Comparison of the Economic and Operational Characteristics of Building Level versus Community Scale Resiliency Strategies

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ABSTRACT

This paper by AESC will at first broadly address considerations for the design of community scale sustainability and resilience strategies including which sustainable and resilient features are best managed at the individual building level versus at a larger community scale, which building technologies and operations methods can contribute to both efficient and resilient performance, and how high-performance building features can be leveraged to also delver resilience benefits. The information provided will be based on the author's experience working in the Self Generation Incentive Program.

Secondly, it will focus on two case studies providing resiliency solutions for an office building and a college campus in Northern California. It will compare the energy efficiency and distributed generation measures recommended for the office building versus college campus and reflecting on the benefits and drawbacks of economies of scale when it comes to control for resiliency versus normal operation. It will also focus on the considerations made in the college campus case study and the tradeoffs that were made in the design of that system. The results of the studies will provide a valuation of resilience benefits from distributed energy resources at individual-building and community scales and a determination of which building technologies and operations methods can contribute to both efficient operation and resilient performance.

Introduction

This paper will attempt to broadly address the following questions based on the experience of the author working as a technical reviewer and then Program Manager in the Self Generation Incentive Program:

- What considerations need to be made when designing community-scale sustainability and resilience strategies, including in both new and existing communities?
    - The definition of resilience in this context is the ability of a power system and it's components to withstand and adapt to disruptions and rapidly recover from them allowing for continuity of power within a building or a community.
- Which sustainable and resilient features are best managed at an individual-building level versus at a larger community scale?
- Which building technologies and operations methods can contribute to both efficient and resilient performance?
- How can high-performance building features be leveraged, changed, or optimized to also deliver resilience benefits? We will present outcomes that could include the following:
    - Identification of best-value efficient and resilient technology at individual-building and community scales
    - Identification of efficient and resilient strategy integration in disaster planning and disaster recovery efforts

Specifically, it will focus on two case studies based on resiliency audits conducted by the author for two facilities, an office building and a college campus. In comparing and contrasting the two it will provide a valuation of the financial benefits and describe the operational characteristics of the two during both a grid outage and when operating in parallel with the grid. This will highlight which building technologies and operational methods can contribute to both efficient operation and resilient performance.

Community-Scale Sustainability and Resilience Strategies

When designing community-scale sustainability and resilience strategies, including in both new and existing communities, the primary consideration is whether the distributed energy resources (DERs) will be front of the meter or behind the meter. The second consideration is whether the whole community or only some members of the community will be participating in the community microgrid. The third consideration is whether there are loads that are critical to the community such as wastewater treatment or electric vehicle charging that need to be backed up as a priority over other loads. Finally, it is important to ensure that the loads and the generation are balanced within the microgrid and that the microgrid has black start and grid forming capabilities.

With regard to the first consideration if the DERs are located front of the meter a microgrid controller is needed that has an automatic transfer switch that can electrically isolate (or island) the microgrid and allow the front of the meter DERs to provide power to the loads that are behind the meter. If the DERs are behind the meter then a master microgrid controller is needed that again, electrically islands the microgrid, and communicates with the DERs behind each individual meter and commands them to allow power to flow onto the islanded microgrid distribution system.

This brings up an important point with regard to the second consideration. If only some members of the community will be participating in the microgrid, power to non-participating members will need to be turned off during an outage. This is possible by use of the switch that is present in smart meters that enables power to be turned off to the customer remotely by the utility. However, utility enablement of this feature will be needed in the event of an outage.

The third consideration regarding critical loads requires that the microgrid controller be programmed such that it will curtail the non-critical loads before the critical loads in the event of low power conditions.

Finally, in order to ensure balanced loads and generation within the microgrid it is necessary to do power flow modeling of the microgrid over the course of a whole year simulating both outage conditions and also operation in parallel with the grid. In order to have black start capabilities so that the microgrid can initiate operation when there is a sudden loss of grid power it is necessary to have DERs with grid forming capability. This could be provided by generators or energy storage systems enabled with inverters that have grid forming capabilities.

Sustainable and Resilient Features Best Managed at an Individual-Building Level Versus at a Larger Community Scale

Larger loads such as wastewater treatment plants, police stations, hospitals, food banks with refrigerated warehouses, jails and prisons, multifamily residences and fleet charging for municipal vehicles such as garbage collection trucks are best managed at a larger community scale with front of the meter DERs.

Smaller loads such as libraries, fire stations, cooling centers, nursing homes, homeless shelters and single-family residences are best managed at the individual building level with behind the meter DERs. The reason for this is that the smaller loads allow for onsite solar and storage that is capable of meeting the site's needs within the footprint of the parcel the building is located on; with, if needed, some augmentation by a generator.

Larger loads on the other hand require larger solar and storage systems and the building and parcel footprint may not accommodate the solar system size needed. This would result in a larger generator installation that would compromise the sustainability aspects of the project.

Building Technologies and Operations Methods that can Contribute to Both Efficient and Resilient Performance

For single family and multifamily projects solar self-consumption can contribute to efficient and resilient performance. In this scenario excess solar power during the day is stored in the battery and used at night during peak hours to offset usage. This has the benefit of providing bill savings as well as reducing greenhouse gas emissions. From a resiliency perspective if the system is sized correctly, it can allow the system to power critical loads indefinitely during an outage as long as there is adequate solar insolation to recharge the battery.

For fleet charging, having carport solar and energy storage as part of the installation helps to offset demand charges during times of high demand for the charging stations. It also reduces the carbon footprint of the charging stations.

For municipal buildings if there is a thermal load such as space conditioning and water heating it may be beneficial to include a combined heat and power (CHP) system to handle the base electrical load of the building and provide heat that can be used for space heating or cooling (with absorption chillers) and water heating. The CHP system can be augmented by solar and energy storage to cover the load that exceeds the base. Siting may be an issue for CHP systems depending on the technology used. Phosphoric acid and molten carbonate fuel cells generate heat and power and can be sited in most air pollution control districts given their California Air Resources Board (CARB) exemption. From a resiliency perspective gas supply typically continues during an electrical outage. So, the CHP system should continue to operate. From a sustainability perspective even fuel cells have a carbon footprint as they emit CO2. However, the waste heat utilization increases the efficiency of the CHP system upwards of 80%.

Nursing homes and medical facilities can benefit from solar and electrochemical storage. Also, since they operate 24/7 they can benefit from thermal energy storage in the summer months. There is an ice energy storage system that pairs with rooftop air conditioning systems that is available by Thule Energy[1] that could be beneficial to shift summertime cooling loads at these facilities and provide bill savings. These systems will need backup battery storage so that the supply fan and pumps for the refrigerant can work during an electrical outage.

Food banks with refrigerated warehouses can also benefit from thermal energy storage. The latest thermal energy storage used in these facilities is a phase change material that is installed in the warehouse space, and charges from the existing refrigeration system and discharges when the system is turned off. This provides greenhouse gas savings by shifting the load from nighttime peak hours to daytime off peak hours. These systems are manufactured and sold by Viking Cold Systems[2]. They do not need backup battery systems as the phase change material thaws out and

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[1] Thermal Energy Storage Solution | Thule Energy Storage

[2] Home - Viking Cold Solutions™

delivers cooling to the warehouse without the need for electricity during discharge. However, to charge the system, electricity will be needed for the refrigeration system to turn back on.

Wastewater treatment plants (WWTP) can benefit from the biogas generated by their anaerobic digesters. This biogas can be cleaned and stripped of hydrogen sulfides, moisture and siloxanes and used in fuel cells to generate electricity and heat. The heat in turn can be used to heat the digesters to promote bacterial activity needed to generate biogas. In these projects the wastewater treatment plant forms a microgrid and islands during an outage with the biogas generators proving power to the WWTP load.

Leveraging High-Performance Building Features to also Deliver Resilience Benefits

Identification of Best-Value Efficient and Resilient Technology Investments Based on Building Types, Geography, and Potential Building- or Community-Level Threats

Energy efficiency and resiliency go hand in hand. It is imperative to reduce the load of the building as much as possible using energy efficiency measures for all electrical end uses, prior to sizing the DERs used for resiliency. This will reduce the cost of the DERs and improve economics over the project's life.

It is important to note that at the same time as resiliency is becoming a priority so is electrification. Electrification results in an increase in the overall electrical load thereby increasing the size of the DERs needed for resiliency. Hence, it is important to use the most energy efficient end use technologies when considering electrification in order to minimize the size and cost of the resiliency solutions.

Finally, it is important to incorporate enabling technologies that tie the DERs and the end use technologies together. This can be in the form of smart electrical panels that allow metering and control of loads on a circuit-by-circuit basis. Using the scheduling feature of smart panels allows timing the loads to go on and off in a way that reduces the overall load of the building and coincides with the generation of intermittent DERs like solar. There are also other benefits such as easier participation in demand response programs.

Valuation of Resilience Benefits from Distributed Energy Resources at Individual-Building and Community Scales

Valuation of resilience benefits can be evaluated from the perspective of avoidance of lost revenue during an outage for example the college case study presented here shows that the college lost 9 days of instruction due to Public Service Power Shutoff (PSPS) events which resulted in a loss of millions of dollars in revenue and unreimbursed expenses.

Valuation of benefits can also be evaluated from the perspective of financial benefits associated with operation of the DERs in parallel with the grid. Benefits can stem from energy arbitrage and demand charge management. In the case of front of the meter assets it could also stem from generating revenue by participating in ancillary markets offered by the Independent System Operator, such as frequency regulation, voltage regulation, spinning and non-spinning reserve.

Identification of Efficient and Resilient Strategy Integration in Disaster Planning and Disaster Recovery Efforts

Microgrids can also export power during an outage, if allowed by the utility, as done by the UC San Diego microgrid in 2007, when a series of wildfires in San Diego County caused

SDG&E to ask that UCSD export 10 MW of power[3]. Consequently, microgrids can create resilience for the communities they serve as well as surrounding communities, if called upon.

One of the most obvious strategies during a disaster is to reduce non-critical loads within the microgrid to extend the backup duration of batteries and be able to rely solely on DER generation.

Strategies will vary depending on the type of usage the building gets, and the number of critical loads based on the usage. But the most obvious strategy is prioritizing critical loads such as a data center within an office building, or communications within an emergency operations center, or HVAC within a cooling center or library. This will allow critical operations to continue during the disaster until power is restored.

Resiliency Study of an Office Building

This office building is located in Red Bluff, California and was first occupied in 2016. It is a 62,000 square foot building with two stories that contain offices, IT rooms, meeting rooms, break areas and lobbies. The HVAC system consists of 5 large roof top DX systems and 9 smaller split condensing units. The interior lighting is 80% LED, except in certain areas where the lighting is fluorescent. There are occupancy sensors in all areas and the outdoor lighting is controlled by photocells.

In order to assess resiliency, the likelihood and impact of an extended power outage from extreme weather was determined; an onsite evaluation of existing electrical infrastructure was done; as well as an onsite evaluation of energy efficiency opportunities; and a load assessment was conducted using interval data. As a result, the annual load was adjusted based on implementation of the energy efficiency measures and the solar photovoltaic and the energy storage systems were sized. Subsequently, an electrical single line diagram was developed for the project along with project cashflows based on Power Purchase Agreement (PPA) and direct purchase options.

The annual energy consumption of the building was determined to be 620,000 kWh per year with a peak demand of 257 kW. Utility bills were roughly $149,000 per year[4].

Given the relative newness of the building the energy efficiency measures recommended were few, including replacement of the remaining T8 fluorescent lamps with LED equivalents and verifying that the duct static pressure reset control measure is functioning for air handler #5.

A breakdown of the electrical loads is given in the pie chart below:

Figure 1. Breakdown of the electrical loads in Red Bluff office building

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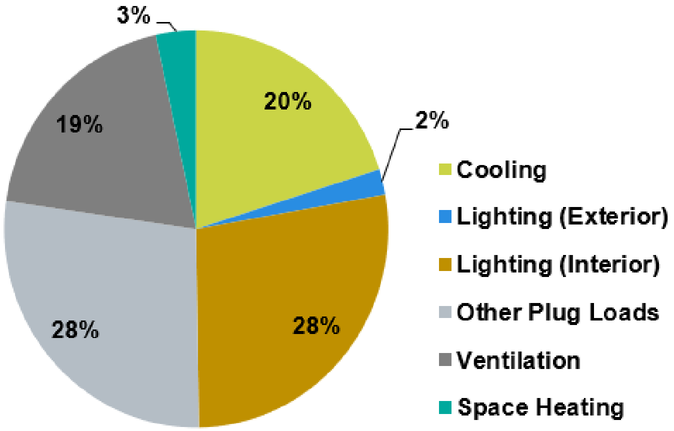
[3] Inside the World's Most Advanced Microgrid: The University of California San Diego | HOMER Microgrid News

[4] Resiliency audit conducted by AESC at an office building in Red Bluff California in 2020.



The proposed resiliency solution was to provide six hours of backup duration between 6 am and 7 pm with a 250 kW/750 kWh lithium ion battery that would be charged by a 360 kW rooftop and carport solar system. The solar system would include eight hundred and ninety-nine (899) 400 Watt solar modules installed on a steel carport structure and on ballasted rooftop racking. Both the solar panels and the energy storage would be served by six (6) 50 kW inverters.

The economic benefits and environmental impacts are shown in table 1 below:

Table 1. Economic benefits and environmental of the resiliency solution developed for the Red Bluff office building

Economics	Solar Net Investment	$735,881
	Battery Net Investment	$563,000
	Total Net Costs	$1,298,881
	IRR	6%
	Break-Even	12.4 years
Environmental Impact	Annual CO2 Emission Reduction	147 tons
	Equivalent Cars Removed from Road	31.7

Resiliency Study of a College Campus

The college campus in this study is located in a tier 2 high fire threat district in northern California and lost 9 instructional days during the 2019 fire season resulting in $3.5 million in lost revenue and unreimbursed expenses. The campus consists of 17 buildings for a combined 469,000 square feet and has an existing solar system but no energy storage. The college serves 9,400 full-time students.

In order to assess resiliency, the likelihood and impact of an extended power outage from extreme weather was determined; an onsite evaluation of existing electrical infrastructure was done to assess the ability to remain safely energized during hazardous conditions such as high winds; as well as an onsite evaluation of energy efficiency opportunities; and a load assessment was conducted using interval data. As a result, the annual load was adjusted based on implementation of the energy efficiency measures and a powerflow analysis was done of the campus distribution system to ensure that generation and loads would be balanced. This was followed by a rate analysis since the existing solar system was implemented under NEM 1.0. A generator and the energy storage systems were sized to provide power to baseloads and load shifting during an outage. Finally, an electrical single line diagram was developed for the project along with project cashflows based on Power Purchase Agreement (PPA) and direct purchase options.

The annual energy consumption of the campus was determined to 6.9 million kWh per year. This was offset by an onsite 4.576 MW solar system that generated 5.5 milllion kWh in 2019; resulting in $290,831 in utility bills per year for electricity[5]. The energy efficiency measures recommended are shown in the table 2 below:

Table 2. The energy efficiency measures recommended for the college campus and estimated savings

EEM #	Measure Description	kWh Saved	Peak kW Reduced	Therms Saved	Annual Cost Savings	Rebate/ Incentive	Project Cost	SPB (yrs)
1	Comprehensive Retrocommissioning	90,600	3	9,900	$28,926	$10,600	$104,500	3.2
2	Interior Lighting LED Upgrade	186,500	24	0	$39,165	$26,000	$717,970	17.7
3	Exterior Lighting LED Upgrade	17,000	0	0	$3,570	$2,000	$27,500	7.1
4	Water Cooled Chiller Upgrade at Allied Health	45,800	1	0	$9,618	$5,700	$267,520	27.2
5	Blower and Controls Upgrade at Sewer Treatment Plant	15,000	1	0	$3,150	$2,000	$78,650	24.3
6	Gym High Bay Lighting LED Upgrade	4,700	1	0	$987	$900	$12,320	11.6

The energy resiliency solution proposed was for an on-campus microgrid. The first step being to implement the energy efficiency measures outlined above in order to reduce load. The second step was to install new solar to offset 95% of the load for one existing building and one planned new construction building. The third step was to partner with a third-party vendor to own and operate a battery energy storage system with a minimum size of 3 MW/5.91 MWh (with a two hour peak discharge duration), a diesel backup generator with a minimum size of 1.75 MW and a microgrid controller. Additional steps were to add controllers to the existing solar systems on campus and connect the existing campus energy management system with the microgrid controller. The details of the solution are provided in table 3 below:

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[5] Resiliency audit conducted by AESC at a Community College in Northern California in 2020.

Table 3. Details of the on-campus microgrid resiliency solution

Existing Solar System	4.58 MW-AC
Battery Energy Storage System	5.90 MWh
Backup Generator System	1.75 MW
Resiliency Services (Year 1, Anticipated to Increase 3% per Year)	$280,000
Fuel Costs per Three Day Outage (per Outage)	$1,437
Scope includes a third party vendor to provide a backup generator and BESS to keep the college online during PSPS related outages	

The assumptions made as part of the powerflow modelling were that the battery energy storage system and the generator were sized to allow resiliency during the highest peak load days with the lowest insolation. The generator fuel costs were calculated using a three-day outage scenario, during high summer usage loads. With the understanding that with refueling the microgrid could be resilient indefinitely. A diesel generator was recommended in order to increase resiliency in the event of a natural gas outage as well as an electricity outage. However, the specifications provided could be used to procure either a natural gas or a diesel generator.

The economics for this solution are provided in table 4 below:

Table 4. Economics of the on-campus microgrid resiliency solution

Cost for Campus	$280,000 per year in the first year with 3% increase per year
Cost for 3rd Party	$7,534,882
	10% IRR based on 20-year cashflow
	Revenue generated by participating in CAISO ancillary services markets and by fees from the college
	Resiliency services provided during the fire season

An on-campus microgrid was not the only solution available to the college. A second solution, offered by the utility, was to place a 115 kV switch on the incoming transmission line to prevent public service power shutoffs at the college during the 2020 fire season. Ultimately, this solution proved to be effective, and the college did not move ahead with installing a microgrid.

Comparison of Building Level versus Campus Resiliency Solutions

The areas of commonality between the two case studies were: 1) energy efficiency was a first step for both projects in order to reduce load prior to the sizing of the DERs, 2) integration of the microgrid control system with the building or campus energy management system makes the load dispatchable and allows for more precise control of the load within the microgrid during an outage. This could be critical in extending the duration of the resiliency required.

Areas of difference between the two case studies was that the college resiliency solution was more of a front of the meter solution provided by a third party where they could potentially generate revenue for themselves during times the grid is up by participating in ancillary services markets. The campus on the other hand paid a fee to the third party for resiliency services during an outage. The resiliency solution for the office building was a behind the meter solution that provided opportunities for energy arbitrage and demand charge management for the building owner when the grid was operational and resiliency when there was an outage. If the system were owned by a third party the building owner would simply pay for the energy used under a power purchase agreement that would provide them with energy at a lower cost than if they were to purchase it from their utility.

Other areas of difference were that the campus was much older than the office building and so there were many more energy efficiency opportunities there. Also, the campus had a very large existing solar system that could be leveraged to provide resiliency, although it needed to be augmented by energy storage and a backup generator to firm up the power available from the intermittent solar production.

Conclusion

Energy efficiency is a key in making resiliency projects cost effective. It is important that DERs used for resiliency be able to provide economic benefit when the grid is operational. Both resiliency solutions and energy efficiency solutions vary based on the end uses in the building or campus, but there is a diverse array of resiliency solutions available for all kinds of end uses ranging from biogas engines for WWTP loads to thermal energy storage for HVAC and refrigeration loads, to electrochemical storage and solar photovoltaics for more common loads resulting from electrification. One important distinction in the management of the DERs and the loads in a microgrid are whether the DERs are located behind the meter or in front of the meter. This is typically determined by the size of the loads and footprint needed for sufficient solar generation to address a significant portion of the load. Large loads may result in front of the meter DERs which are located away from the load or else the siting of generators to augment the limited solar generation. Energy storage is a key when installing solar generation to be able to provide resiliency when the sun is down. The two case studies highlighted some of these facts.

References

Thermal Energy Storage Solution | Thule Energy Storage

Home - Viking Cold Solutions™

Inside the World's Most Advanced Microgrid: The University of California San Diego | HOMER Microgrid News

Resiliency audit conducted by AESC at an office building in Red Bluff California in 2020.

Resiliency audit conducted by AESC at a Community College in Northern California in 2020.