RESILIENCE FOR FREE

How Solar+Storage Could Protect Multifamily Affordable Housing from Power Outages at Little or No Net Cost

Seth Mullendore, Robert G. Sanders, Lewis Milford, with Henry Misas and Adje Mensah

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RESILIENT POWER

A project of Clean Energy Group

ABSTRACT

This report, Resilience for Free, shows that solar+storage systems can reduce costs and increase power resiliency in multifamily affordable housing. The report contains the first public analysis about whether it is economical to install solar+storage in affordable housing—making a strong case for greater public and private support for solar+storage development in affordable housing to serve critical public needs.

This work suggests that battery storage is the emerging third generation of clean energy technologies for affordable housing in the country—following investments made in energy efficiency and renewable energy.

With the right market structures and incentives, solar+storage systems can provide an economic return while making affordable housing energy resilient by powering critical loads like common area lighting, water, and communications—protecting vulnerable residents at little to no net cost: resilience for free.

ACKNOWLEDGEMENTS

This paper is a product of Clean Energy Group and part of a series of reports issued through the Resilient Power Project, a joint project of Clean Energy Group (*www.cleanegroup.org*) and Meridian Institute (*www.merid.org*). This project works to expand the use of clean, distributed generation for critical facilities to avoid power outages; to build more community-based clean power systems; and to reduce the adverse energy-related impacts on poor and other vulnerable populations from severe weather events. The authors would also like to thank Todd Olinsky-Paul, Maria Blais Costello, and Avital Szulc for their valuable input on this report. This project has been generously funded by The JPB Foundation, The Kresge Foundation, and The Surdna Foundation. The views and opinions expressed in this report are solely those of the authors. For more information, please visit *www.resilient-power.org*.

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ON THE COVER

A block of high-rise apartment buildings that remain devoid of power, heat, and water stand in front of other buildings that have their utilities intact in the Brighton Beach neighborhood of New York, November 2, 2012.

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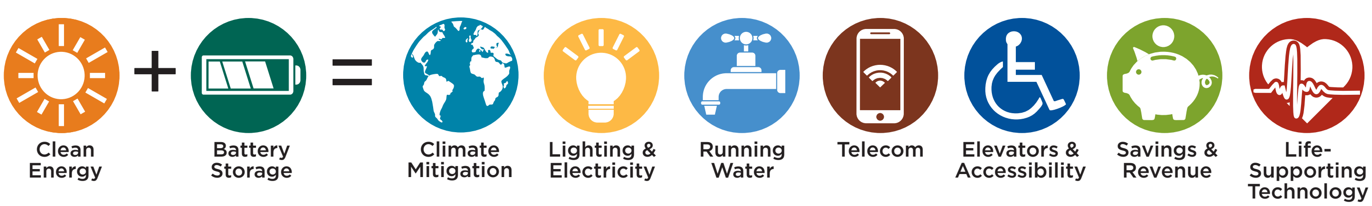

RESILIENT POWER | PROTECTING COMMUNITIES IN NEED

In the aftermath of Hurricane Sandy, residents of New York City housing projects congregate around a generator to power their mobile phones after days without electricity.

Executive Summary

BENDING THE ARC OF SOLAR+STORAGE TECHNOLOGIES TO BENEFIT LOW-INCOME COMMUNITIES

AFFORDABLE HOUSING MIGHT NOT BE the first market that comes to mind for solar and battery storage technologies. But it is the one that might need it the most.

Our analysis is timely, as energy storage is beginning to play a larger role in the U.S. power system.

Three years ago, Superstorm Sandy knocked out power to over eight million people across the Mid-Atlantic states and New England—stranding the infirm, the elderly, and other vulnerable residents in dark apartments without essential services. Tens of thousands of residents in public housing in New York City alone were left without power for long periods of time, resulting in prolonged misery and hardship.

A movable charging station served a devastated area in the aftermath of Superstorm Sandy on November 15, 2012 in Breezy Point, NY.

The disaster showed that—more than an inconvenience—losing power is life threatening to those who need electricity to power elevators, mobility devices, medical equipment, and refrigeration for medicine. And once disaster strikes, low-income and vulnerable populations—those requiring supportive services—have the most difficulty dealing with the consequences. They often lack the income, savings, insurance, and access to communication channels and information to recover from the adverse impacts of disruptive weather events.

Hospitals, nursing homes, 911 call centers, emergency shelters, and other critical facilities also need reliable, resilient electrical power to deliver emergency services to the community when the supporting power grid is down.

These most vulnerable residents and those who depend on critical public facilities don't have time to wait for improved technologies to trickle down to their communities—not when they can be economically feasible today.

Solar photovoltaics (PV) and battery storage systems ("solar+storage") can help them now. These technologies can provide reliable power for a range of critical facilities and essential building service loads. They can power water booster pumps, lighting, telecommunications, fire alarms and security cameras, elevators, and climate controls. They can mean the difference between safety and harm, protection and tragedy, dangerous evacuation or sheltering in place when outages occur.

In addition to protecting people from harm during prolonged power outages, solar+storage also can enable low-income housing developers to generate significant electric bill savings by reducing utility demand charges or generating revenue through providing grid services.

While these technologies look promising, developers of affordable housing and community projects still must make their decisions on the basis of cost and return on investment. To help developers better understand the economic feasibility of protecting people with these

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new technologies, Clean Energy Group (CEG), a national nonprofit organization seeking to expand clean energy markets, undertook this groundbreaking analysis of solar+storage projects in three case studies. This work is part of a larger, multi-year effort for the Resilient Power Project, a joint project of CEG and Meridian Institute.

Clean Energy Group set out to answer the question whether it is economical to install solar+storage technologies to power common area loads in multifamily affordable housing buildings. It undertook this analysis for three cities: Chicago, Washington, D.C., and New York City. To get the best information, CEG enlisted the services of experienced solar+storage experts[1] to help prepare economic models.[2]

This analysis is timely, as energy storage is beginning to play a larger role in the U.S. power system. Companies like Tesla and SolarCity have done an exceptional job of connecting solar and battery storage in the public's mind as a potent economic and climate mitigation strategy.

The challenge now is to bend the technology trend for battery storage to serve public markets such as affordable housing and other essential services in low-income communities.

However, the efforts of these companies are primarily targeted toward large-scale, private, commercial customers who want to reduce their utility bills.

The challenge now is to bend the technology trend for battery storage to serve public markets such as affordable housing and other essential services in low-income communities.

As this analysis shows, there is now no economic or technical excuse to leave low-income and vulnerable people at risk now or in the future.

Key Findings

This report is the first to highlight the following findings on multifamily affordable housing as an economic market segment for solar+storage technologies:

- ***Solar+storage can reduce operating costs in multifamily affordable housing*** in key cities, including New York City, Washington, D.C., and Chicago, helping low-income families, the elderly, and people needing supportive housing. A range of cost-effective opportunities exists to install solar+storage in affordable housing throughout the country, particularly in areas where utility demand charges are high and where electricity markets are structured to provide revenue for grid services from battery storage systems.

- ***Battery storage can complement energy efficiency and stand-alone solar measures to further reduce facility costs.*** Batteries with solar systems can achieve similar building operating-cost savings as those from stand-alone PV systems and energy efficiency measures, and without any required change in resident behavior. Energy and community developer experts should explore solar+storage; it can be a complementary approach to reducing electricity bills for housing developers.

- ***The payback period for investment in solar+storage systems can be as short as a few years.*** The investment scenario for solar+storage technologies can closely resemble payback periods for stand-alone solar and energy efficiency measures. Solar+storage is a new technology that is already demonstrating economic promise compared to these conventional measures that are now established with mature markets.

- ***Resilient power can be implemented at no net cost over the lifetime of a project.*** Although market rules and incentives differ in each of the three cities studied, each of the cities' economic models indicates that solar+storage can be successfully deployed with a payback period significantly shorter than the expected lifetime of the project. By presenting projects in three different cities, we evaluate which regulatory and policy environments are more successful in supporting resilient power development.

- ***There is a need to develop smarter, targeted incentives*** to improve the economics of solar+storage systems in states like New York that now lack the incentives and market structures to properly support distributed energy storage in low-income communities. In such environments, it can be challenging to economically develop resilient power projects for affordable housing. Properly structured new incentives in New York would help to create larger resilient power markets and protect vulnerable populations through improved resiliency and utility bill savings. This report sets out detailed recommendations for how incentive programs could be structured to support a robust and resilient distributed solar+storage market for affordable housing and community facilities in New York and other states.

- ***These preliminary findings are significant and make a strong case for the installation of more projects*** and for greater public and private support for solar+storage development in affordable housing. This analysis should serve as an impetus to consider affordable housing for targeted investment in solar+storage technologies.

Introduction

Solar-plus-batteries are set to begin a dramatic transformation of human civilization. The transformation has already begun, but will really pick up steam during the next decade. That is great news, because cheap energy powers our economy, and because clean energy will help stop climate change.[6]

THE CENTRALIZED U.S. ELECTRIC POWER system is highly vulnerable to disruption. Whether due to hurricanes, tornadoes, fires, earthquakes, or other disasters, it is often not there at times when people need it the most.

Foremost, resilient power is the ability to provide essential power to critical facilities and services when grid outages occur. Advanced resilient power technologies also have the capacity to provide electric power and economic benefits each and every day. They can reduce power bills and generate revenue by providing valuable grid services, as opposed to diesel-powered and other emergency back-up generators that sit idle most of the time and are prone to failure when finally called upon.

Clean Energy Group, through its Resilient Power Project, began work two years ago to address how to fully enable access to the benefits of clean, reliable energy for low-income and vulnerable populations in an economically sustainable way. Our response then, and the work of the project to date, has been to focus on the resilient power benefits of customer-sited clean energy.

In particular, solar PV combined with battery storage (solar+storage) can provide protection to vulnerable communities during extended power outages. As we worked to examine the economics of these systems in the multi-family affordable housing sector, we began to realize how persuasive the economics for solar+storage projects can be—effectively meeting a building's common area electricity demands from clean energy while providing resilient power for free, in many instances.

The economic case for solar+storage works because battery storage technology benefits from a number of economic opportunities. Battery storage can reduce utility bills through demand management and electricity time-

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Soldiers evacuated 500 patients from Bellevue Hospital during Superstorm Sandy on Wednesday, Oct. 31, 2012. Despite losing power the hospital stayed open using an emergency generator on the roof which was refueled by soldiers carrying 5-gallon fuel jugs up 13 floors to keep the 1,000-gallon tank filled.

shifting; and it can generate revenue through participation in demand response programs and wholesale electricity markets such as frequency regulation. And it can do all of this while still providing resilient power during grid outages.

So far, commercial and industrial customers have been first adopters to capture the economic benefits of energy storage for their operations. Our challenge has been to take advantage of this largely economically driven market for commercial customers and to shape it also toward community and public needs. That is, we want to move these technologies into community projects like affordable housing, assisted living, fire and police, and other critical facilities to help protect communities from power outages, reduce their utility bills, and enable clean energy—and broaden the use of these technologies to benefit all social and economic groups.

See Appendix A for more information about how solar+storage works and how resilient power technologies can be financed and deployed.

BOX 1

A Somber Anniversary: Three Years after Superstorm Sandy

The vulnerability of communities to power outages, especially for low-income, elderly, and disabled residents, has been well documented.

In New York City, Superstorm Sandy left 80,000 public housing residents without power in 35,000 units in over 400 buildings. 45,000 of these residents were ordered to evacuate, but 85 percent of them ended up "sheltering in place" for various reasons including health, lack of mobility, fear and simply not knowing where to go. Many never received the evacuation orders because of communication lapses.

For weeks and months following the storm, these residents endured prolonged power outages under deplorable conditions, living without heat, hot water, electricity, working elevators, and running water. Many had no other affordable place to stay, and no means of leaving their neighborhoods because they could not walk down multiple flights of stairs and, even if they could, mass transit was no longer operating.[3] A *New York Times* story on Sand Castle, a low-income housing project located in Queens that lost power after Sandy, highlights the sad tragedies that result when power is lost.[4]

Vulnerable populations in New York are still at risk. Today, six acute-care hospitals, a psychiatric hospital, 22 nursing homes, and 18 adult care facilities are still located in New York City's designated Hurricane Evacuation Zone – and are expected to provide vital housing and services to communities during the next major storm.[5]

This is a national problem. A recent Center for American Progress report, *Heavy Weather: How Climate Destruction Harms Middle- and Lower-Income Americans,* reinforced what was already widely known: vulnerable communities, including the elderly, disabled and economically challenged, are more vulnerable than the general population to destructive storms and the power outages they create.

For these residents, flooding, heat waves, ice and snowstorms, and other natural disasters may present life-threatening challenges—and the lack of resilient power only exacerbates the problem. If shelters and other supportive facilities don't have reliable power to provide heat and air conditioning,

Superstorm Sandy leaves over 80,000 New York City public housing residents in the dark, as shown from this photo taken on October 31, 2012.

refrigeration for medicines, and power to recharge electronic medical and mobility devices, the elderly and disabled may be left stranded without the basic necessities for survival.

The traditional solution to deal with outages has been backup power in the form of diesel generators located on-site. But these are designed to run only during emergencies and periodic exercising, and therefore sit idle most of the time. Furthermore, once on-site fuel supplies are exhausted, diesel generators are dependent on fuel deliveries that may not be possible during a disaster. Not only do they represent sunk costs without any associated value streams, they are prone to fail when called upon.

Community-based resilient power such as solar+storage can protect the people who have the greatest difficulty responding and recovering from the destruction caused by extreme weather events and related power outages. By providing appropriately sized resilient power systems, vulnerable multifamily housing residents will have the ability to safely shelter in place during the next extended power outage, reducing demands on overwhelmed first responder and emergency shelter services.

Resilient Power in Three Cities

AN ECONOMIC ANALYSIS

THIS ANALYSIS EXAMINES THE ECONOMICS of using solar+storage technologies to power common area loads in multifamily affordable housing in three cities: Chicago, Washington, D.C. and New York City. These cities were specifically selected based on the economic opportunities available in each location and the availability of data on building profiles to allow us to develop sound models. To get the best information, Clean Energy Group enlisted the services of experienced solar+storage experts to help prepare economic models.

Here are the basic assumptions in the economic models:

- The buildings modeled in our analysis are representative of affordable multifamily and senior housing facilities with multiple floors and resident capacities in the range of 100 to 300 units.
- Project expenses reflect actual estimated operations and maintenance costs, including system maintenance, warranties, additional insurance, management software, and system removal at the end of the project life.
- Savings and revenue valuations are based on estimated utility bill savings, either through offsetting grid electricity with solar energy or management of peak demand costs where applicable, as well as projected revenue through the sale of solar renewable energy certificates (SRECs) and participation in frequency regulation markets where available.
- While there are a variety of possible solar+storage configurations (see Box 2), for simplicity, our analysis assumes that solar PV and battery storage are being developed as new installations deployed at the same time.
- Because these projects are assumed to be new solar+storage installations, the 30 percent investment tax credit (ITC) is applied to both the solar and storage systems in each case. Installations involving retrofits, adding batteries to existing solar, may not be eligible to take advantage of the ITC and should adjust their economic valuation accordingly.[8]
- All projects in our analysis utilize the modified accelerated cost recovery system (MACRS), which allows capital depreciation to be deducted over the first several years of the project.
- Battery replacement occurs at year 10 for lithium-ion batteries and year 7 for lead-acid batteries. Battery replacement costs are estimated based on current battery technology and cost trends.
- Inverter replacement occurs at year 10 for all projects.
- Aggregation of storage resources and the inclusion of additional sources of on-site generation are not considered in this analysis.[9]

In addition to determining which technology options make the most sense for each building, a number of other factors should be accounted for prior to designing an optimal resilient power system: including critical load evaluation (see Box 3), physical siting constraints,[10] potential for utility bill savings (see Box 4), possible sources of revenue, and available incentives. While the systems modeled in this analysis are not optimized to power critical loads for any predetermined duration, each is designed to maximize resiliency benefits within reasonable economic and physical siting constraints.[11]

ANALYSIS MODEL NO. 1

Chicago, Illinois

Chicago Project Summary			
System Size	200-kW solar-only	200-kW solar +100-kW/ 50-kWh lithium-ion battery	200-kW solar + 300-kW/ 150-kWh lithium-ion battery
Initial Cost*	$493,000	$606,000	$832,000
Payback Period	20+ years	11.8 years	6.2 years

* Initial project costs refer to year zero net project expenses after federal tax credits and any additional tax credits have been applied.

For Chicago, we modeled a prototypical affordable housing development evaluating the addition of two possible systems: a 200-kilowatt solar PV system with either a 1) 100-kilowatt/50-kilowatt-hour lithium-ion battery system or 2) a 300-kilowatt/150-kilowatt-hour lithium-ion battery system. The choice between two battery system sizes is included in the analysis to illustrate the battery storage economies of scale that are possible under certain market conditions.

With relatively low electricity prices and modest levels of solar insolation, the economics of solar PV in Chicago are less than ideal. Though Illinois does not currently have a market for solar renewable energy certificates (SRECs), our analysis assumes that they can be sold on the Pennsylvania market, which allows for the purchase of out-of-state SRECs. As shown in Table 1 and Figure 1, even with the sale of SRECs included, installing solar alone results in a negative value proposition. The solar system fails to break even over the 20-year projected lifetime of the project.

Because batteries can generate additional revenue, adding battery storage to the proposed stand-alone solar PV system improves the overall economics of the project.

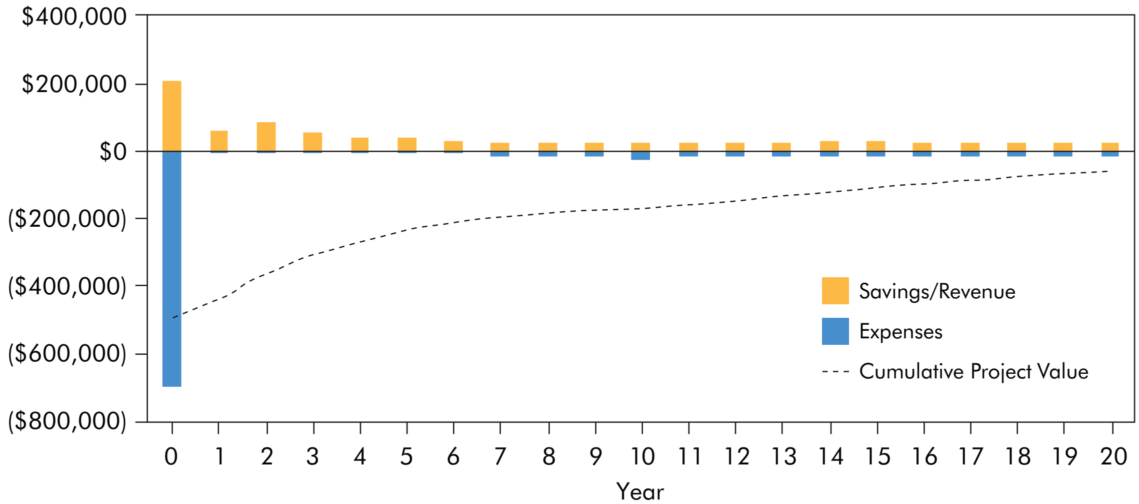
TABLE 1

20-year economic analysis of a 200-kilowatt solar-only system in a Chicago affordable housing building (values in thousands of dollars, see Appendix B, Table B1 for full dataset).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y10	Y15	Y20
PV Energy Savings	0.0	19.9	20.2	20.5	20.8	21.1	21.4	21.7	22.7	24.4	26.4
Frequency Regulation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar Renewable Energy Certificates	0.0	3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.5	0.0
Operating Expenses	0.0	(4.1)	(4.2)	(4.3)	(4.4)	(4.5)	(4.6)	(4.7)	(5.1)	(5.7)	(11.0)
System Installation/ Replacement Costs	(698.9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(18.3)	0.0	0.0
Tax Credits & Liabilities	205.5	34.7	59.6	32.9	16.9	16.8	4.8	(9.1)	(1.3)	(9.9)	(6.8)
Net Cash Flow	(493.4)	54.3	79.4	52.9	37.1	37.2	25.3	11.6	1.7	12.5	8.7

FIGURE 1

20-year annual and cumulative project valuation of a 200-kilowatt solar-only system in a Chicago affordable housing building.



Of course, a solar-only installation cannot provide the resilient power benefits that are so essential to these projects. Stand-alone solar systems are typically configured to shut down when the power system goes down. Nevertheless, the economics of a solar PV installation without battery storage is included in this analysis and the subsequent evaluations to illustrate the relative economics of a solar-only versus a combined resilient solar+storage system.

Chicago is located within the PJM Interconnection territory, which enables the battery storage system to generate revenue through participation in the grid frequency regulation market. Because of this, battery system sizing considers not only the support of essential critical loads, but optimal sizing for frequency regulation market participation as well.

The first battery option examined for Chicago is a 100-kilowatt/50-kilowatt-hour system. As shown in Table 2 and Figure 2, the addition of energy storage significantly improves the economics of the solar+storage system over a solar-only installation. In this case, incorporating a 100-kilowatt battery into the system results in a simple payback of fewer than 12 years.

In other words, because batteries can generate additional revenue, adding battery storage to the proposed stand-alone solar PV system improves the overall economics of the project.[12]

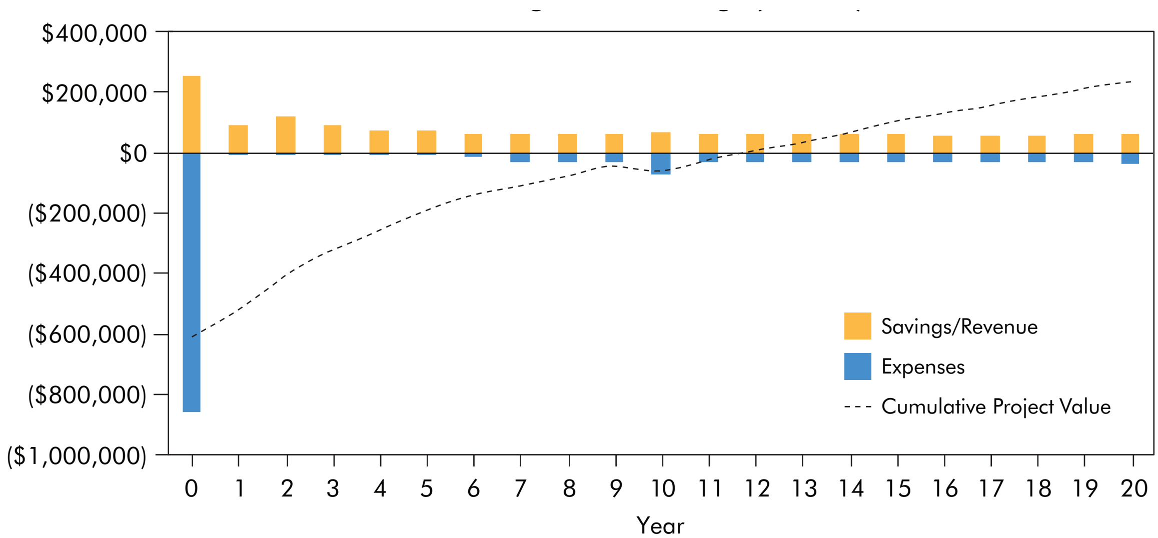
TABLE 2

20-year economic analysis of a 200-kilowatt solar and 100-kilowatt/50-kilowatt-hour lithium-ion battery storage system in a Chicago affordable housing building (values in thousands of dollars, see Appendix B, Table B2 for full dataset).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y10	Y15	Y20
PV Energy Savings	0.0	19.9	20.2	20.5	20.8	21.1	21.4	21.8	22.7	24.5	26.4
Frequency Regulation	0.0	36.7	36.6	36.3	36.2	36.0	35.8	35.6	35.1	34.2	33.4
Solar Renewable Energy Certificates	0.0	3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.5	0.0
Operating Expenses	0.0	(6.8)	(7.0)	(7.1)	(7.3)	(7.5)	(7.7)	(7.9)	(8.5)	(9.6)	(18.4)
System Installation/ Replacement Costs	(858.9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(66.3)	0.0	0.0
Tax Credits & Liabilities	252.5	32.4	63.0	30.4	10.8	10.8	(4.6)	(21.7)	4.7	(21.5)	(16.9)
Net Cash Flow	(606.4)	85.9	116.5	83.8	64.1	64.1	48.7	31.5	(8.7)	31.1	24.5

FIGURE 2

20-year annual and cumulative project valuation of a 200-kilowatt solar and 100-kilowatt/50-kilowatt-hour lithium-ion battery storage system in a Chicago affordable housing building.



A larger battery storage system is also considered for Chicago. Put simply, the larger the battery, the greater the frequency regulation revenues generated. Because the soft costs involved in installing a battery system do not tend to scale proportionately with the size of the storage system, these costs typically account for a smaller portion of the overall system cost as storage capacity is increased. For this reason, the per-kilowatt net return possible through providing frequency regulation services generally increases along with the size of the battery.

The effect of installing a larger, 300-kilowatt/150-kilowatt-hour, lithium-ion battery system can be seen in Table 3 and Figure 3. While the initial project investment is higher, the larger battery system results in a significantly improved simple payback period of about six years. Also, the 20-year cumulative revenue of the larger system increases nearly $600,000 as compared to the smaller battery system. In addition to improving the economics of the project, the larger storage system can support critical loads for a longer duration or allow for additional, less critical loads to be supported during a power outage.

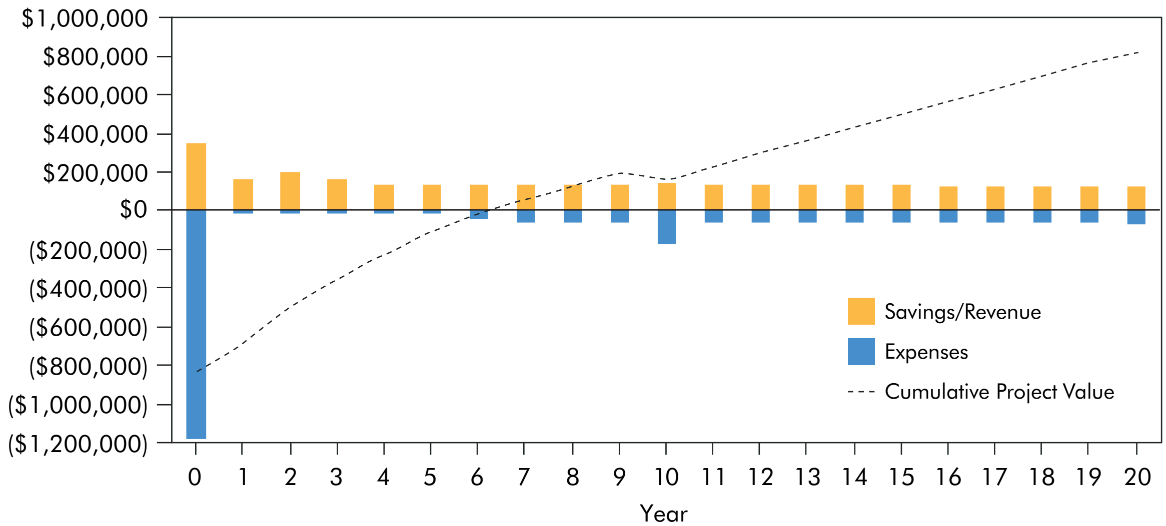
TABLE 3

20-year economic analysis of a 200-kilowatt solar and 300-kilowatt/150-kilowatt-hour lithium-ion battery storage system in a Chicago affordable housing building (values in thousands of dollars, see Appendix B, Table B3 for full dataset).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y10	Y15	Y20
PV Energy Savings	0.0	19.9	20.2	20.5	20.8	21.1	21.4	21.8	22.7	24.5	26.4
Frequency Regulation	0.0	110.1	109.6	109.0	108.5	107.9	107.3	106.8	105.2	102.6	100.1
Solar Renewable Energy Certificates	0.0	3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.5	0.0
Operating Expenses	0.0	(12.3)	(12.6)	(12.9)	(13.2)	(13.5)	(13.9)	(14.2)	(15.3)	(17.3)	(27.1)
System Installation/ Replacement Costs	(1178.9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(162.3)	0.0	0.0
Tax Credits & Liabilities	346.6	27.6	69.9	25.2	(1.7)	(1.5)	(24.9)	(48.2)	16.1	(46.3)	(40.6)
Net Cash Flow	(832.3)	149.1	190.8	145.6	118.0	117.7	93.7	69.8	(29.9)	67.0	58.8

FIGURE 3

20-year annual and cumulative project valuation of a 200-kilowatt solar and 300-kilowatt/150-kilowatt-hour lithium-ion battery storage system in a Chicago affordable housing building.



BOX 2

Types of Resilient Power Projects

Solar+storage resilient power projects fall into one or more of several project types:

- **Battery storage installed at the same time solar PV is installed.** This generally represents the best economic case for the project developer, especially in new construction projects. The separation of critical loads with dedicated wiring and separate panel box can be done at the same time the solar PV system wiring is installed, avoiding the need to rewire these loads later. Both the solar and battery storage systems will qualify for the ITC if installed concurrently and sized appropriately. These projects are also eligible for the MACRS.

- **Existing solar PV systems retrofitted with battery storage.** In a solar retrofit project, battery storage is installed to complement an existing solar PV system. Because it is installed at a later date, the battery system may not necessarily be eligible for the ITC. However, MACRS is still available to partially recover the cost of the storage system.

- **Hybrid resilient power systems that combine solar+storage with other on-site generation.** In some instances where building space and budget constraints don't permit solar+storage alone to cover larger critical loads, projects can be designed with additional on-site generation, such as small combined heat and power (CHP) systems.

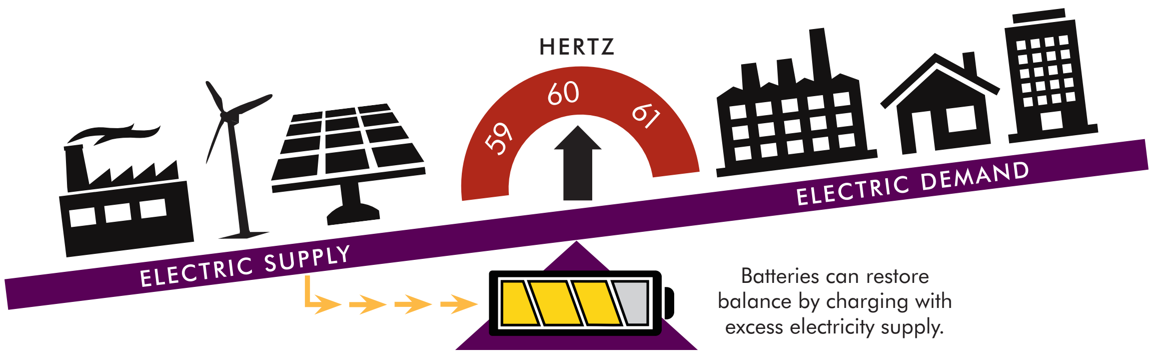
- **Aggregated energy storage systems located at multiple sites.** In regions where solar+storage assets can provide grid services, such as frequency regulation and demand response, multiple systems can be aggregated together to meet minimum participation threshold requirements. For instance, the PJM Interconnection requires a minimum capacity of 100 kilowatts for resources, either individual or aggregated, to bid into its frequency regulation market.

Frequency Regulation and Battery Storage

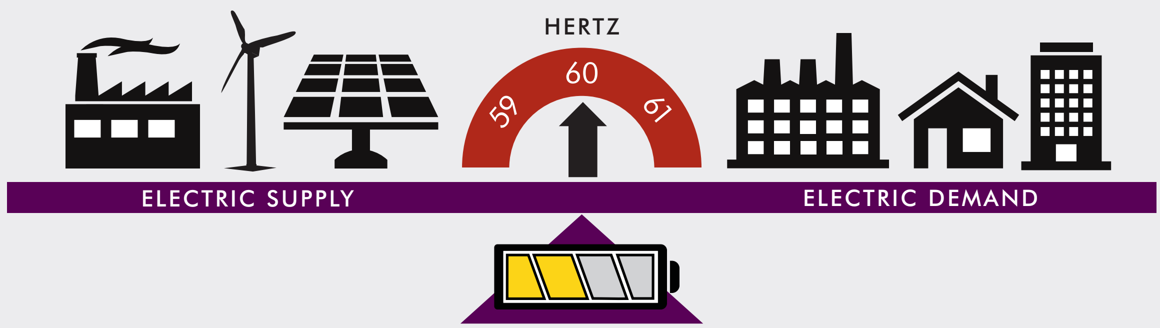
Frequency regulation is used to balance power supply, the amount of electricity being generated, with power demand, the amount of electricity being used at all times. The U.S. electricity grid is designed to operate at a frequency of 60 hertz. Failure to maintain this frequency within a small operating range can damage the power system and result in blackouts. Adding battery storage to the electricity system can provide valuable, fast-response frequency regulation services used to stabilize the power grid.

TOO MUCH SUPPLY

When there is too much power supply or not enough demand, frequency will drift higher than 60 hertz. Battery storage can help balance the system by charging to absorb the excess power.

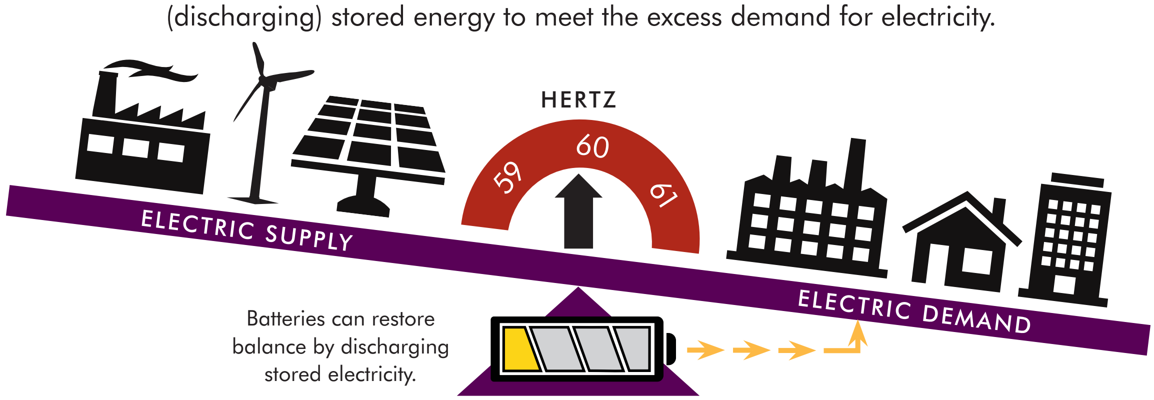


EQUILIBRIUM



TOO MUCH DEMAND

When there is too much power demand or not enough power supply, frequency will fall lower than 60 hertz. Battery storage can help balance the system by releasing (discharging) stored energy to meet the excess demand for electricity.



ANALYSIS MODEL NO. 2

Washington, D.C.

Washington, D.C. Project Summary		
System Size	360-kW solar-only	360-kW solar +100-kW/ 50-kWh lithium-ion battery
Initial Cost	$788,000	$901,000
Payback Period	3.5 years	3.5 years

The economics of solar PV in Washington, D.C. are quite different than in the Chicago area. This is largely due to Washington, D.C.'s aggressive solar mandate, driving solar renewable energy credits (SRECs) to historically high prices. SRECs are currently priced at nearly $500 per-megawatt-hour of solar produced.

Because of this, a larger 360-kilowatt PV system is considered for the D.C. project. Our analysis assumes that high SREC prices hold for the first 5 years of the project. They then drop by 50 percent from year 6 through year 15, at which point they disappear completely.

Based on this evaluation, the solar-only installation achieves a short project payback of about 3.5 years (see Table 4 and Figure 4).

While the payback period is similar for solar-only, the solar+storage system achieves a higher cumulative project value over 20 years and provides a crucial resiliency benefit that solar-only systems cannot.

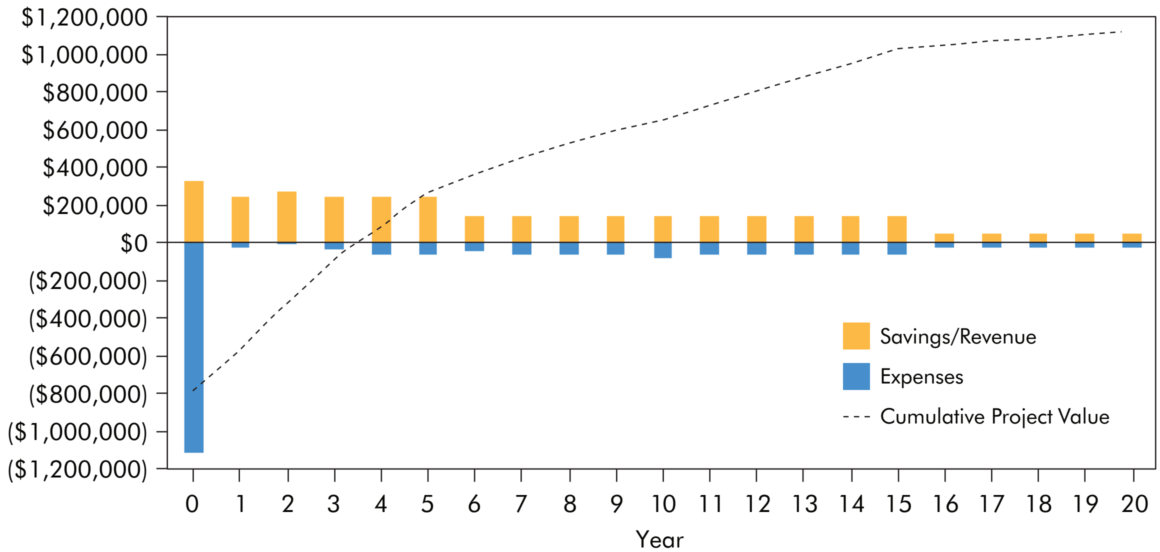
TABLE 4

20-year economic analysis of a 360-kilowatt solar-only system in a Washington, D.C. affordable housing building (values in thousands of dollars, see Appendix B, Table B4 for full dataset).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y10	Y15	Y20
PV Energy Savings	0.0	35.8	36.4	36.9	37.5	38.0	38.6	39.2	40.9	44.1	47.5
Frequency Regulation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar Renewable Energy Certificates	0.0	211.9	210.8	209.7	208.7	207.6	103.3	102.8	101.3	98.7	0.0
Operating Expenses	0.0	(7.1)	(7.3)	(7.4)	(7.6)	(7.8)	(8.0)	(8.2)	(8.8)	(10.0)	(16.7)
System Installation/ Replacement Costs	(1116.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(32.9)	0.0	0.0
Tax Credits & Liabilities	328.1	(22.4)	22.3	(25.1)	(56.9)	(56.6)	(34.9)	(58.8)	(44.2)	(58.4)	(13.5)
Net Cash Flow	(787.9)	218.2	262.2	214.1	181.7	181.3	99.0	74.9	56.3	74.4	17.2

FIGURE 4

20-year annual and cumulative project valuation of a 360-kilowatt solar-only system in a Washington, D.C. affordable housing building.



Like Chicago, Washington, D.C. is located within the PJM Interconnection and able to participate in the frequency regulation market. For sake of comparison with the Chicago project, a 100-kilowatt/50-kilowatt-hour system is considered in the D.C. analysis as well. Frequency regulation revenue potential is the same throughout PJM regardless of location, so the estimated frequency regulation revenue in D.C. is the same as that for the Chicago project. The same would be true for any location within PJM.

As can be seen in Table 5 and Figure 5, the resilient solar+storage project retains an extremely favorable simple payback period of around 3.5 years. While the payback period is similar for solar-only, the solar+storage system achieves a higher cumulative project value over 20 years and provides a crucial resiliency benefit that solar-only systems cannot.

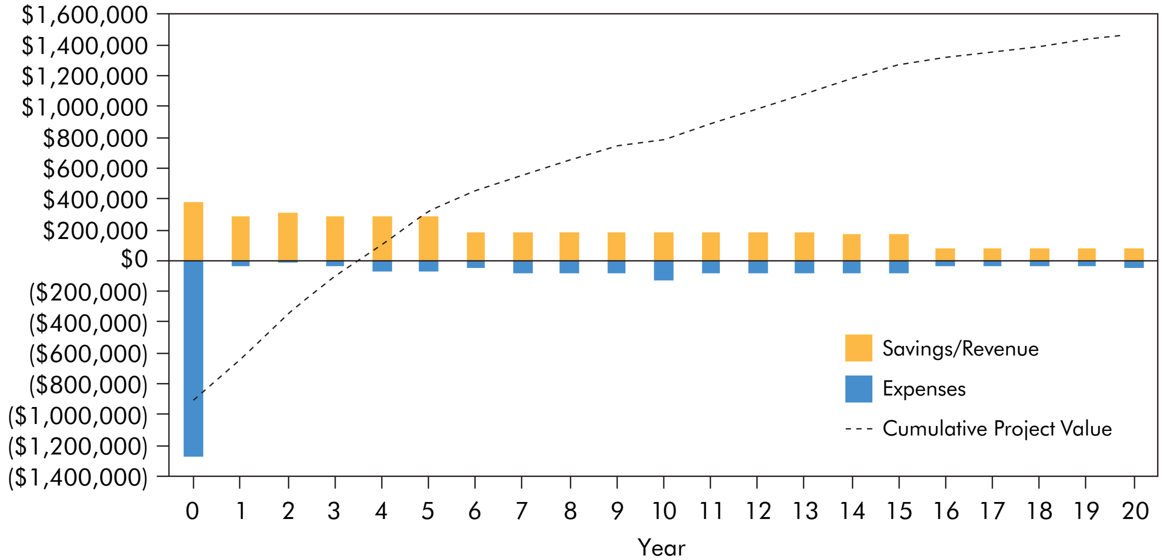
TABLE 5

20-year economic analysis of a 360-kilowatt solar and 100-kilowatt/50-kilowatt-hour battery storage system in a Washington, D.C. affordable housing building (values in thousands of dollars, see Appendix B, Table B5 for full dataset).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y10	Y15	Y20
PV Energy Savings	0.0	35.8	36.4	36.9	37.5	38.0	38.6	39.2	40.9	44.1	47.5
Frequency Regulation	0.0	36.7	36.5	36.3	36.2	36.0	35.8	35.6	35.1	34.2	33.4
Solar Renewable Energy Certificates	0.0	211.9	210.8	209.7	208.7	207.6	103.3	102.8	101.3	98.7	0.0
Operating Expenses	0.0	(9.8)	(10.1)	(10.3)	(10.6)	(10.8)	(11.1)	(11.4)	(12.3)	(13.9)	(22.6)
System Installation/ Replacement Costs	(1276.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(80.9)	0.0	0.0
Tax Credits & Liabilities	375.1	(23.6)	25.7	(26.3)	(60.0)	(59.6)	(42.5)	(67.9)	(34.4)	(66.7)	(23.8)
Net Cash Flow	(900.9)	251.0	299.3	246.4	211.8	211.2	124.1	98.3	49.8	96.5	34.4

FIGURE 5

20-year annual and cumulative project valuation of a 360-kilowatt solar and 100-kilowatt/50-kilowatt-hour battery storage system in a Washington, D.C. affordable housing building.



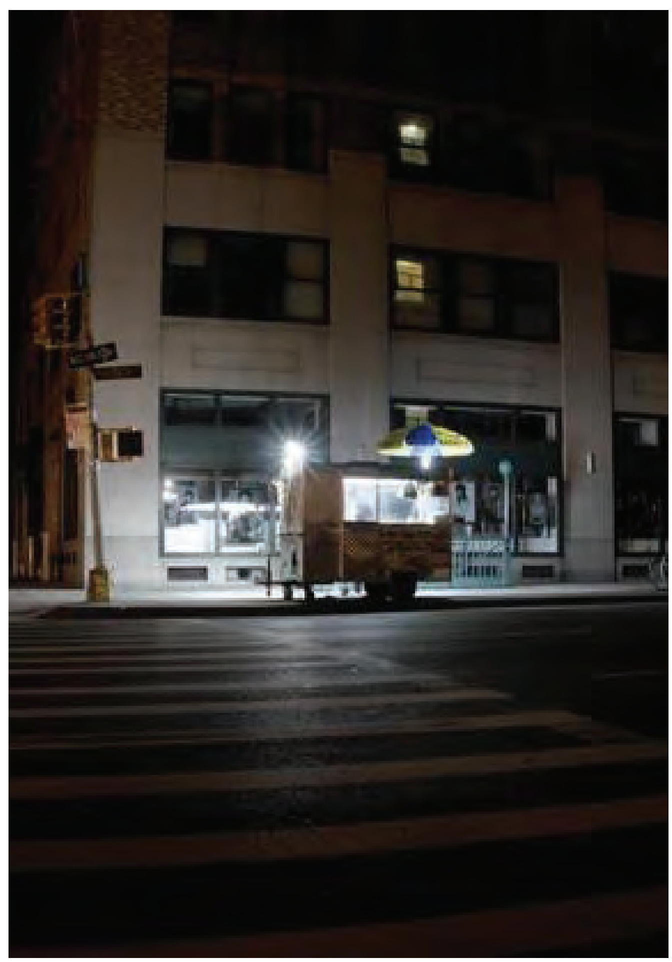
BOX 3

Evaluating Critical Loads

Multifamily affordable housing developers do not typically look to resilient power for replacing 100 percent of their grid-supplied power. Instead, it is more realistic and economically feasible for developers to size a system in order to supply power to specific critical building loads for certain required durations.

The following are some of the critical loads commonly found in multifamily buildings that solar+storage systems can be designed to support:

- Mobility and accessibility devices such as elevators
- Water booster pumps
- Common area lighting
- Telecommunications equipment
- Security cameras and fire alarms
- Servers and computers
- Cell phone charging stations
- "Cool rooms" for elderly and medically vulnerable residents



A food cart serves hungry New York City residents during a power outage that lasted several days after Superstorm Sandy.

ANALYSIS MODEL NO. 3

New York City

New York City Project Summary		
System Size	30-kW solar-only	30-kW solar + 30-kW/ 60-kWh lead-acid battery
Initial Cost	$58,000	$128,000
Payback Period	4.3 years	14.2 years

The financial picture for solar+storage is considerably different in New York City. While the economics are favorable for resilient solar+storage deployment in New York City and warrant investment, they are not nearly as favorable as in the other two cities.

The reason for this is quite simple. New York currently lacks incentives and market structures to properly support distributed energy storage development. In the absence of strong supportive policy, favorable economics for resilient power solar+storage projects become more difficult to achieve in New York.

The state does have an incentive program in place through the New York State Energy Research Development Authority (NYSERDA) to encourage deployment of stand-alone solar PV, the NY-Sun Solar Electric Incentive Program. This program helps improve the economics of the solar side of a resilient power project.

The solar PV array proposed in our analysis is limited to 30 kilowatts, given the majority of multifamily buildings in the city have space-constrained rooftops.[13] Despite the relatively small size of the system, the combination of higher electricity prices and the NYSERDA incentive still results in a good solar-only payback of just over four years (see Table 6 and Figure 6).

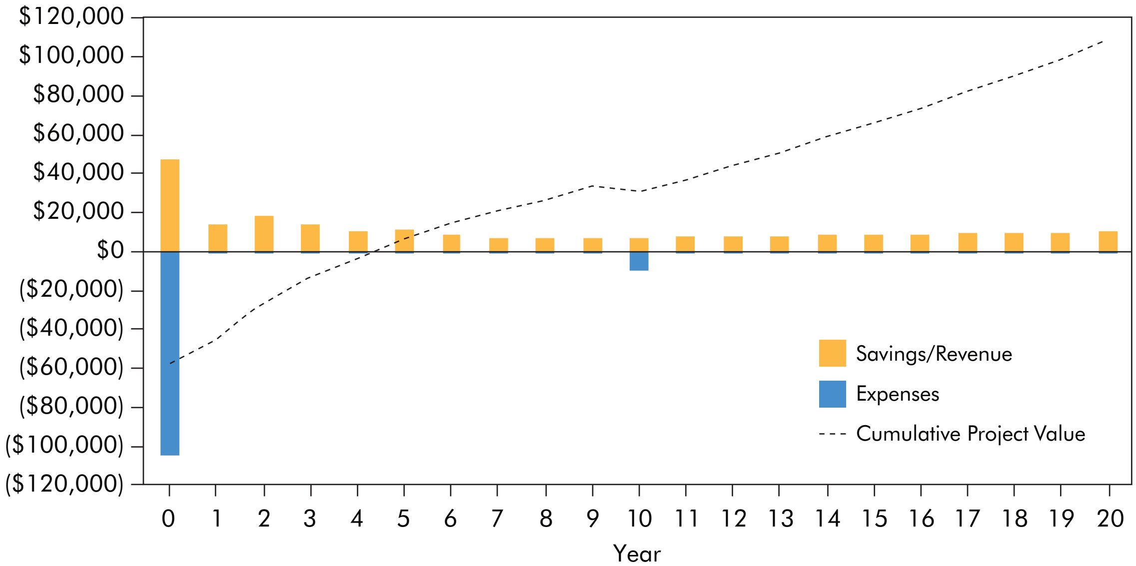
TABLE 6

20-year economic analysis of a 30-kilowatt solar-only system in a New York City affordable housing building (values in thousands of dollars, see Appendix B, Table B6 for full dataset).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y10	Y15	Y20
PV Energy Savings	0.0	5.4	5.6	5.8	6.0	6.2	6.4	6.6	7.3	8.5	10.1
Demand Charge Reduction Savings	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar Renewable Energy Certificates	0.0	(0.6)	(0.6)	(0.6)	(0.7)	(0.7)	(0.7)	(0.7)	(0.8)	(0.9)	(1.1)
Operating Expenses	(105.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(9.0)	0.0	0.0
System Installation/ Replacement Costs	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tax Credits & Liabilities	23.3	8.2	13.1	7.9	4.7	4.7	2.4	0.0	0.0	0.0	0.0
Net Cash Flow	(57.7)	13.0	18.1	13.0	10.0	10.2	8.0	5.9	(2.5)	7.6	9.0

FIGURE 6

20-year annual and cumulative project valuation of a 30-kilowatt solar-only system in a New York City affordable housing building.



Unlike Chicago and Washington, D.C., small battery storage systems in New York City are not currently able to economically participate in regional frequency regulation or other wholesale electricity markets. This is due to several factors, such as the makeup of available resources within the grid balancing territory, but primarily due to the design of the New York ISO frequency regulation market. Specifically the New York market has a 1-megawatt capacity threshold for market participation, making it difficult for small, distributed systems to participate. Additionally, market compensation mechanisms for fast-response frequency regulation resources are not structured in a manner that allows for advanced energy storage systems to economically compete with slower-responding resources like natural gas and hydro, as they are in PJM. Due to these market limitations, there are no comparable grid-based, ancillary services opportunities in New York.

Perhaps most importantly, New York does not have any incentive programs specifically designed to support resilient, solar+storage projects. For example, New York City utility Con Edison's Demand Management Program is structured in a way that makes it difficult for battery storage projects to economically take advantage of available incentives.[14] While the current Con Edison/NYSERDA Enhanced Demand Management Program provides significant incentives for storage (up to $2,100 per kilowatt), the program requires batteries to be discharged between 2 pm and 6 pm during summer months, which is not typically when a multifamily building's peak load occurs. Based on our analysis, structuring resilient solar+storage systems to match the program requirements can result in uneconomic projects. Because of this, the Con Edison incentive was not included in the final project model, as meeting its requirements would have worsened the project economics.

Without meaningful incentives and viable grid services revenue opportunities, the only economic proposition for battery storage in New York City is through management of utility demand charges, using a method known as peak shaving (see Box 4). By reducing a facility's peak energy demand, battery storage can deliver utility bill savings each month. However, unlike frequency regulation revenue, demand charge savings are based on each building's unique real-time load profile. Therefore, savings vary significantly from one project to the next and returns may not scale up accordingly as battery size is increased.

In addition, current New York City regulations and permitting on battery storage have hindered the adoption of advanced batteries that are becoming less expensive over time and are more suited to frequent cycling. At present, New York City fire safety and permitting regulations make it difficult to site lithium-ion and other advanced storage systems inside buildings within the city. Local authorities having jurisdiction in New York City have been reviewing battery system applications for peak demand management and resiliency due to the densely populated urban setting in which these systems would operate. In contrast, lithium-ion batteries have been installed in many locations inside buildings throughout California. Local New York City regulations are currently under review pending further research and analysis but no clear date for a decision has been made public. Due to this limitation, only lead-acid batteries are considered in our analysis.

The proposed system analyzed here is designed to best work within these limitations and the less than optimal regulatory environment in New York. Based on representative electricity demand profiles for common area electric loads in affordable housing buildings in New York City and the noted constraints, a 30-kilowatt/60-kilowatt-hour lead-acid battery system is considered in this analysis.

Despite all of these obstacles, the economic return for such a solar+storage project in New York City is still favorable. Even with the local market and regulatory barriers, the economic analysis results in a net positive return over the life of the project. Solar PV energy savings support the project economics, with demand charge savings helping to offset the cost of the battery system over time (see Table 7 and Figure 7). The result is that the project shows a modest 20-year return and a simple payback period of about 14 years.

Even with the local market and regulatory barriers, the economic analysis results in a net positive return over the life of the project.

TABLE 7

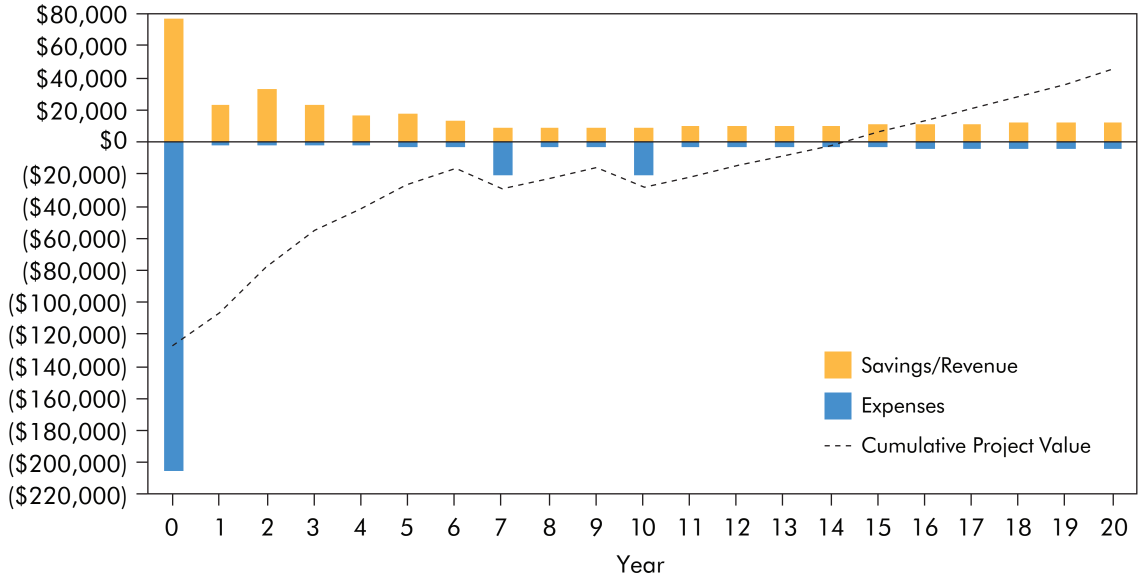
20-year economic analysis of a 30-kilowatt solar and 30-kilowatt/60-kilowatt-hour lead-acid battery storage system in a New York City affordable housing building (values in thousands of dollars, see Appendix B, Table B7 for full dataset).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y10	Y15	Y20
PV Energy Savings	0.0	5.4	5.6	5.8	6.0	6.2	6.4	6.6	7.3	8.5	10.1
Demand Charge Reduction Savings	0.0	1.8	1.8	1.9	1.9	1.9	2.0	2.0	2.1	2.3	2.5
Solar Renewable Energy Certificates	0.0	(2.4)	(2.5)	(2.5)	(2.6)	(2.7)	(2.8)	(2.9)	(3.1)	(3.6)	(4.2)
Operating Expenses	(205.0)	0.0	0.0	0.0	0.0	0.0	0.0	(18.0)	(18.0)	0.0	0.0
System Installation/ Replacement Costs	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tax Credits & Liabilities	53.3	16.0	25.6	15.4	9.2	9.2	4.6	0.0	0.0	0.0	0.0
Net Cash Flow	(127.7)	20.8	30.6	20.5	14.5	14.6	10.2	(12.3)	(11.8)	7.2	8.3

New York City residents fill up water jugs from a fire hydrant during a blackout in 2003 that left more than 55 million people in northeastern U.S. and Ontario, Canada without power. Some were without power for two days.

FIGURE 7

20-year annual and cumulative project valuation of a 30-kilowatt solar and 30-kilowatt/60-kilowatt-hour lead-acid battery storage system in a New York City affordable housing building.



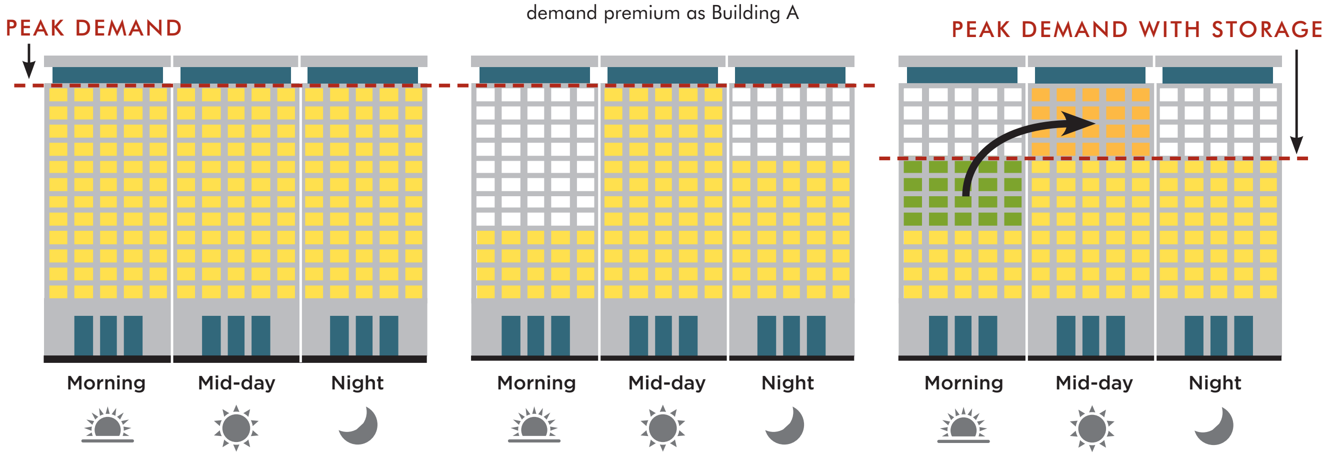
How Energy Storage Can Reduce Demand Charges

Demand is the total amount of electric load required by the customer's electric equipment operating at any given time. Utilities assess demand charges based on the highest average demand, (i.e. Peak Demand) that occurs over any interval (usually 15-minutes) during each billing period, and it is measured in kilowatts. Utilities assess energy consumption charges based on the total amount of electricity consumed over any period, and it is measured in kilowatt-hours.

Building A
Has high energy consumption and reaches the same high level of demand throughout the day and night

Building B (Scenario 1)
Only reaches its highest level of demand in the middle of the day, consuming less energy, but paying the same peak demand premium as Building A

Building B (Scenario 2)
Stores energy in the morning to offset high demand in the middle of the day, lowering utility peak demand



In **Scenario 1**, Building A and Building B will incur the same peak demand charges over the course of the day, even though Building A will have consumed considerably more energy during that time. In **Scenario 2**, Building B can use energy storage to reduce its mid-day grid energy consumption by meeting some of its demand with on-site stored energy. **This could reduce its overall peak demand** for the period, resulting in a lower utility bill.

Grid Energy Consumption
Stored Energy
Stored Energy Consumption

BOX 4

Reducing Utility Bills—Reducing Energy Usage and Shaving Peak Demand Charges

Batteries can reduce utility bills in affordable housing in ways that conventional approaches of energy efficiency and stand-alone solar cannot. The difference is based on the portions of the electric bill that each measure is designed to reduce. The explanation requires delving into the arcane complexities of utility electric bills, but it's worth the effort if you want to help low-income properties reduce their electric bills.

In the past, the principal technology means to reduce utility bills in affordable housing has been an array of energy efficiency measures. For years, advocates for energy efficiency in this sector have stated,

> "Increasing the energy efficiency of the nation's low-income multi-family housing will also make it more affordable. Affordability is especially important since energy prices are rising faster than the overall rate of housing costs in the United States."[15]

A variety of low-income housing tax credits, public system benefit charge programs, and weatherization programs have been directed at this sector to reduce utility bills to benefit low-income residents and affordable housing developers. These efficiency measures are usually targeted to reduce energy usage, and over the years the energy savings have generally been significant.

In addition, many affordable housing developers have come to install stand-alone solar technologies to complement energy efficiency measures. This has resulted in additional bill savings, chiefly through offsetting the purchase of grid-supplied power. There is a considerable amount of installed solar PV capacity in affordable housing and a great deal of momentum behind adding solar systems to low-income housing.[16]

To date, the major rationale for making energy improvements in multifamily affordable housing has been to reduce utility bills by reducing energy consumption ("usage charges" measured in kilowatt-hours). But there are limits to this strategy—and this is where the specific parts of the electric bill come in.

Reducing *energy usage charges*—the primary target of both energy efficiency and stand-alone solar—affects only one side of a multifamily/commercial electric bill. These strategies typically do little to reduce the other side of the bill—*demand charges*. And it is these peak demand charge rates that are rising more quickly than energy usage rates across the country. (See illustration on page 21.)

In many geographic markets, demand charges can represent 50 percent or more of an electric bill. Unlike solar and most efficiency measures, energy storage can directly target demand charges. A properly sized energy storage system with smart software controls can efficiently manage peaks in demand and dramatically reduce customers' utility bills—a process known as "peak shaving."

Commercial and industrial customers in parts of California, New York, and Hawaii are already using energy storage to save on utility bills by cutting demand charge expenses. According to analysis by the energy systems integration and management software company Geli, those energy storage savings could soon expand to include customers in another 43 states if battery prices continue their downward spiral.[17]

The bottom line is that batteries represent a new way to reduce electric bills in affordable housing, and those reductions should result in a return to the individual tenant in increased investment in measures beneficial to them.

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Conclusions

GETTING THE MARKET RULES AND INCENTIVES RIGHT

WHILE OUR ANALYSIS FINDS FAVOR-able economic conditions for resilient solar+storage project development in multifamily affordable housing in each of the three cities explored, it also illuminates the need for additional targeted support in those regions where markets and savings opportunities are less established, as illustrated in the analysis of New York City.

In spite of the clear need for resilient power, solar+storage is not thriving in New York. It is true that regulators and policymakers are working on a massive effort to redesign the state's power system, known as Reforming the Energy Vision (REV). Some programs have already been implemented, like the NY-Sun Commercial/Industrial Incentive Program that supports new larger commercial and industrial solar projects that include storage.[18] However, most new provisions are not yet in place and may not be for some time to come. Moreover, the REV process has acknowledged that future tariff proposals may not be effective in producing sufficient market activity in low-income communities, a difficult segment for the private sector to penetrate in the near future. In the meantime, the state is supporting a few one-off resiliency efforts, such as the NY Prize award for community microgrid projects. But these alone cannot create or sustain the necessary market conditions for continued solar+storage development.

As a result, in New York, there is currently limited market opportunity or targeted incentives in place to support small-scale, customer-sited energy storage development in a way that leads to economically sound projects—especially in low-income communities. Those opportunities that do exist, like Con Edison's Demand Management incentive program, may not align well with a building's energy storage needs or are highly dependent on building energy usage, like utility demand charge savings that can be limited by the shape and magnitude of a building's energy demand profile. In other words, existing incentives and market conditions are not designed to drive sufficient activity either in low-income or other more commercial markets.

Given these circumstances, until long-term, effective market mechanisms are established, states like New York may need to do more to bring solar+storage technologies to vulnerable populations. They should consider implementation of dedicated, well-crafted energy storage incentive programs to drive the adoption of solar+storage systems in the affordable housing sector now, not years from now.

California's Self-Generation Incentive Program (SGIP), while not perfect, is an example of a state-wide incentive that has helped develop an emerging, distributed energy storage market.[19]

In particular, if New York—or other states—desire to encourage resilient solar+storage projects now, it should consider an incentive program with the following elements:

- Set a budget for the incentive that applies specifically to storage applications combined with solar. Capacity to provide resiliency independent of the electric grid should be encouraged or required, and added incentives put in place to support any additional project costs.
- Set a capacity-based incentive level that is high enough to encourage project development and declines as market mechanisms develop and mature.[20]
- Any time requirement for a system to discharge at rated capacity should be based on a building's average peak duration, as opposed to Con Edison's 4-hour "system peak" period.
- There should be no constraint as to when the system must be discharged. In order to lower utility peak demand, the Con Edison incentive requires discharge of the battery to the grid during the period between 2 pm and 6 pm, which does not typically match the customer peaks experienced in residential buildings like affordable housing.
- The program should give priority to projects in low-income areas, serving vulnerable populations in affordable housing and similar critical community facilities.

This type of incentive program would leverage small public expenditures, serve a public need, and develop markets and projects far beyond what is presently possible under current regulatory and policy frameworks. It would work in advance of any longer-term regulatory changes brought about by the REV process, while aligning with the early recommendations in that process that priority attention must be given to storage projects in low-income areas.

With the proper incentives and market structures, it might be quite possible to create private market participation in solar+storage markets in low-income areas—a market driven approach to resilient power projects in low-income neighborhoods.

What these recommendations also suggest is that, with the proper incentives and market structures, it might be quite possible to create private market participation in solar+storage markets in low-income areas—a market driven approach to resilient power projects in low-income neighborhoods. This might also occur through the REV process proposal of allowing for utility ownership or management of third-party solar+storage assets expressly benefiting low-income residential customers.

Finally, such a New York storage incentive also could lead to economic retrofits of the stand-alone PV systems that are already deployed in the state and in New York City but that did not work during Sandy when the grid went down. The state now has an underutilized resource of over 450 megawatts of stand-alone solar PV that could be made available during an outage.[21] These existing systems could be made to work independent of the grid if batteries and islanding capabilities were added. A smart incentive aimed at adding batteries to those systems would leverage the existing PV resource, representing millions in public and private dollars already invested, and turn it into an economical and productive source of power during the next storm.

PUTTING IT ALL TOGETHER

Although preliminary, these findings represent the first-of-its-kind analysis of the economics of solar+storage in multifamily affordable housing for three U.S. cities. We now know one thing for certain—it can be economical today to install solar+storage in affordable housing in certain key regional markets.

With these surprisingly favorable economics, there is now enough evidence to encourage, if not convince, affordable housing developers and community project developers to investigate the economics of solar+storage. The financials pencil out to use solar+storage as a viable means of protecting residents and reducing power costs. In many parts of the country, with high demand charges and properly structured electricity markets, solar+storage projects are economically viable and should be considered.

However, with the pressing need for more resilient buildings to protect people in need, pure market forces should not be the only way to protect people against the next major disaster. Our analysis further suggests that policy makers in states like New York that want more resilient power must do more.

With the pressing need for more resilient buildings to protect people in need, pure market forces should not be the only way to protect people against the next major disaster.

These states should consider implementing targeted incentive programs that support solar+storage development in low-income and affordable housing sectors. Such programs are needed to improve the economics of those projects, protect those in need, and accelerate market development for resilient power technologies in low-income communities.

Three years after Superstorm Sandy, it is time to act without delay.

A sign hangs from a waterfront home in Long Beach, N.Y., Nov. 6, 2012.

ENDNOTES

1 Henry Misas, Senior Project Engineer, Bright Power and Adje Mensah, CEO, AF Mensah

2 The analysis represents real costs, savings and revenue based on data and specifications compiled from actual solar+storage development opportunities in affordable housing buildings.

3 See: *http://www.rebuildajustny.org/wp-content/uploads/2014/03/Weathering_The_Storm.pdf*

4 See: *http://www.nytimes.com/2012/12/20/nyregion/at-queens-high-rise-fear-death-and-myth-collided.html*

5 See: *http://www.nyc.gov/html/recovery/downloads/pdf/sandy_aar_5.2.13.pdf*

6 See: *http://www.bloombergview.com/articles/2015-04-08/clean-energy-revolution-is-way-ahead-of-schedule*

7 See *http://www.greentechmedia.com/articles/read/US-Solar-Plus-Storage-Market-to-Surpass-1-Billion-by-2018*

8 There seems to be considerable confusion about whether batteries added to existing solar systems can take advantage of the ITC. For those considering retrofits, determining the answer to that question is important.

9 Highly efficient generation devices, such as combined-heat-and-power (CHP) units, may often make sense when combined with solar+storage in a resilient power application. They can increase the resiliency benefits of a system and may improve the overall economics as well. In general, adding solar+storage to an existing or planned CHP system should not negatively impact the economics or functionality of the system.

10 In many cases, specific space constraints may drive design decisions regarding what is the optimal size of a solar+storage system. A facility may have limited space for placement of solar panels and battery storage systems.

11 Actual resiliency benefits will be highly dependent on which critical loads are supported and use of devices during an outage. For instance, lighting and refrigeration may be in constant use whereas elevators and charging stations are likely to be used more intermittently.

12 It should be noted that the frequency regulation market is much smaller than the wholesale capacity market and that grid operator needs for fast-response resources like energy storage may be subject to eventual saturation, potentially affecting market prices and participation of new resources. Reliance on this source of revenue is another financial risk that must be managed and hedged in any project development.

13 Larger representative solar PV system sizes may be more feasible in certain areas of the city, such as the outer boroughs.

14 The Con Edison Demand Management Incentive requires that demand is reduced over a 4-hour period, between the hours of 2pm and 6pm. In addition to this being an inordinately long period for discharge of battery systems (twice the duration required by California's SGIP incentive), the peak for many buildings, particularly residential and those with solar, occurs in the morning or evening hours outside of this period. Because of this, the storage capacity is not available for system owners to realize additional cost savings through reductions in their facility's peak demand.

15 See: *http://aceee.org/files/pdf/resource/brown_and_wolfe_energy_efficiency_in_multifamily_housing_2007.pdf*

16 See White House announcement to increase solar access for low and moderate income groups: *https://www.whitehouse.gov/the-press-office/2015/07/07/fact-sheet-administration-announces-new-initiative-increase-solar-access*

17 See: *http://www.greentechmedia.com/articles/read/Analytic-Design-is-Key-to-Opening-New-Energy-Storage-Markets.*

18 The NY-Sun Commercial/Industrial Incentive provides an additional incentive of $50,000 for solar projects of 200 kilowatts or greater that incorporate energy storage. Though larger than the type of system typically feasible for a New York City affordable housing project, a larger solar+storage system was considered in this analysis; however, the payback period exceeded the 20-year project lifetime.

19 See: *http://www.cpuc.ca.gov/PUC/energy/DistGen/sgip*

20 Currently, California's SGIP incentive is set at $1,400 per kilowatt for advanced energy storage. The incentive available through Con Edison's Demand Management Program is $2,100 per kilowatt. Calculation of initial incentive levels should account for existing market conditions and actual project costs—especially the added costs of making the building grid independent and resilient—in each region and be set accordingly.

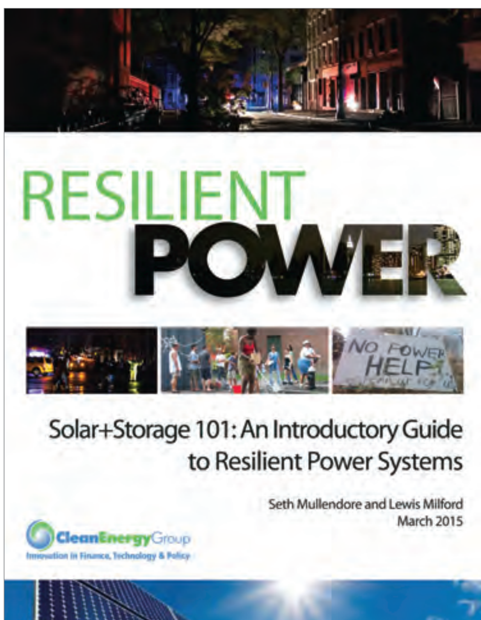
21 See Solar Energy Industries Associate Solar Market Insight Report 2015 Q1: *http://www.seia.org/research-resources/solar-market-insight-report-2015-q1*

APPENDIX A

Background on Resilient Power

How solar+storage technologies work

While solar PV systems have the ability to generate electricity independent of the utility grid, many PV system owners are surprised to discover that their building is left without power during a grid outage, even when the sun is shining. This is because the majority of PV systems installed today lack the ability to operate independent of the grid when an outage occurs, a process known as islanding.



For safety reasons, solar systems without islanding capabilities are configured to automatically shut down and disconnect from the grid when the utility grid goes down, leaving a valuable source of renewable power disabled when it is needed most.

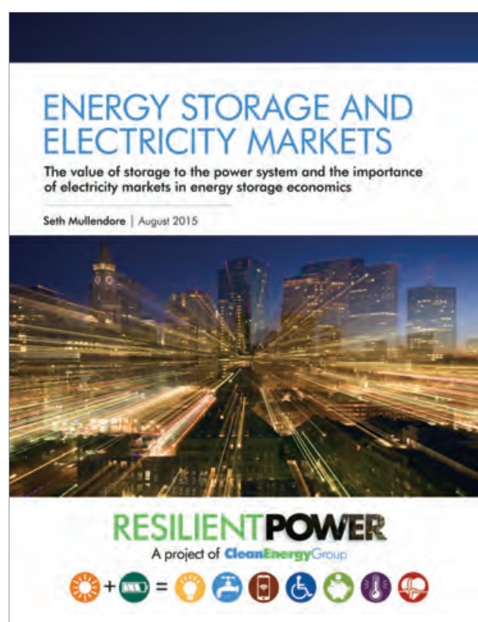
Resilient solar+storage systems differ from typical solar-only installations in two important ways: 1) the ability to disconnect, or island, from the central grid during an outage to continue to generate electricity for the building, and 2) the addition of an energy storage component, usually a battery, to store energy and release it to power loads when needed.

Adding battery storage gives the PV system the flexibility to be used independent of the grid, and gives the solar+storage system owner the capability to control when power is used locally, when it is exported to the grid, and when it is stored for later use. Battery storage may also allow the system owner to benefit throughout the year from utility bill savings and revenue generated by providing grid services.

To learn more about how solar+storage systems work and the benefits they provide, see *http://www.cleanegroup.org/assets/2015/Energy-Storage-101.pdf*

How battery storage can benefit from electricity markets

In order to function properly, the electric power system must operate within a narrow frequency range. Because of this, a constant balance must be maintained between electricity supply (generation) and electricity demand (consumption), both of which are in a constant state of flux. The difficulty in ensuring this balance is further compounded by the fact that today's electric power system has very little capacity to store energy.



To support the balancing and complex operation of the power grid, a number of specifically targeted electricity markets have been developed. Energy storage is able to provide a number of these valuable grid services and has begun to play an important role in two of the most widely adopted and integral electricity market products: ancillary services and demand response.

Ancillary services cover a range of grid support services. For energy storage, the most important market is frequency regulation—providing balancing services to keep grid frequency within operational bounds. Battery storage technologies currently play a large role in providing frequency regulation services in the PJM Interconnection territory, which covers much of the Mid-Atlantic.

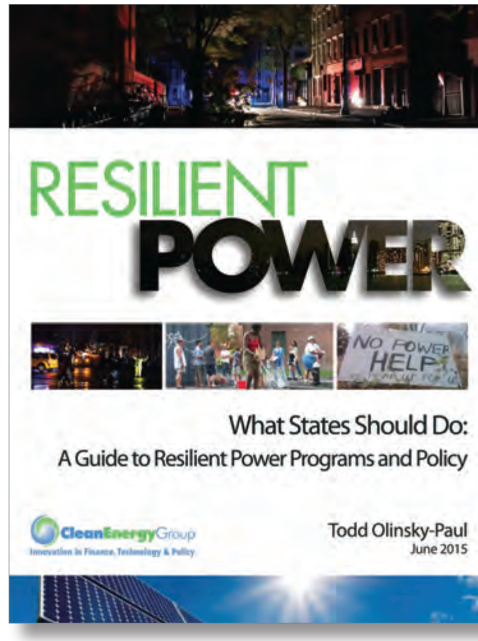
Batteries are also playing an increasing role in utility demand response programs. These programs were developed as a demand side resource to help operators avoid power interruptions at times when consumer electricity demand threatens to exceed available generation supply. Demand response markets for energy storage have been developed in New York, California, and Hawaii and are being explored in other regions of the country as well.

These markets only represent a small fraction of the potential services energy storage can provide to the power system. It is likely that new market opportunities will emerge as grid operators become more familiar with energy storage technologies and the need for flexible resources becomes more apparent as variable renewable generation plays a larger role in the energy mix.

To learn more about the value of battery storage to the power system and the importance of electricity markets in energy storage economics, see *http://www.cleanegroup.org/assets/2015/Energy-Storage-And-Electricity-Markets.pdf*

How public investment can bend new battery storage technologies toward public needs

Economic markets for storage are now starting to take off in a major way, with the market for customer-sited solar+storage systems alone expected to grow to more than $1 billion by 2018 in the United States.[7] Hundreds of battery storage projects are now in the works around the country; however, most are geared to installing battery systems in commercial and industrial customer sites to reduce utility bills or generate revenue.



Fortunately, interest from affordable housing developers in resilient power is occurring at a time of increasing policy support for energy storage. These policy and market advances have already had significant impact throughout the country, especially in California, New York, and the Northeast.

For example, the following programs have been implemented in the Northeast over the past 18 months:

- Massachusetts: $40 million resilient power program for municipalities
- New Jersey: $3 million program for resilient energy storage and $200 million Energy Resilience Bank (the first such institution in the nation)
- Connecticut: $48 million microgrid program
- New York: $40 million community microgrid program
- Vermont: $12.5 million resilient power, solar+storage microgrid project

Because of these state programs, 40 municipalities in the Northeast have resilient power projects underway, which will support more than 90 critical facilities, at a likely capital cost of several hundred million dollars. To learn more about effective state programs to advance resilient power, see *http://www.cleanegroup.org/assets/2015/Resilient-States.pdf*.

How to craft an integrated financing strategy for community resilient power projects

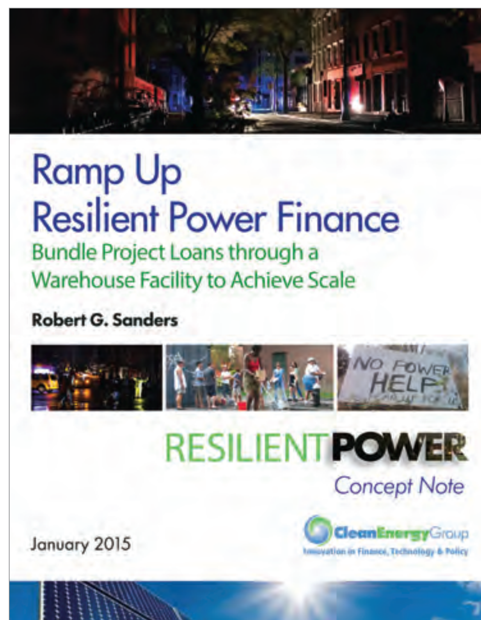
Any financing strategy needs to begin first with multi-family housing developers investigating and determining for themselves the feasibility of solar+storage opportunities for specific properties in their portfolios. Given that demand, an efficient financing strategy will respond to scalable pipelines of projects that can access financing on terms that meet the financing needs of those developers. There are numerous market participants who have roles to play in a financing strategy for solar+storage projects:

- Many solar+storage companies bring their own third-party financing to projects they develop.
- Commercial and state "green" banks can provide debt financing to early stage technology markets once there is demonstrated demand for financing and credit enhancement to reduce risk.
- State and municipal agencies can provide incentives, subsidies, and credit enhancement to reduce project and credit risk.
- Foundations can provide technical assistance funding for project predevelopment expenses, program related investments (PRIs) for credit enhancement, and grants that support new financing programs for resilient power projects.

Rather than a series of one-off projects, one proven approach would be to use a warehouse credit facility to aggregate a portfolio of transactions that share a similar structure and underwriting standard. A warehouse credit facility is a short-term credit facility used to assemble a portfolio of originated loans into a financial security that is sold to investors, ultimately reducing the cost of financing and replenishing capital to be lent again.

One important role of the warehouse credit facility is its ability to communicate the required underwriting criteria, transaction structures, and documentation that transactions need to conform to in order to be purchased and securitized for institutional investors. This is how low-cost, long-term capital can be made available to a pipeline of resilient power projects.

Clean Energy Group has examined the use of warehouse credit facilities for resilient power projects, see *http://www.cleanegroup.org/assets/Uploads/2015-Files/RPP-Concept-Paper-Warehouse-Credit.pdf*



For a complete list of Clean Energy Group's Resilient Power Project resources, including reports and case studies, upcoming and archived webinars, newsletters and more, please visit *www.resilient-power.org*.

APPENDIX B

Analysis Model Data

Full 20-year economic analysis datasets for Analysis Models No. 1-3 found on pages 10-21 of the report. Tables 1-7 and Figures 1-7 within the report Analysis Models are based on the data shown in the following tables.

ANALYSIS MODEL NO. 1

Chicago, Illinois

TABLE B1

20-year economic analysis of a 200-kilowatt solar-only system in a Chicago affordable housing building (values in thousands of dollars).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
PV Energy Savings	0.0	19.9	20.2	20.5	20.8	21.1	21.4	21.8	22.1	22.4	22.7
Frequency Regulation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar Renewable Energy Certificates	0.0	3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6
Operating Expenses	0.0	(4.1)	(4.2)	(4.3)	(4.4)	(4.5)	(4.6)	(4.7)	(4.8)	(4.9)	(5.1)
System Installation/ Replacement Costs	(698.9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(18.3)
Tax Credits & Liabilities	205.5	34.7	59.6	32.9	16.9	16.8	4.8	(9.1)	(9.2)	(9.3)	(1.3)
Net Cash Flow	(493.4)	54.3	79.4	52.9	37.1	37.2	25.3	11.6	11.7	11.8	1.7

	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
PV Energy Savings	23.1	23.4	23.8	24.1	24.5	24.9	25.2	25.6	26.0	26.4
Frequency Regulation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar Renewable Energy Certificates	3.6	3.6	3.5	3.5	3.50	0.0	0.0	0.0	0.0	0.0
Operating Expenses	(5.2)	(5.3)	(5.4)	(5.6)	(5.7)	(5.9)	(6.0)	(6.2)	(6.3)	(11.0)
System Installation/ Replacement Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tax Credits & Liabilities	(9.5)	(9.5)	(9.6)	(9.7)	(9.8)	(8.4)	(8.5)	(8.6)	(8.7)	(6.8)
Net Cash Flow	12.0	12.1	12.3	12.4	12.5	10.6	10.8	10.9	11.0	8.6

TABLE B2

20-year economic analysis of a 200-kilowatt solar and 100-kilowatt/50-kilowatt-hour lithium-ion battery storage system in a Chicago affordable housing building (values in thousands of dollars).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
PV Energy Savings	0.0	19.9	20.2	20.5	20.8	21.1	21.4	21.8	22.1	22.4	22.7
Frequency Regulation	0.0	36.7	36.5	36.3	36.1	36.0	35.8	35.6	35.4	35.3	35.1
Solar Renewable Energy Certificates	0.0	3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6
Operating Expenses	0.0	(6.8)	(7.0)	(7.1)	(7.3)	(7.5)	(7.7)	(7.9)	(8.1)	(8.3)	(8.5)
System Installation/ Replacement Costs	(858.9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(66.3)
Tax Credits & Liabilities	252.5	32.4	63.0	30.4	10.8	10.8	(4.6)	(21.7)	(21.7)	(21.7)	4.7
Net Cash Flow	(606.4)	85.9	116.5	83.8	64.1	64.1	48.7	31.4	31.4	31.3	(8.7)

	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
PV Energy Savings	23.1	23.4	23.8	24.1	24.5	24.9	25.2	25.6	26.0	26.4
Frequency Regulation	34.9	34.7	34.6	34.4	34.2	34.0	33.9	33.7	33.6	33.4
Solar Renewable Energy Certificates	3.6	3.6	3.5	3.5	3.5	0.0	0.0	0.0	0.0	0.0
Operating Expenses	(8.7)	(8.9)	(9.1)	(9.4)	(9.6)	(9.8)	(10.1)	(10.3)	(10.6)	(18.4)
System Installation/ Replacement Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tax Credits & Liabilities	(21.6)	(21.6)	(21.5)	(21.5)	(21.5)	(20.0)	(20.0)	(20.0)	(20.0)	(16.9)
Net Cash Flow	31.3	31.2	31.2	31.1	31.1	29.0	29.0	29.0	29.0	24.5

TABLE B3

20-year economic analysis of a 200-kilowatt solar and 300-kilowatt/150-kilowatt-hour lithium-ion battery storage system in a Chicago affordable housing building (values in thousands of dollars).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
PV Energy Savings	0.0	19.9	20.2	20.5	20.8	21.1	21.4	21.8	22.1	22.4	22.7
Frequency Regulation	0.0	110.1	109.6	109.0	108.5	107.9	107.4	106.8	106.3	105.8	105.2
Solar Renewable Energy Certificates	0.0	3.8	3.7	3.7	3.7	3.7	3.7	$3.6	3.7	3.6	3.6
Operating Expenses	0.0	(12.3)	(12.6)	(12.9)	(13.2)	(13.5)	(13.9)	(14.2)	(14.6)	(15.0)	(15.3)
System Installation/ Replacement Costs	(1178.9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(162.3)
Tax Credits & Liabilities	346.6	27.6	69.9	25.2	(1.8)	(1.5)	(24.9)	(48.2)	(48.0)	(47.8)	16.1
Net Cash Flow	(832.3)	149.1	190.8	145.6	118.0	117.7	93.7	69.8	69.5	69.1	(30.0)

	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
PV Energy Savings	23.1	23.4	23.8	24.1	24.5	24.9	25.2	25.6	26.0	26.4
Frequency Regulation	104.7	104.2	103.7	103.2	102.6	102.1	101.6	101.1	100.6	100.1
Solar Renewable Energy Certificates	3.6	3.6	3.6	3.5	3.5	0.0	0.0	0.0	0.0	0.0
Operating Expenses	(15.7)	(16.1)	(16.5)	(16.9)	(17.3)	(17.8)	(18.2)	(18.7)	(19.1)	(27.1)
System Installation/ Replacement Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tax Credits & Liabilities	(47.3)	(47.0)	(46.8)	(46.5)	(46.3)	(44.6)	(44.4)	(44.1)	(43.9)	(40.6)
Net Cash Flow	68.4	68.1	67.7	67.4	67.0	64.6	64.3	63.9	63.6	58.8

ANALYSIS MODEL NO. 2

Washington, D.C.

TABLE B4

20-year economic analysis of a 360-kilowatt solar-only system in a Washington, D.C. affordable housing building (values in thousands of dollars).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
PV Energy Savings	0.0	35.8	36.4	36.9	37.5	38.0	38.6	39.2	39.7	40.3	40.9
Frequency Regulation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar Renewable Energy Certificates	0.0	211.9	210.8	209.7	208.7	207.6	103.3	102.8	102.3	101.8	101.3
Operating Expenses	0.0	(7.1)	(7.3)	(7.4)	(7.6)	(7.8)	(8.0)	(8.2)	(8.4)	(8.6)	(8.8)
System Installation/ Replacement Costs	(1116.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(32.9)
Tax Credits & Liabilities	328.1	(22.4)	22.3	(25.1)	(56.9)	(56.6)	(34.9)	(58.8)	(58.8)	(58.7)	(44.2)
Net Cash Flow	(787.9)	218.2	262.2	214.1	181.7	181.3	99.0	74.9	74.8	74.7	56.3

	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
PV Energy Savings	41.5	42.2	42.8	43.4	44.1	44.7	45.4	46.1	46.8	47.5
Frequency Regulation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar Renewable Energy Certificates	100.7	100.2	99.7	99.2	98.7	0.0	0.0	0.0	0.0	0.0
Operating Expenses	(9.1)	(9.3)	(9.5)	(9.8)	(10.0)	(10.2)	(10.5)	(10.8)	(11.0)	(16.7)
System Installation/ Replacement Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tax Credits & Liabilities	(58.6)	(58.6)	(58.5)	(58.5)	(58.4)	(15.2)	(15.4)	(15.5)	(15.7)	(13.5)
Net Cash Flow	74.6	74.6	74.5	74.4	74.4	19.3	19.5	19.8	20.0	17.2

TABLE B5

20-year economic analysis of a 360-kilowatt solar and 100-kilowatt/50-kilowatt-hour battery storage system in a Washington, D.C. affordable housing building (values in thousands of dollars).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
PV Energy Savings	0.0	35.8	36.4	36.9	37.5	38.0	38.6	39.2	39.7	40.3	40.9
Frequency Regulation	0.0	36.7	36.5	36.3	36.2	36.0	35.8	35.6	35.4	35.3	35.1
Solar Renewable Energy Certificates	0.0	211.9	210.8	209.7	208.7	207.6	103.3	102.8	102.3	101.8	101.3
Operating Expenses	0.0	(9.8)	(10.1)	(10.3)	(10.6)	(10.8)	(11.1)	(11.4)	(11.7)	(12.0)	(12.3)
System Installation/ Replacement Costs	(1276.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(80.9)
Tax Credits & Liabilities	375.1	(23.6)	25.7	(26.3)	(60.0)	(59.6)	(42.5)	(67.9)	(67.7)	(67.6)	(34.4)
Net Cash Flow	(900.9)	251.0	299.3	246.4	211.8	211.2	124.1	98.3	98.1	97.8	49.8

	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
PV Energy Savings	41.5	42.2	42.8	43.4	44.1	44.7	45.4	46.1	46.8	47.5
Frequency Regulation	34.9	34.7	34.6	34.4	34.2	34.0	33.9	33.7	33.5	33.4
Solar Renewable Energy Certificates	100.7	100.2	99.7	99.2	98.7	0.0	0.0	0.0	0.0	0.0
Operating Expenses	(12.6)	(12.9)	(13.2)	(13.5)	(13.9)	(14.2)	(14.6)	(14.9)	(15.3)	(22.6)
System Installation/ Replacement Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tax Credits & Liabilities	(67.3)	(67.1)	(67.0)	(66.8)	(66.7)	(26.4)	(26.4)	(26.5)	(26.5)	(23.8)
Net Cash Flow	97.4	97.2	96.9	96.7	96.5	38.2	38.3	38.4	38.4	34.4

ANALYSIS MODEL NO. 3

New York City

TABLE B6

20-year economic analysis of a 30-kilowatt solar-only system in a New York City affordable housing building (values in thousands of dollars).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
PV Energy Savings	0.0	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.3
Demand Charge Reduction Savings	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar Renewable Energy Certificates	0.0	(0.6)	(0.6)	(0.6)	(0.7)	(0.7)	(0.7)	(0.7)	(0.7)	(0.8)	(0.8)
Operating Expenses	(105.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(9.0)
System Installation/ Replacement Costs	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tax Credits & Liabilities	23.3	8.2	13.1	7.9	4.7	4.7	2.4	0.0	0.0	0.0	0.0
Net Cash Flow	(57.7)	13.0	18.1	13.0	10.0	10.2	8.0	5.9	6.1	6.3	(2.5)

	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
PV Energy Savings	7.5	7.7	8.0	8.3	8.5	8.8	9.1	9.4	9.7	10.1
Demand Charge Reduction Savings	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar Renewable Energy Certificates	(0.8)	(0.8)	(0.9)	(0.9)	(0.9)	(0.9)	(1.0)	(1.0)	(1.0)	(1.1)
Operating Expenses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
System Installation/ Replacement Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tax Credits & Liabilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Cash Flow	6.7	6.9	7.1	7.4	7.6	7.9	8.2	8.4	8.7	9.0

TABLE B7

20-year economic analysis of a 30-kilowatt solar and 30-kilowatt/60-kilowatt-hour lead-acid battery storage system in a New York City affordable housing building (values in thousands of dollars).

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
PV Energy Savings	0.0	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.3
Demand Charge Reduction Savings	0.0	1.8	1.8	1.9	1.9	1.9	2.0	2.0	2.1	2.1	2.1
Solar Renewable Energy Certificates	0.0	(2.4)	(2.5)	(2.5)	(2.6)	(2.7)	(2.8)	(2.9)	(3.0)	(3.0)	(3.1)
Operating Expenses	(205.0)	0.0	0.0	0.0	0.0	0.0	0.0	(18.0)	0.0	0.0	(18.0)
System Installation/ Replacement Costs	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tax Credits & Liabilities	53.3	16.0	25.6	15.4	9.2	9.2	4.6	0.0	0.0	0.0	0.0
Net Cash Flow	(127.7)	20.8	30.6	20.5	14.5	14.6	10.2	(12.3)	5.9	6.1	(11.8)

	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
PV Energy Savings	7.5	7.7	8.0	8.3	8.5	8.8	9.1	9.4	9.7	10.1
Demand Charge Reduction Savings	2.2	2.2	2.2	2.3	2.3	2.3	2.4	2.4	2.4	2.5
Solar Renewable Energy Certificates	(3.2)	(3.3)	(3.4)	(3.5)	(3.6)	(3.7)	(3.9)	(4.0)	(4.1)	(4.2)
Operating Expenses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
System Installation/ Replacement Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tax Credits & Liabilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Cash Flow	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.9	8.1	8.3

KEY PROJECT STAFF

Lewis Milford

PRESIDENT

Lewis Milford is president and founder of Clean Energy Group (CEG) and Clean Energy States Alliance (CESA), two national nonprofit organizations that work with state, federal, and international organizations to promote clean energy technology, policy, finance, and innovation. Mr. Milford is also a nonresident senior fellow at the Brookings Institution. He works with many public agencies and private investors in the United States and Europe that finance clean energy. Mr. Milford is frequently asked to appear as an expert panelist at energy conferences throughout the United States and Europe. His articles on clean energy have appeared in many print and online publications including *The New York Times, The Boston Globe, The National Journal, The Huffington Post*, and *Renewable Energy World*. Before founding these two organizations, he was vice president of Conservation Law Foundation, New England's leading environmental organization. Prior to that, he was a government prosecutor on the Love Canal hazardous waste case in New York and previously directed the Public Interest Law Clinic at American University Law School where he represented veterans on a range of legal issues, including gaining compensation for their harmful exposure to Agent Orange and nuclear radiation. He has a J.D. from Georgetown University Law Center.
LMilford@cleanegroup.org

Seth Mullendore

PROJECT MANAGER

Seth Mullendore is a project manager for Clean Energy Group, where he serves as an analyst and technical adviser for power systems, solar PV applications, and battery storage projects. Mr. Mullendore works with state and municipal policy leaders, and project developers on outreach and coordination of energy storage project development, and he provides research and reporting of energy storage technologies, policies, and supporting market structures. Prior to joining Clean Energy Group, he served as a Sustainable Energy Fellow with Union of Concerned Scientists and worked with Maine Clean Communities to help advance clean transportation initiatives in Maine. Seth has participated in a number of academic research projects directly related to renewable energy, energy storage, and energy equity. Mr. Mullendore holds a M.S. in Civil & Environmental Engineering from Stanford University, and a B.S. in Geosciences from the University of Southern Maine.
Seth@cleanegroup.org

Todd Olinsky-Paul

PROJECT DIRECTOR

As project director for Clean Energy Group and Clean Energy States Alliance (CESA), Todd Olinsky-Paul directs the Energy Storage and Technology Advancement Partnership (ESTAP), a federal-state funding and information sharing project that aims to accelerate the deployment of electrical energy storage technologies in the United States. He also works on resilient power in the areas of combined-heat-and-power (CHP) and critical infrastructure energy resiliency. Todd joined CESA from the Pace Energy and Climate Center, where he served as the Manager of Communications, Education, and Outreach, as well as an Energy Policy Analyst. His recent work has focused on energy storage technologies and policy, renewable thermal generation and siting issues, renewable energy and grid interactions, financing and policy incentives, and emerging technologies. He has authored numerous reports for state and federal agencies. Mr. Olinsky-Paul has a M.S. in Environmental Policy from Bard College and a B.A. from Brown University.
Todd@cleanegroup.org

Robert Sanders

SENIOR FINANCE DIRECTOR

With over twenty-five years of experience in community development and energy-related commercial finance, Rob Sanders has deep expertise in designing, implementing and evaluating financing programs, financial products and related services in the areas of clean energy and sustainable community development. As senior finance director for Clean Energy Group, Mr. Sanders has written extensively about clean energy finance and resilient power, especially in connection with economically disadvantaged communities. Mr. Sanders was formerly the Managing Director of Energy Finance for The Reinvestment Fund, a leading innovator in the financing of neighborhood and economic revitalization. In this capacity, he served as Fund Manager for the Sustainable Development Fund, a $32 million fund created by the Pennsylvania PUC to promote renewable energy and energy efficiency, as well as TRF Fund Manager for the Pennsylvania Green Energy Loan Fund and the Philadelphia metropolitan area EnergyWorks Loan Fund. As lead for all energy investing, he made loans, leases, equity investments and performance-based grant incentives. Mr. Sanders holds an M.C.P. from the University of California at Berkeley and a B.A. from Stanford University.
RSanders@cleanegroup.org

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Clean Energy Group (CEG) is a national, nonprofit organization that promotes effective clean energy policies, develops low-carbon technology innovation strategies, and works on new financial tools to advance clean energy markets. CEG works at the state, national, and international levels with stakeholders from government, the private sector, and nonprofit organizations. CEG promotes clean energy technologies in several different market segments, including resilient power, energy storage, solar, and offshore wind. Above all, CEG also works to create comprehensive policy and finance strategies to scale up clean energy technologies through smart market mechanisms, commercialization pathways, and financial engineering. CEG created and now manages a sister organization, the Clean Energy States Alliance, a national nonprofit coalition of public agencies and organizations working together to advance clean energy through public funding initiatives.

CleanEnergyGroup

50 State Street, Suite 1, Montpelier, VT 05602
Phone 802.223.2554 • Fax 802.223.4967
Email info@cleanegroup.org • Web www.cleanegroup.org