utility" section, you are able to choose an electricity rate from your location after entering an address, or choose to input your own electricity rate by checking the "Custom Electricity Rate" box. This information will help tailor the results to your specific facility.

While the utility tariff for a site will not affect the onsite system's performance during an outage, it can have a significant impact on how storage and onsite generation can be used to reduce the site's electricity bills during normal grid operations. An onsite system can shift when power is drawn from the grid to avoid buying electricity from the grid at times when the price is highest, in addition to offsetting grid purchases or using net-metering to reduce the site's monthly bill. These savings can significantly reduce the cost of a resilience investment, and as shown in the case studies, even result in cost savings for public facilities.



Under the "Load Profile" Section, two options are available. If you have detailed data about your electricity usage – one year of hourly, 30-minute, or 15-minute interval usage values – entering it under the "upload" tab will give you the most accurate assessment. If you do not have data at this level of detail, you can instead use the "simulate" tab using your annual energy consumption in kilowatt hours as well as a representative building type. If you are uncertain about which building type will best match the pattern of your own site's usage, you can click on the blue question mark for more detail on how to choose the correct building type. Users can click the blue question mark for additional details and a sample custom load profile example, as well as the "chart typical load data" to review what each of the profiles look like. If your goal is resiliency, then you will need to enter the critical energy load profile you want for the outage you are planning to withstand. You can include a percentage, upload your own critical load profile, or even build your own.[29]

Next, under "Financial", you can include a host discount rate percentage, electricity cost escalation rate,

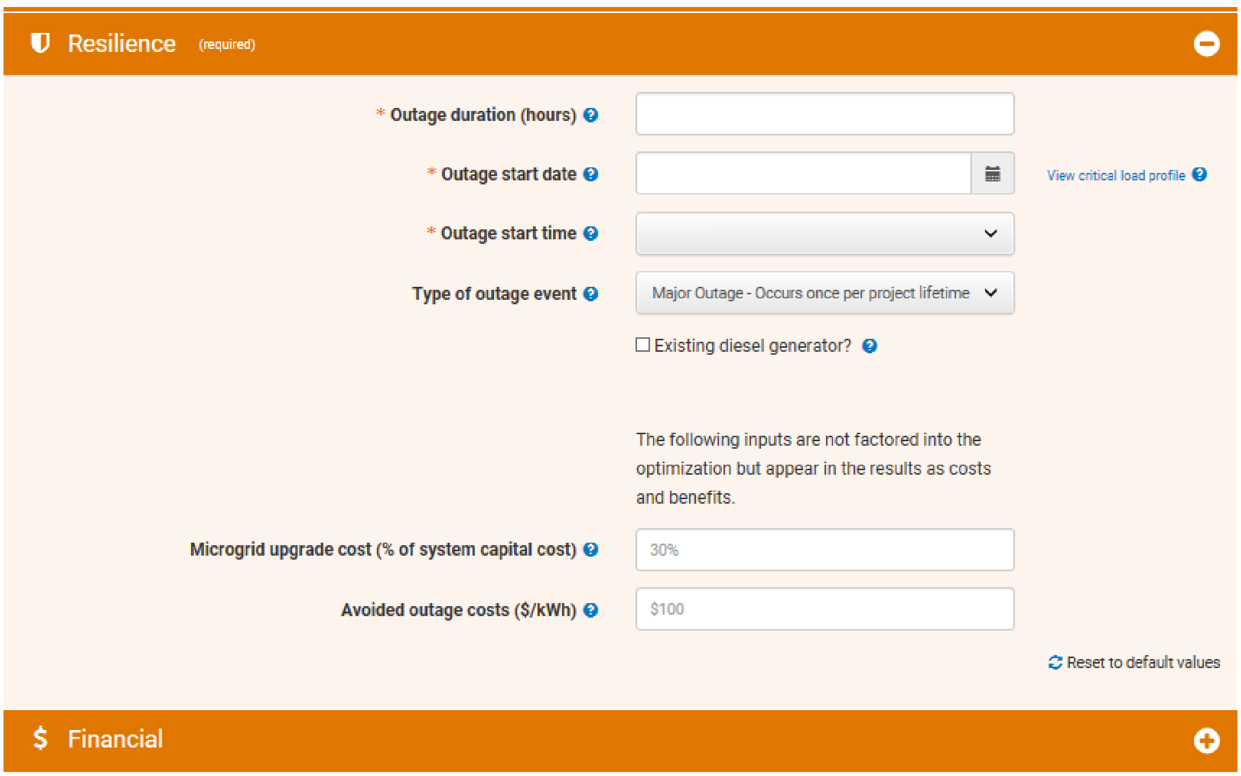
[29] The Critical Load Builder allows the user to create a daily emergency load profile by building a list of equipment critical to the function of the site, specifying the equipment's wattage, quantity, daily operation hours, and annual operation months. This feature is only accessible when users are logged into a registered account and is based on SolarResilient, a tool developed by Arup, under contract to the Department of the City and County of San Francisco, with funding from the U.S. Department of Energy. More information is available at: https://reopt.nrel.gov/tool/REopt%20Lite%20Web%20Tool%20User%20Manual.pdf

analysis period, and additional cost and tax rates if applicable. REopt Lite features automatic defaults in most sections so if you are unable to determine the specific numbers for your state, city, or K-12 school, you can use the greyed out defaults.

Step Three: Specify an outage to withstand

(Note: If your goals do not include resiliency and outage survivability, skip this step.)

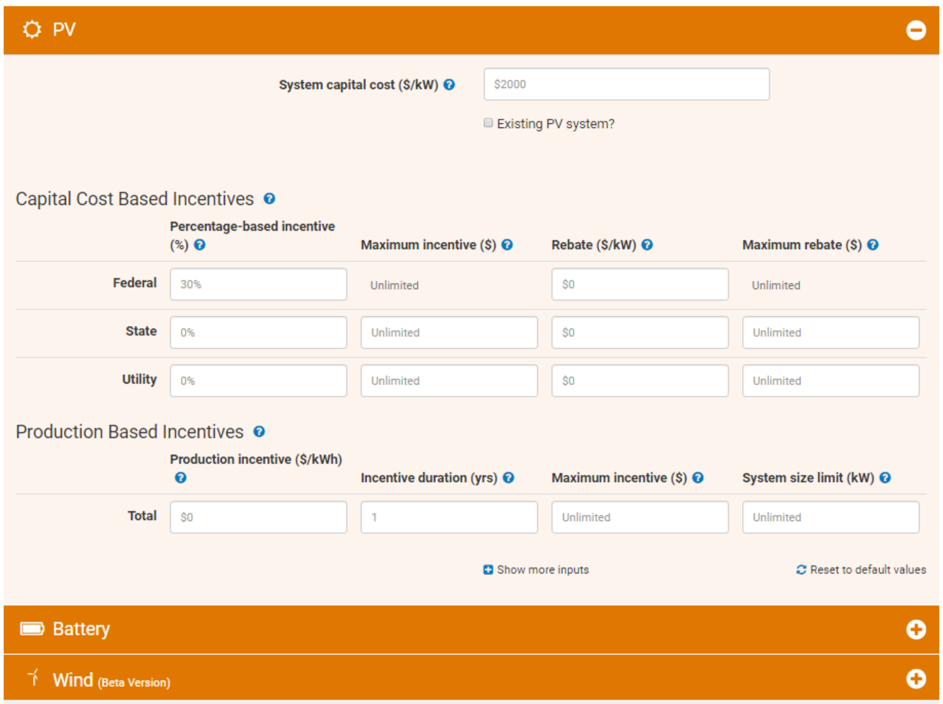
If you are planning for resilience and have grid outage requirements your buildings need to withstand, this sections allows you to plan for a specific time, date, and type of event. If you have existing diesel generator information for your site, check the “Existing Diesel Generator?” box and include any details regarding the generator. This section also allows you to include a microgrid upgrade cost (which includes additional costs associated with making a system ready to operate separately from the grid during an outage), and avoided outage costs, which will not be factored into the optimization, but appear in the results as costs and benefits.



While the resilience goals will be the main objective that the tool will satisfy, it will do so at the lowest lifecycle cost of electricity, which is why financial factors are included.

Step Four: Select technologies for analysis

REopt Lite is capable of modeling systems with any combination of solar photovoltaic (PV), wind, and battery storage technologies. (The ability to assess Combined Heat and Power Systems is in the process of being added as an option.) Existing onsite generation can also be considered as an input to the model. To withstand an outage of any length, battery storage or an existing generator will be required, and REopt Lite will choose the size of each enabled technology to meet the specified goal at the lowest lifecycle cost. To properly assess the costs, users can also specify the level of different financial incentives that are available for each technology type. Each of these three technologies may be eligible for federal, state, or utility incentives that can reduce the cost of the initial investment, or save money on future energy bills. More information about incentives for which a project might be eligible are available at the [Database for State Incentives for Renewable Energy].



Step Five: Review results

REopt Lite provides a range of economic and energy performance results that are compared side-by-side between the simulated "business as usual" case, with no new DER investment, and the "optimized" case, which has the highest possible net present value given the inputs you have provided. An example of this information is provided in the results snapshot below:

Results Comparison

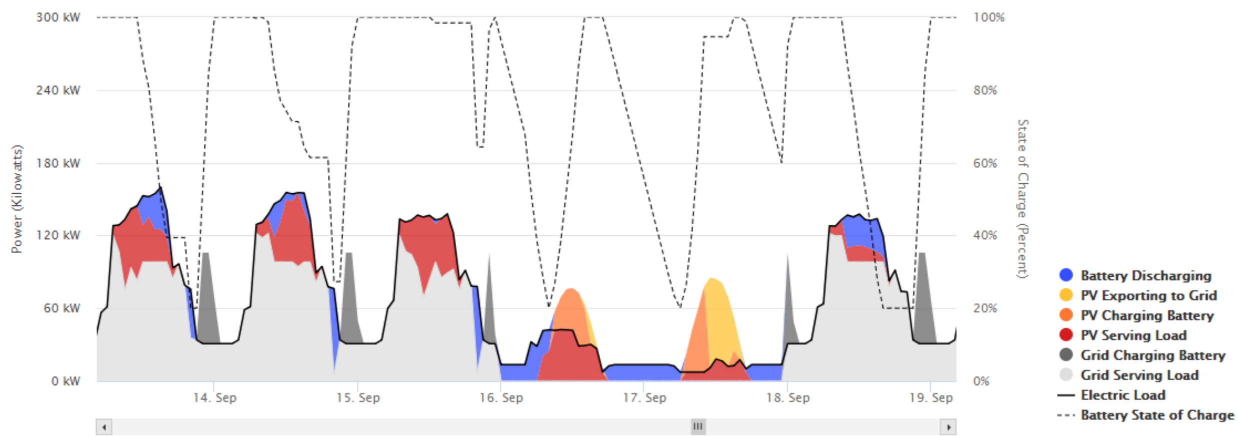
These results show how doing business as usual compares to the optimal case.

	Business As Usual	Optimal Case	Difference
System Size, Energy Production, and System Cost			
PV Size	0 kW	277 kW	277 kW
Annualized PV Energy Production	0 kWh	348,176 kWh	348,176 kWh
Net CAPEX + Replacement + O&M	$0	$342,171	$342,171
Energy Supplied From Grid in Year 1	1,356,401 kWh	1,048,425 kWh	307,976 kWh
Year 1 Utility Cost — Before Tax			
Utility Energy Cost	$91,964	$71,083	$20,881
Utility Demand Cost	$52,456	$45,189	$7,267
Utility Fixed Cost	$0	$0	$0
Utility Minimum Cost Adder	$0	$0	$0
Life Cycle Utility Cost — After Tax			
Utility Energy Cost	$1,306,909	$1,010,170	$296,738
Utility Demand Cost	$745,454	$642,187	$103,268
Utility Fixed Cost	$0	$0	$0
Utility Minimum Cost Adder	$0	$0	$0
Total System and Life Cycle Utility Cost — After Tax			
Total Life Cycle Costs	$2,052,363	$1,994,529	$57,834
Net Present Value	$0	$57,834	$57,834

More detailed results are also available – for each scenario entered into the tool, REopt Lite generates a “pro forma” spreadsheet that provides annual solar PV production, cost savings, and cash flows.[30]

If a resilience goal was specified in the first step above, REopt Lite results will also include information about the performance of the DER system during an outage. The graph below is an example output from REopt Lite that shows the optimized dispatch strategy for a solar PV and storage microgrid.

[30] https://www.nrel.gov/docs/fy18osti/70885.pdf

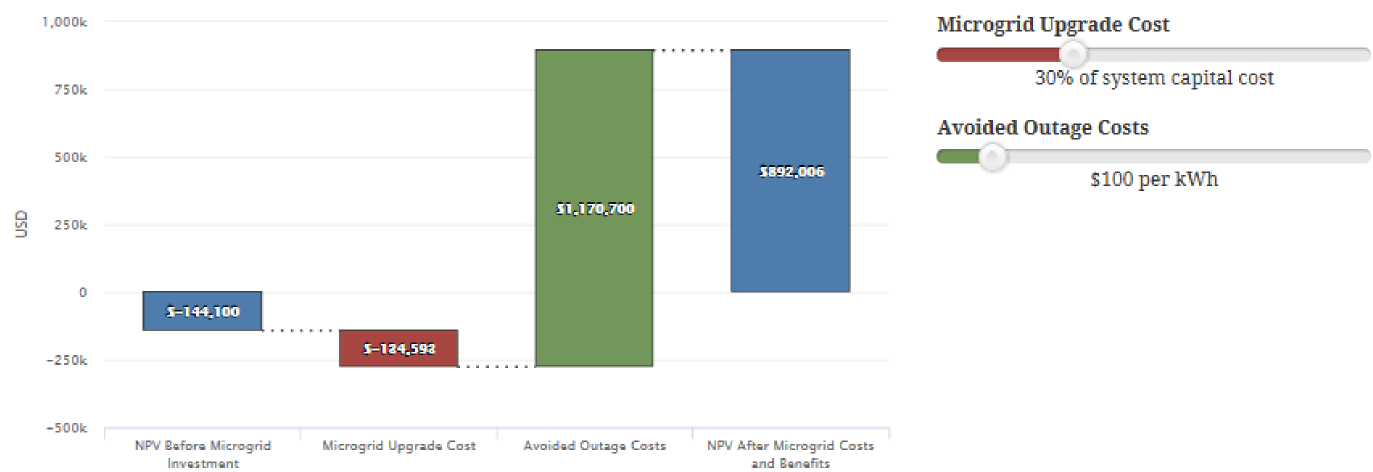


In the illustrative results above, a grid outage begins just after midnight on September 16th. For the next 48 hours, critical loads at the modeled facility are met by a combination of solar PV generation and battery storage discharging, until the grid connection is restored on September 18th.

REopt Lite also allows users to explore how the cost-effectiveness of a resilience investment can change when a value of continuing operations is considered. The graphic below shows how estimating an avoided outage cost, sometimes referred to as a value of lost load, can change the assessment of a resilience investment from being a net cost to a net benefit for the facility. In this image, the avoided outage cost is listed at the default value of $100/kwh for a total of about $1.2 million (in green), providing resilience benefits that result in a net present value of almost $900,000.

Effect of Resilience Costs and Benefits

This chart shows the cumulative effect of resilience costs and benefits on the project's net present value (NPV). The microgrid upgrade cost and avoided outage costs are not factored into the optimization results



Further details on REopt lite features and instructions are available in the full User Manual: https://reopt.nrel.gov/tool/REopt%20Lite%20Web%20Tool%20User%20Manual.pdf

Once REopt Lite has been used to provide the estimated results above, the site also includes suggestions for next steps for considering the development of a project:

Next Steps

This model provides an estimate of the techno-economic feasibility of solar, wind, and battery, but investment decisions should not be made based on these results alone. Before moving ahead with project development, verify:

- The utility rate tariff is correct. Note that a site may have the option or may be required to switch to a different utility rate tariff when installing a PV, wind, or battery system. Contact your utility for more information.
- Actual load data is used rather than a simulated load profile.
- PV, wind, and battery costs and incentives are accurate for your location. There may be additional value streams not included in this analysis such as ancillary services or capacity payments.
- Financial inputs are accurate, especially discount rate and utility escalation rate.
- Other factors that can inform decision-making, but are not captured in this model, are considered. These may include roof integrity, shading considerations, obstacles to wind flow, ease of permitting, utility interconnection rules, and availability of funding.

Contact NREL at reopt@nrel.gov for more detailed modeling and project development assistance.

REopt Lite can be a helpful tool to understand the simulated impacts of investments in distributed energy resources for cost savings and/or resilience at facilities across the U.S. Using the tool to assess a portfolio of buildings can help identify which are the most promising for new distributed energy investments. Alternatively, considering a set of scenarios for one building or facility in the tool could help determine the preferred balance of cost, onsite energy generation, and resilience capabilities.

Appendix B: Distributed Energy Resource Customer Adoption Model (DER-CAM)

Before you start…

Gather Information

- For each building or campus to be assessed, the following information is needed:
- Address
- Utility tariff
- Annual, monthly, or hourly energy consumption (electric and natural gas, if applicable)
- Building construction date (before or after 1980, or new construction)
- Further information can help make your analysis more accurate, or provide additional detail:
- Estimated space available (in square feet) for new onsite generation and/or storage
- Existing onsite backup power (e.g., diesel generator or existing onsite solar PV)

Know Your Goal

Are you trying to minimize energy bills with the lowest cost set of DER technologies?

Are you trying to meet a certain amount of your energy demand with onsite generation?

Are you trying to prepare to withstand a grid outage of a certain length, at a certain time of the year? Or do you have an internal value of maintaining power during a grid outage, and want to assess if some suite of distributed energy resources can successfully maintain power in a cost-effective way?

Once you have the necessary information about your facilities, download and get familiar with the model. DER-CAM requires more inputs and includes the ability to assess a wider range of technologies than REopt Lite, and this also means that performing analysis will likely take more time in this model. The DER-CAM website includes introductory information about the model and its capabilities, as well as instructions for downloading the software onto your computer. As you analyze options for your facilities, the user's manual and related materials on this site can help you with step-by-step instructions for inputting information and reviewing results.

Step One: Set up a new project

Start by entering the basic information about your site, including building type (e.g., office, school building, hospital) and age, annual energy consumption, and location information. This basic information will help tailor the results to your specific facility based on energy use patterns and solar resource availability.

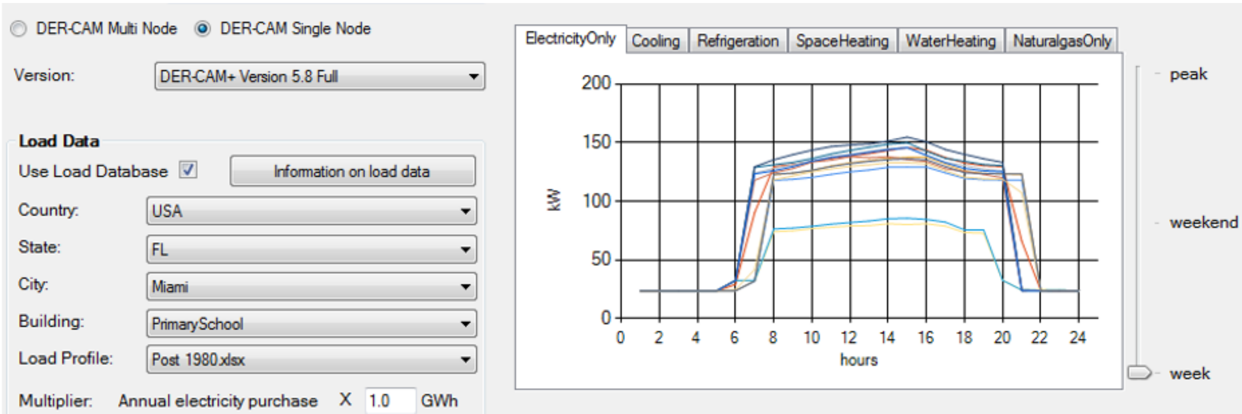


Figure 1 DER-CAM (In Single Node mode, for a single building) allows users to select default load shape data, based on location and annual electricity consumption.

Step Two: Create a "base case"

Once the basic facility information is entered, the model creates a "base case" scenario, where no new technologies are installed on the site. When creating this scenario, it is important to replace the default utility bill information with the information specific to the utility serving the area under "electricity rates." The information about your utility rate will enable the model to strategically use any energy storage technology to shift load, reducing projected energy costs.

You can also indicate a preferred discount rate for valuing costs and benefits in the present versus future years, as well as indicate the time period you'd like the analysis to cover. Some jurisdictions may have maximum payback periods for any new investment in a public building, which can be set as a requirement here. Once the required fields are completed, click "run" at the top of the screen to create a base case without any new technologies. This case will include a modeled energy cost for the facility, which will be used in the next steps.

Step Three (Optional): Simulate grid outage under current conditions

After entering the "BaseCaseCost" from the previous run into the "Financial Settings", "Resiliency and Reliability" parameters can be entered to specify the length and details of the outage that you would like to be prepared for. This data will determine the necessity of load-curtailing DER. In the 'Outage Definition' subsection, you can specify when an outage will occur and the hourly availability of the utility grid on the day of an outage. Under "Number of Days", you can add scheduled outages by changing the value of emergency days in a given month, as long as the total number of days in that month remains the same. For example, if you want to simulate a scheduled two-day outage in October on a Monday and Tuesday, change the number of emergency-week days in October to 2 and decrease the total number of modeled week days in October by 2.

In the "Load Curtailment Parameters" subsection of the model, you can assign a value of lost load, which the model treats as the cost of curtailing energy use due to an outage, and will seek to balance this cost against the cost of installing a larger onsite system. You can set the cost of curtailing a kilowatt hour of energy demand for different priority levels of an electricity or heating outage, allowing the model to reduce some energy use during an outage, but place a higher value on continuing to serve critical equipment. If you want to ensure that the full outage will be survived in the simulation, you can set the cost of curtailment to a high amount (for example, $700/kwh, as shown below). The "MaxHours" parameter can be used to specify that an outage will take place over multiple consecutive days. More description is available on the input screen.

	F1	F2	F3	VariableCost	MaxCurtailment	MaxHours
1	node1	LowCR	electricity	0.00	0.00	0.00
2	node1	MidCR	electricity	0.00	0.00	0.00
3	node1	HighCR	electricity	700.00	1.00	120.00
4	node1	LowCR	heating	0.00	0.00	0.00
5	node1	MidCR	heating	0.00	0.00	0.00
6	node1	HighCR	heating	0.00	0.00	0.00

Figure 2 DER-CAM "Load Curtailment Paramaters" screen, which allow you to tell the model how much you may be willing to spend to serve your energy needs during an outage (in $/kwh).

This step will produce a modified "base case," where the model sees an updated annual energy cost, which includes the cost of having no way to maintain operations during a grid outage. Both regular operating costs, as well as the costs of losing operations during an outage, will be costs that the model tries to minimize in the next step.

Step Four: Create a DER investment scenario

This is where the model uses the options you specify to find the lowest-cost way to meet your goals with DER technologies installed at the facility. In this step, you will indicate which of the available technologies you'd like the model to consider, and which resilience, financial, or other characteristics are most important to you. By integrating its assessment, the model will consider the ability of any new system to lower energy bills and meet resilience goals based on your goals.

Storage Units

	F1	F2	FixedInvest	ForcedInvestCapacity	ExistingYN	Age
1	node1	ElectricStorage	0	0	0	0
2	node1	H2Storage	1	0	0	0
3	node1	Electrolyzer	1	0	0	0
4	node1	HeatStorage	0	0	0	0
5	node1	ColdStorage	0	0	0	0
6	node1	FlowBatteryEnergy	0	0	0	0
7	node1	FlowBatteryPower	0	0	0	0
8	node1	EVs1	1	0	0	0

Figure 3 On this screen, DER-CAM allows the user to specify what types of storage should be considered in the optimized scenario, as well as if existing storage capacity already exists at the site.

Step Five: Review results

The results will display recommended investments into new technologies, along with costs and savings from utilizing the technologies chosen. It will also display how much of the site's energy consumption will come from the onsite generation versus what is purchased from the grid. The "results" page has a range of information on energy generation, storage, and savings, as well as financial information.

Figure 4 DER-CAM's results page shows the change in costs, share of electricity needs met by on-site generation, and emissions impacts of a solar PV investment.

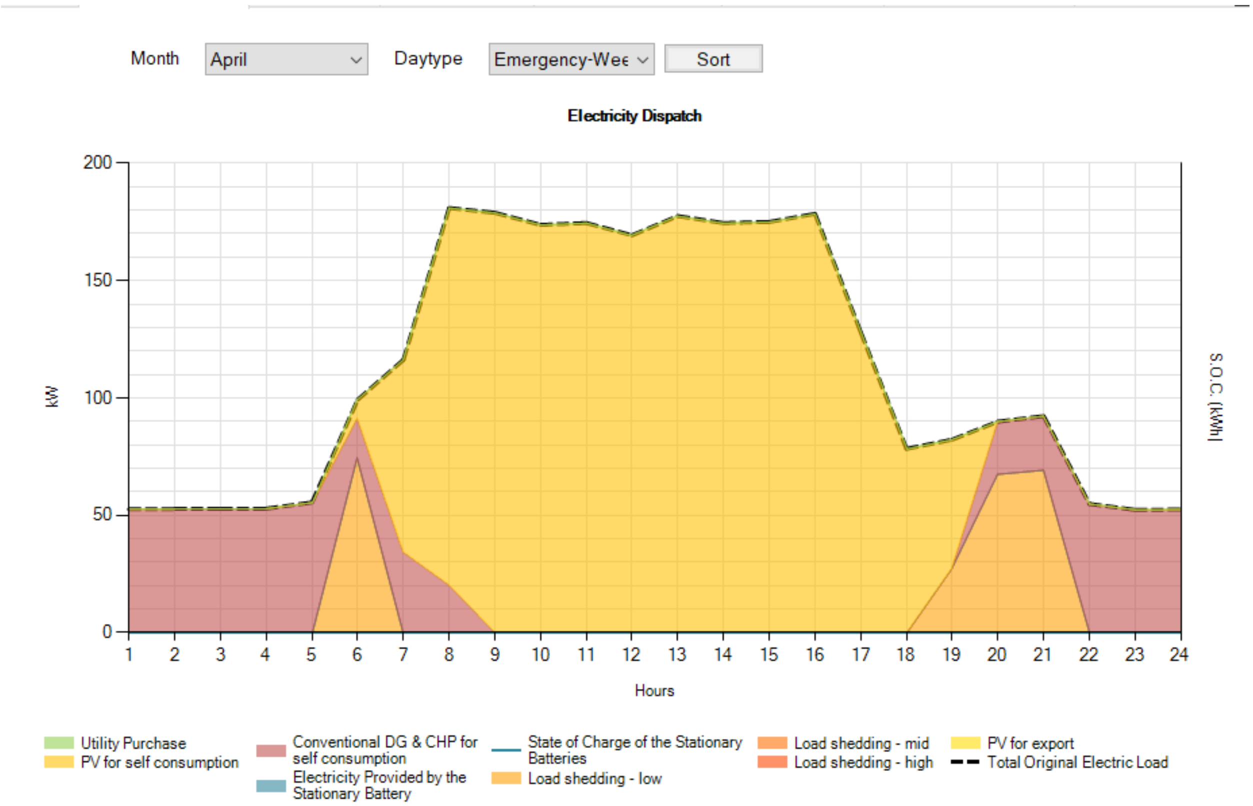


Figure 5 DER-CAM's "Electricity Dispatch" results, with "emergency" day type selected, demonstrate how during a grid outage, an onsite CHP system, Solar PV, and demand response ("load shedding") meet the electricity needs at the modeled site.

As with REopt Lite, DER-CAM can be a helpful tool to understand the simulated impacts of investments in distributed energy resources for cost savings and/or resilience at facilities across the U.S. Using the tool to assess a portfolio of buildings can help identify which are the most promising for new distributed energy investments. Alternatively, considering a set of scenarios for one building or facility in the tool could help determine the preferred balance of cost, onsite energy generation, and resilience capabilities.

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For more information, visit:

energy.gov/eere/slsc

Or email:

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