Jump-Start

How Activists and Foundations Can Champion Battery Storage to Recharge the Clean Energy Transition

CleanEnergyGroup
Innovation in Finance, Technology & Policy

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CLEAN ENERGY GROUP

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. Neither organization accepts corporate contributions.

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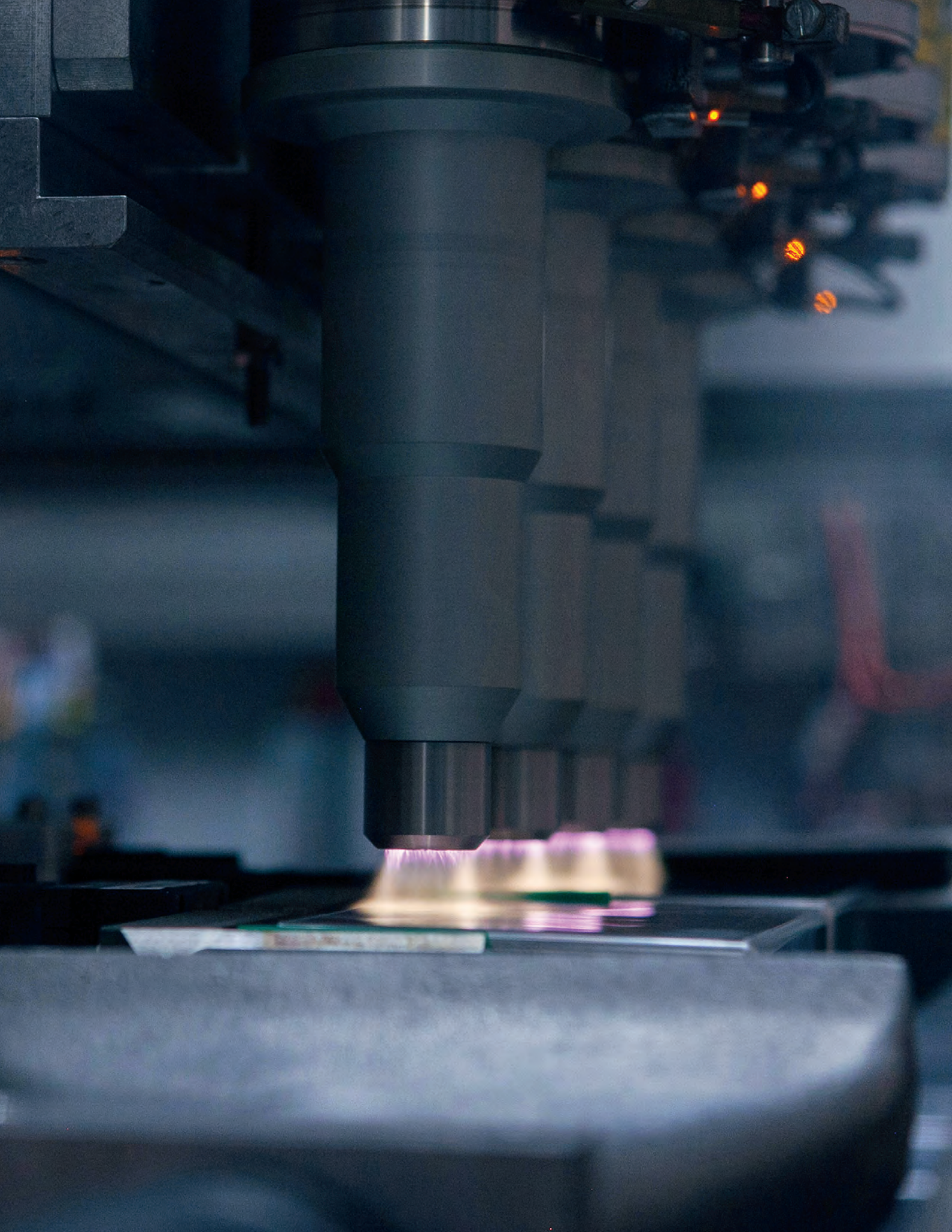
Contents



Introduction

Why we wrote this report

> "Several of the big trends in in clean electricity depend, in one way or another, on batteries. How fast batteries get better and cheaper will help determine how fast renewable energy grows, how fast fossil fuel power plants get shut down, and how fast the vehicle fleet electrifies."
>
> **David Roberts**, *Vox*[1]

This report is for activists and foundations who want to understand how battery storage can become a new part of their clean energy and climate advocacy. It is designed to explain the many emerging economic, equity, and environmental trends for battery storage use across all elements of the energy system.

It argues that activists and foundations need creative new strategies to advocate for battery storage in these changing markets.

It tries to answer two basic questions for advocates and foundations: what do we need to know to understand these opportunities, and what actions should we support to realize them?

These are not theoretical concerns. Clean Energy Group (CEG) has been involved in energy storage policy from the public-interest perspective for the last five years.

Lithium-ion battery cells are cleaned with plasma gas at the BMW factory in Germany.

Groups as diverse as cities, low-income community groups, industry, environmental advocates, foundations, and investors have asked us these questions.

We have prepared this handbook to synthesize and share our knowledge about battery storage policies and our experience working on these market development issues.

We recommend more than 50 key actions that should be taken to make battery storage an essential part of the clean energy transition.

But having said that, this is only a framework, not an encyclopedia of knowledge. This battery storage advocacy field guide likely will raise more questions than it answers. And it certainly is not complete or the final word, as we could well have missed some important issues.

> ***We have prepared this handbook to synthesize and share our knowledge about battery storage policies and our experience working on these market development issues.***

What's more, some of what we say likely will be discounted or opposed by those with different views, which is expected on these controversial issues.

But it should, if considered as a whole, prompt more action and calls for change for how we could advance battery storage, either as a stand-alone system or paired with renewables, to meet our environmental, equity, economic development, and public safety goals.

This paper is arranged in two parts.

The first part outlines 10 key issue areas where CEG has developed a reasonably sound understanding of current market trends in battery storage, the benefits from the technology, and the actions to accelerate change:

1. ***Lower Electric Bills: Reducing Demand Charges.*** The commercial customer-sited economic case for behind-the-meter battery storage.
2. ***Resilient Power: Providing Protection in Storms and Outages.*** In disasters and every-day life, resilient solar PV and battery storage (solar+storage) systems prove better options to protect against power outages.
3. ***Equity and Justice: Bending the Arc of the Technology Curve toward Vulnerable Populations.*** Low-income people should benefit from resilient power now, not years from now through technology trickle down.

View inside the battery storage container at the Stafford Hill Microgrid in Rutland, VT.

4. ***Public Health: Creating Greater Protection for Medical Care and Hospitals.*** Health care facilities should start to explore use of solar+storage for cost reductions and power protection.
5. ***Finance: From Mainstream to Low-Income Markets.*** A tale of two financial worlds demands more action to get new resilient power technologies to the poor.
6. ***The Future of Solar: It's Storage.*** With changing net metering policies, evolving utility rates, and the need for more flexible generation, storage is essential to future success of solar.
7. ***Emissions Reductions: Replacing Fossil-Fueled Peaker (and Maybe Baseload?) Plants.*** Battery storage could soon put fossil-fueled peaker plants at economic risk, a competitive disruption possibly facing existing fossil-fueled baseload plants over the longer term.
8. ***Utility Markets: Emerging Role of Large-Scale Energy Storage Systems.*** In-front-of-the-meter battery storage is a way to reduce grid-level capacity payments and secure other system benefits.

9. ***Electric Vehicle Charging: Optimizing Price and Reducing Power Outages at Public Charging Stations.*** Utility demand charges and the risk of power outages demand use of on-site storage at public EV charging stations along major highways and transportation routes.

10. ***International: Becoming a Global Market.*** The time is right for an international collaborative effort to scale up storage and overcome market obstacles.

The island of Ta'u in American Samoa has a solar-powered microgrid with over 5,000 solar panels generating 1.4 megawatts of electricity and 60 Tesla Powerpacks, which could power the island's electricity needs for up to three days.

Each of the 10 areas addresses three basic concerns:

- The Issues
- The Opportunities and Challenges
- The Actions

The second part of the paper then explores more recent issues that we have not worked on in detail, but enough to suggest much more analysis and discussion is needed to determine the proper role for battery storage.

The topics covered in the "*Emerging Issues: At the Beginning of the Transition*" part of the paper, include:

- Will residential systems ever have an economic case for storage?
- Will zero net energy (ZNE) efforts require storage to be part of any building solution?
- What role will storage play in the build out of wind power, especially its role in offshore wind projects?
- Will power-to-gas, a process that converts electrical power to a gas fuel, play a role in long-term energy storage?
- How important will storage be for the economic deferral of utility transmission and distribution system costs?
- What safety standards are needed for the installation of lithium-ion batteries?
- In disasters, should portable solar+storage emergency backup units be made available by emergency responders?
- What must happen to reduce the social and other impacts of the extraction of raw materials for batteries?
- What are the odds that lithium-ion batteries become the indisputable industry standard?
- Is it likely that electric vehicle batteries would be used collectively to support the grid?
- Will batteries power airplanes some day?
- In monopoly utility states, can PURPA be used to force utilities to accept storage projects?
- Can the ubiquitous "blockchain" movement be used to support a peer-to-peer energy marketplace for solar+storage?
- What's the best federal role to support storage?
- Is there a "right to storage?"

If clean energy and climate activists and their funders do not develop a strategic focus on battery storage, they will miss what could be this generation's greatest clean energy opportunity.

For each topic, we suggest some paths for further inquiry, advocacy, and philanthropy.

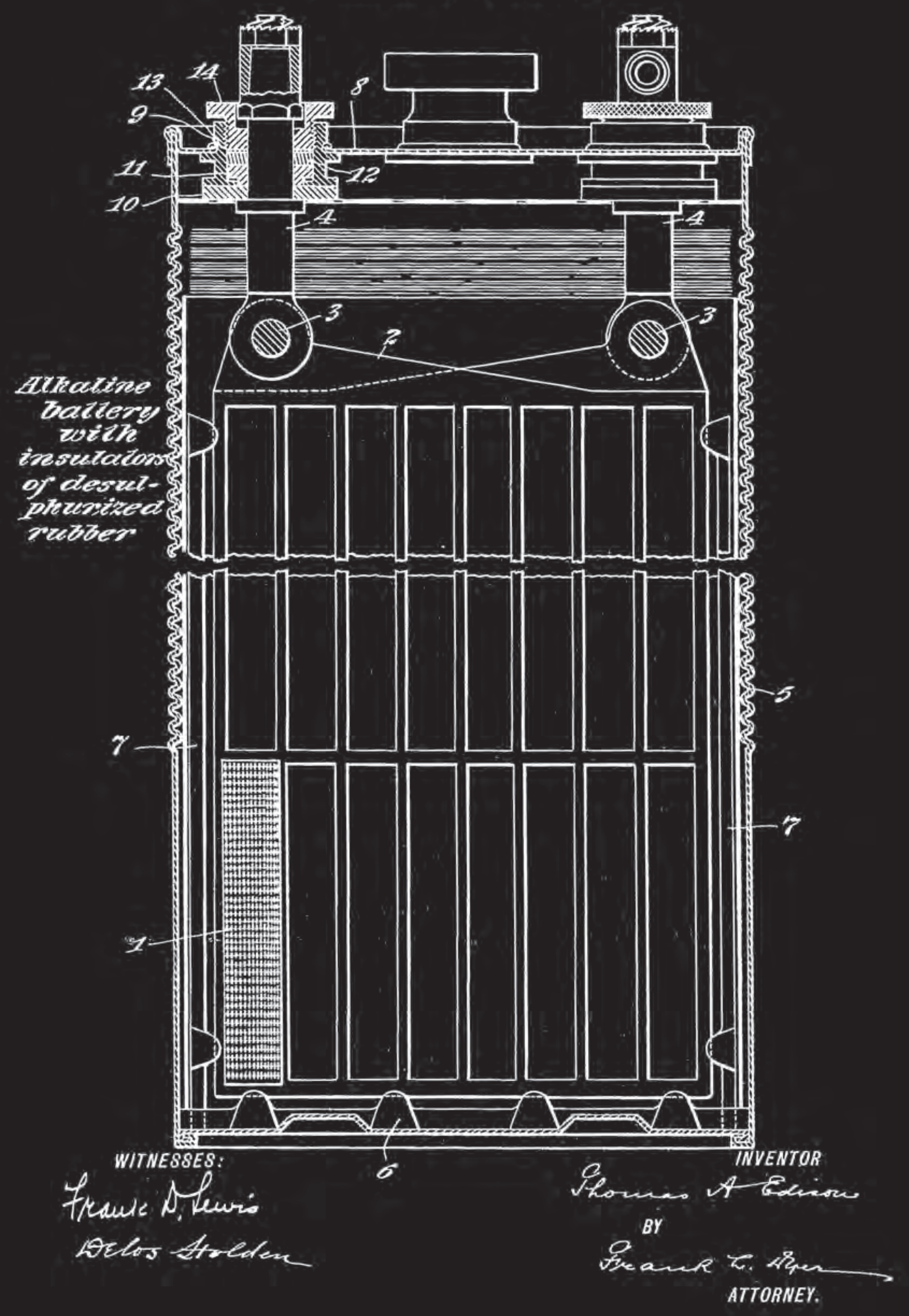
This guide identifies many significant opportunities for activists and foundations to support battery storage market strategies, so that storage and renewables can produce major environmental, equity, and economic benefits now, not just in the future. This is a hopeful document. Its premise is that we are on the cusp of a significant technological change in energy that we've not seen for over 100 years. But this is also a cautionary warning with a serious message. ***If clean energy and climate activists and their funders do not develop a strategic focus on battery storage, they will miss what could be this generation's greatest clean energy opportunity.***

No. 827,297. PATENTED JULY 31, 1906.

T. A. EDISON.

ALKALINE BATTERY.

APPLICATION FILED JULY 21, 1904.



Background

Why energy storage is important now

"Falling capex costs, an increasing need for flexible resources and greater confidence in the underlying technology will continue to drive energy storage uptake. . . . Policies rather than economics alone will determine the rate of uptake."

Bloomberg New Energy Finance[1]

The inventor of the battery had few realistic hopes for its success. In 1893, Thomas Alva Edison, with the light bulb created, had nothing but contempt for his battery competitors' claims to store electricity, and nothing but praise for his own invention. He told this to a reporter:

> The storage battery is, in my opinion, a catch-penny, a sensation, a mechanism for swindling by stocking companies. The storage battery is one of those peculiar things which appeal to the imagination, and no more perfect thing could be desired by stock swindlers than that very self-same thing. In 1879, I took up that question, and devised a system of placing storage batteries in houses connected to mains and charging them in the day time, to be discharged in the evening and night to run incandescent lamps.[2]

But despite his confident public stance, privately he was aware of his own battery's limitations. Frustrated by years of design problems, with over 140 battery patents, he wrote to his wife that "he hoped there would be no batteries in heaven."[3]

Thomas Edison's 1906 patent for an alkaline battery.

As it turned out, his nickel-iron battery didn't fare much better than his competition. While it was an early success in the first generation of electric cars, it was driven into the trash heap of technological history by the more reliable, mass produced, gas-powered Model T.

The world's leading technology consultant, McKinsey, now says battery storage is the "next disruptive technology in the power sector." According to a 2017 report, "low-cost storage could transform the power landscape."

But time often proves some geniuses to have been right all along. It has taken over a century for the technology to overcome many of its nascent shortcomings. Today, battery storage seems finally on a solid path to match Edison's early boasts.

The world's leading technology consultant, McKinsey, now says battery storage is the "next disruptive technology in the power sector."[4] According to a 2017 report, "low-cost storage could transform the power landscape." The implications are profound:

> At today's lower prices, storage is starting to play a broader role in energy markets, moving from niche uses such as grid balancing to broader ones such as replacing conventional power generators for reliability, providing power-quality services, and supporting renewables integration.[5]

The impressive results for storage are in for 2017. Battery installations were up 27 percent to 431 megawatt hours in 2017. And that growth is expected to double in 2018.[6]

The long-term future potential for market growth is also huge, according to a 2018 study from the Brattle Group:

> The study finds that storage market potential could grow to 50,000 MW over the next decade if storage costs continue to decline and state regulatory policies… remove barriers that prevent storage resources from realizing multiple value streams.[7]

This long arc of technological history is important context for how advocates, foundations, and policymakers have approached clean energy strategies in more recent times—with targeted programs and persistent patience—and why such an approach for battery storage is needed now.

Since the 1980s, energy and environmental advocates have promoted technology-specific clean energy policies and public investments. Thirty years ago, these early movements were focused on energy efficiency. The strategies expanded to utility-scale wind in the 1990s and then to distributed solar at the turn of the century.

Targeted utility incentives for energy efficiency jumpstarted the clean energy market, and they are the mainstay today, three decades after their inception. State and federal policies have created tax credits for wind and solar, state-level utility investment charges, renewable portfolio standards, and net metering for solar photovoltaics (PV) systems, which have led to extraordinary cost reductions and scale up of clean energy markets.

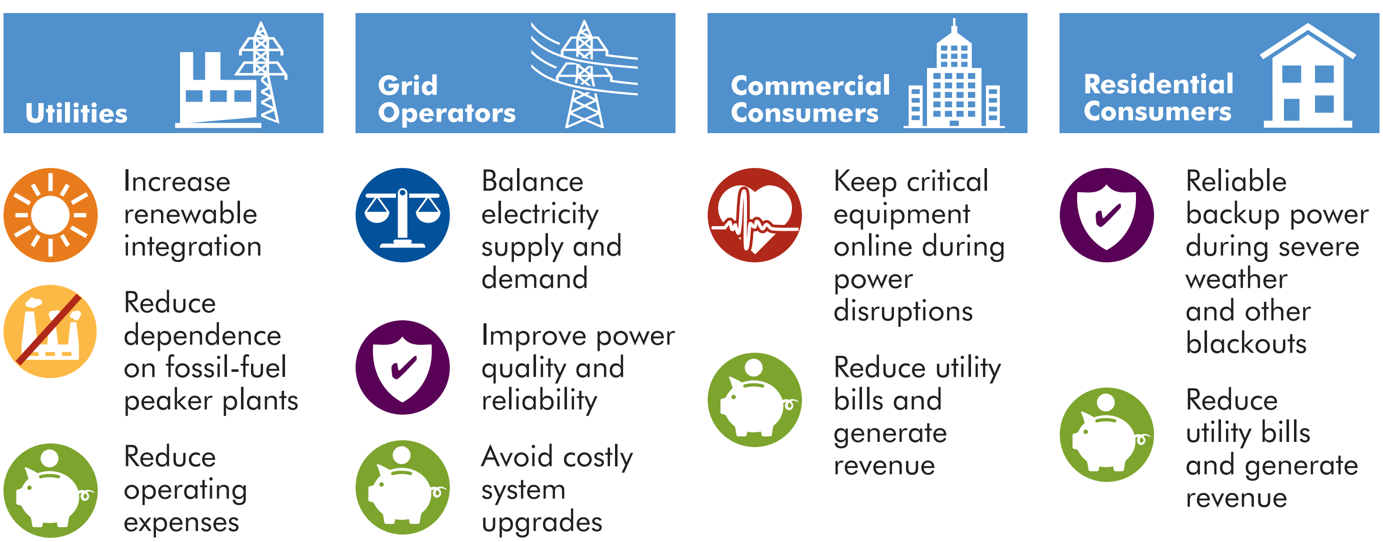
More recently, advocates have called for environmental justice and equity strategies to ensure that these clean energy programs are fairly designed and justly administered to benefit low-income communities.[8]

Now, after a hundred years of technology improvement, an old enabling technology—battery storage[9]—has emerged anew. Whether the title is deserved yet, it is repeatedly called the "holy grail" of clean energy as it could solve the variable production problem faced by many renewable energy technologies, the same power shifting challenge Edison tried to solve.

The technology might well transform all sectors of the economy, with the potential to enable the eventual decarbonization of our energy system.

FIGURE 1

The Value of Storage



Energy storage technologies have the capacity to benefit each segment of the power system.

As shown on Figure 1 (p. 11), battery storage is a complex technology that has ever growing applications:

- It can be scaled to work with different electric generation systems, from building level to baseload power.
- It can be combined with distributed generation technologies such as solar or wind (onshore or offshore) to reduce fossil fuel emissions.
- It can produce versatile benefits, including economic, health, safety, and energy resiliency.
- It can reduce utility demand charges and electric bills for commercial customers and vulnerable low-income residents.
- It can be used by utilities to reduce regional capacity payments.
- It can generate revenue from grid applications like frequency regulation.
- It can provide resilient power for community microgrids like those envisioned for Puerto Rico.
- It can work in transportation, by enabling electric vehicle (EV) public charging stations to reduce their utility charges, or perhaps, according to some of its wildest boosters, to power electric airplanes.

The technology might well transform all sectors of the economy, with the potential to enable the eventual decarbonization of our energy system.

These varied uses, which will only expand over time, are what makes battery storage technology so important to clean energy and climate change. While we are at the earliest stages of this technology's development, storage could be a critical transformational enabling energy technology for this century.

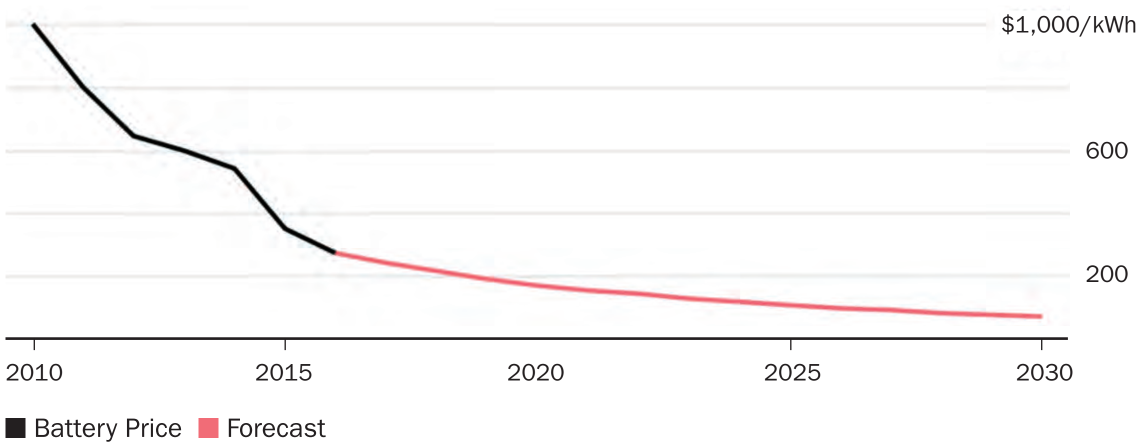
Whether it lives up to this potential will depend on technology developments and policies.

We have seen an historic reduction in the cost of battery storage in the last few years. No longer a distant dream of Edison, cost declines have made battery storage an everyday part of our lives—from laptops to electric vehicles to stationary, building-sized batteries.

The price of lithium-ion batteries dropped more than 70 percent between 2010 and 2016, following a pattern of 19 percent cost reductions with every doubling of global capacity, a trend that is expected to continue, as shown in Figure 2.[10]

And, right on time, according to Bloomberg New Energy Finance's most recent 2017 numbers, the costs of battery storage have "fallen by a remarkable 24 percent since 2016"—far exceeding their earlier projections.

FIGURE 2
Falling Prices of Lithium-Ion Batteries



Source: Bloomberg New Energy Finance

Every time the global supply of batteries doubles, prices drop 19 percent.

In a late March 2018 cost update, BNEF wrote, "the conclusions are chilling for the fossil fuel sector."[11]

Battery technology is not made by hand as in Edison's day, and its costs are not tied to volatile fossil fuel prices. Rather, this is the first time in history that energy technologies like solar—and now battery storage—can benefit from the same cost-reducing, manufacturing economies of scale that produce ever cheaper and ubiquitous information-age technologies like personal computers, cell phones, and disk drives.[12]

Due to cost reductions, there are three obvious storage applications where the economics work now.

First, they make financial sense for commercial-customer applications located behind the meter, where batteries can reduce demand changes and provide resiliency, while adding value to solar installations at the same time.

Second, battery storage also could replace economically a significant number of the hundreds of gas peaker plants—especially those polluting, less frequently run plants located in heavily congested grid areas with high utility costs—in the next few years.

And third, there are numerous utility-scale storage projects coming on line in many states that will enable more renewable energy resources onto the grid and reduce transmission and capacity costs.

These three, reasonably certain, economically-driven markets could propel storage into the mainstream and produce significant environmental and economic benefits.

Additionally, in future energy markets, there might be ways for renewables and storage to replace or reduce reliance on baseload fossil-fueled plants, a topic of intense debate.

To crack these markets, there are still numerous barriers inhibiting greater storage adoption, as was the case for the solar industry about 20 years ago. For storage, these barriers include information gaps about technology options, costs, safety, benefits, and other market barriers; an absence of coordinated state and federal policies and programs to achieve cost reductions and encourage market uptake; and a lack of constancy across available incentives, financing options, and business models.

All of this gets to the message of this paper: we need to jump-start new strategies for clean energy, climate, and environmental justice advocacy that fully incorporate the benefits from battery storage.

We have seen some limited combination of federal tax credits, state mandates, incentives, and other programs begin to shape the direction of early storage market development. But to overcome these obstacles and scale up the technology in time to address climate and other pressing energy needs, more supportive policies and strategies are needed.

Future storage policies are likely to resemble more the socket wrench than the hammer, geared to fit the multiple and still emerging applications that this technology offers. Like technology innovation itself, this policy process should be driven by progress and adapted to new data and opportunities—ratcheted to fit new markets taking shape. Different types of analyses and policies will be needed for each application.

All of this gets to the message of this report: we need to jump-start new strategies for clean energy, climate, and environmental justice advocacy that fully incorporate the benefits from battery storage.

The environmental community and its philanthropic supporters should lead this effort. They can help shape this 100-year-old technology curve to serve public purposes today—reduced carbon emissions, broad clean energy equity, and expanded economic benefits—and not just to serve short-term, private interests, but to benefit all.

The Resilient Power Project

The Resilient Power Project, a joint initiative of Clean Energy Group and Meridian Institute, works to accelerate market development of solar photovoltaics (PV) plus battery energy storage (solar+storage) technologies for resilient power applications serving low-income communities. The Resilient Power Project advances the following strategies to provide new technology solutions in affordable housing and critical community facilities to address key climate and resiliency challenges:

> **Community Resiliency** — Solar+storage can produce revenue streams and reduce electricity bills, enhancing equity and community economic resiliency.
>
> **Climate Adaptation** — Solar+storage systems can provide highly reliable power resiliency as a form of climate adaptation in severe weather, allowing residents to shelter in place during power disruptions with cleaner and healthier solutions.
>
> **Climate Mitigation** — Battery storage is an enabling technology and emerging market driver to increase adoption of solar PV and other distributed, clean energy generation; and for emerging baseload power applications that advance carbon emission reduction efforts.

The Resilient Power Project is designed to bend the arc of the emerging solar+storage technology market to equitably benefit all sectors of the public, especially the poor and disadvantaged—not as an afterthought, but in its early stages as a matter of foundational market and policy design.

The Project undertakes original economic and technical research and analysis and identifies market opportunities and barriers to widespread adoption of solar+storage systems. The Project produces reports and webinars focused on resilient power and solar+storage policy developments and projects from across the country, showcasing leading business, policy, and community advocates.

It collaborates with the Clean Energy States Alliance (CESA) on its Energy Storage Technology Advancement Partnership (ESTAP) Project, with the U.S. Department of Energy and Sandia National Lab, (see *http://bit.ly/CESA-ESTAP*), as well as CESA's efforts with states to develop low-income solar+programs programs for low-income communities.

The Resilient Power Project is supported by the generous support of The JPB Foundation, The Kresge Foundation, Surdna Foundation, Barr Foundation, Energy Foundation, Jane's Trust, The Nathan Cummings Foundation, The Merck Family Fund, and the 11th Hour Project. **www.resilient-power.org**

Top Ten Trends to Cha

Below is an overview of ten trending issue areas and benefits of battery storage that will be explained in the following sections of the report. They are meant to give the reader a brief summary of key reasons to champion more rapid deployment of energy storage technologies to meet environmental, equity, economic development, and public safety goals.

1 Lower Electric Bills

Reducing Demand Charges

Millions of commercial utility customers across a multitude of states have the potential to lower their electricity bills with battery storage, but few established behind-the-meter markets currently exist. As with expanding solar markets, the economic opportunities for storage must be paired with supportive policies and programs to establish thriving markets and ensure that all customers are able to tap into the cost-saving benefits of battery storage.

2 Resilient Power

Providing Protection in Storms and Outages

Battery storage is increasingly an option for meeting power needs after disasters, like the unprecedented number this country has faced this past year. With power outages on the rise, the status quo energy systems have failed too often, resulting in death, damage, and prolonged suffering. Better technology solutions such as solar+storage are now viable alternatives to protect people from the dangers of power outages before, during, and after the next storm.

3 Equity and Justice

Bending the Arc of the Technology Curve toward Vulnerable Populations

Early adopters of innovative, disruptive technologies are typically the well-to-do and, so far, battery storage is no exception. Most of the economic benefits of storage are now realized by commercial utility customers who are saving money from these systems through electricity bill reductions. Very few of these projects are in disadvantaged communities; ironically, low-income customers need the benefits of solar and battery storage systems the most. Advocacy and policy must be directed to ensure that all commu-nities benefit from these technologies now, not ten years from now.

4 Public Health

Providing Greater Protection for Medical Care and Hospitals

We are at a critical period where solar+storage solutions can, for the first time, be deployed at scale resulting in significant health benefits while improving economic conditions and addressing issues of equity and climate mitigation. This is the future of more resilient health care: using resilient and clean power systems that do not fail when they are needed, that are supported by renewable power and battery storage, and that help health care delivery systems do their job.

mpion Battery Storage

5 Finance

From Mainstream to Low-Income Markets

Low- and moderate-income (LMI) communities have lagged far behind commercial and upscale markets in implementing solar+storage technologies. Contributing to that challenge is a persistent financing gap. There are new ownership and finance models beginning to address the economic barriers to deploy resilient power technologies in disadvantaged communities, as well as market-building interventions that foundations and advocates could use to leverage additional sources of capital to advance solar+storage solutions in these markets.

6 The Future of Solar

It's Storage

As more solar PV is connected to the grid, eventually leading to oversupply and solar curtailment, its value to the grid decreases. By transforming solar into a flexible, responsive, dispatchable resource, energy storage can preserve the value of solar to the power system. It can insulate solar customers from adverse changes to solar policies and utility rate structures that could jeopardize the value of their clean energy investments.

7 Emission Reductions

Replacing Fossil-Fueled Peaker (and Maybe Baseload?) Plants

Storage could replace existing and new, uneconomic gas-fired peaker plants, especially in congested urban distribution areas, in the coming years. Over the long term, whether solar+storage could operate as an economic, baseload firm resource is a critical and contentious issue in clean energy policy. Both of these opportunities call for more systematic work on storage—to understand how market-based, declining cost and longer duration discharge trends impact whether storage and renewables could significantly reduce fossil fuel emissions from the power system by mid-century, a key decarbonization target.

8 Utility Markets

The Emerging Role of Large-Scale Energy Storage Systems

Without storage, generation and transmission must be overbuilt to accommodate rare demand peaks and to maintain grid stability, while integrating high volumes of variable resources like solar and wind. Energy storage can help to solve these problems, while providing other valuable grid services as a least-cost alternative that pays for itself. And these benefits can be provided by batteries installed behind customer meters as well as from batteries on utility distribution grids.

9 Electric Vehicle Charging

Prices and Power Outages at Public Charging Stations[1]

Public fast charging stations for electric vehicles face some of the same utility "demand charges" that are now prevalent in most commercial building rates. Conventional ratemaking likely will not lower demand charges to levels that will be acceptable to the public, which will not tolerate variable, high rates for charging their electric vehicles. Similarly, charging stations will be subject to the same power outage problems facing the electric grid. On-site battery storage at charging stations could be the technology solution that addresses both the demand charge and power outage problems, results that require dedicated policy and market development strategies to be put in place.

10 International

Becoming a Global Market

The energy storage market is a global work in progress. Early markets in many countries all face the same start-up issues as with any relatively new energy technology. This is a perfect time for advocates and others to work together across borders to address similar technical, market, and policy issues. Coordination and consensus around ways to support the emerging market could accelerate progress across the globe. At present, no such international or multi-national collaboration exists. It should be an important element of any future storage advocacy.


UNIT ENERGIZED
DC DISCONNECT
WARNING
Arc Flash and
Shock Hazard
Appropriate PPE Required
PRINCETON
POWER SYSTEMS
Clean Power Made Simple
GTIB-30
GreenCharge
GridSynergy
STORAGE
GS 30-60 P

1

Top Ten Trends to Champion Battery Storage

Lower Electric Bills

Reducing Demand Charges

"Every day we speak to school districts, municipalities, and other companies who face increasing costs in their utility bills. Traditional efficiency cost cutting measures including solar and LED lighting can only reduce a bill by so much. Energy storage directly addresses the demand charge problem so many organizations face."[1]

Vic Shao, Chairman, ENGIE Storage

Summary

Millions of commercial utility customers across a multitude of states have the potential to lower their electricity bills with battery storage, but few established behind-the-meter markets currently exist. As with expanding solar markets, the economic opportunities for storage must be paired with supportive policies and programs to establish thriving markets and ensure that all customers are able to tap into the cost-saving benefits of battery storage.

Battery storage system supplies power to a Safeway supermarket in San Jose, CA.

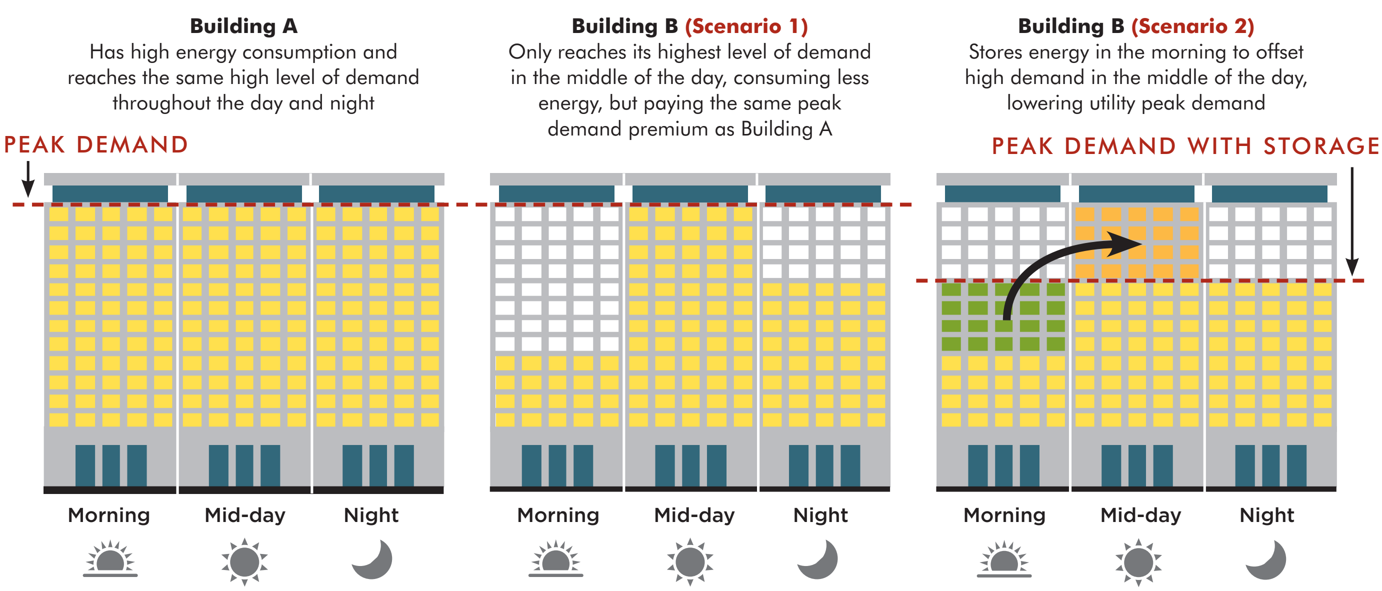
The Issues

From grocery stores to multifamily affordable housing to public schools, commercial customers small and large have embraced solar energy to cut energy costs and advance environmental goals. While a solar PV system can deliver significant savings by reducing a customer's electricity consumption expenses, there is another, less well-known side to the energy cost equation—utility demand charges.

Unlike usage charges, which account for the amount (kilowatt-hours) of electricity consumed throughout a period, demand charges track the highest rate (kilowatts) of electricity consumption during a period. Essentially, electricity demand tracks the total amount of energy that is being consumed at a given time. The more devices using electricity at the same time, the higher the customer's demand.[2]

Demand charges generally serve as a way for utilities to recover the cost of maintaining enough generation, transmission, and distribution capacity to meet the highest electricity demand of all their customers.[3] The charges are intended to cover the expense of utility investments in grid infrastructure such as transformers, substations, wires, and generation resources.

FIGURE 3
How Energy Storage Can Reduce Demand Charges



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

Historically, there has been a balance between electricity consumption and the need for these investments, with electricity consumption growing at essentially the same rate as peak demand. However, in recent years, these trends have begun to diverge. Grid-supplied electricity consumption has remained stagnant or even declined in many parts of the country, while peak demand has continued to steadily rise.[4]

A higher percentage of grid expenses are now going toward resources devoted to peak demand capacity, even though these resources are seldom used.

This means that a higher percentage of grid expenses are now going toward resources devoted to peak demand capacity, even though these resources are seldom used (for example, natural gas "peaker" plants must be paid even when they are not running, to ensure they will be ready on the rare occasions that they are needed to meet demand spikes). Largely because of this, demand charges have risen at a faster rate than electricity consumption charges for many commercial utility customers.

In California, which has some of the highest demand charge rates in the country, demand charges for customers with the state's three big investor-owned utilities have increased at an annual rate of 8 percent to 17 percent over the last decade.[5] By comparison, the state's commercial electricity consumption rates rose at an average annual rate of less than three percent.

Both behind-the-meter (BTM) solar and energy storage technologies—those installed at a customer's site—have the potential to reduce demand.

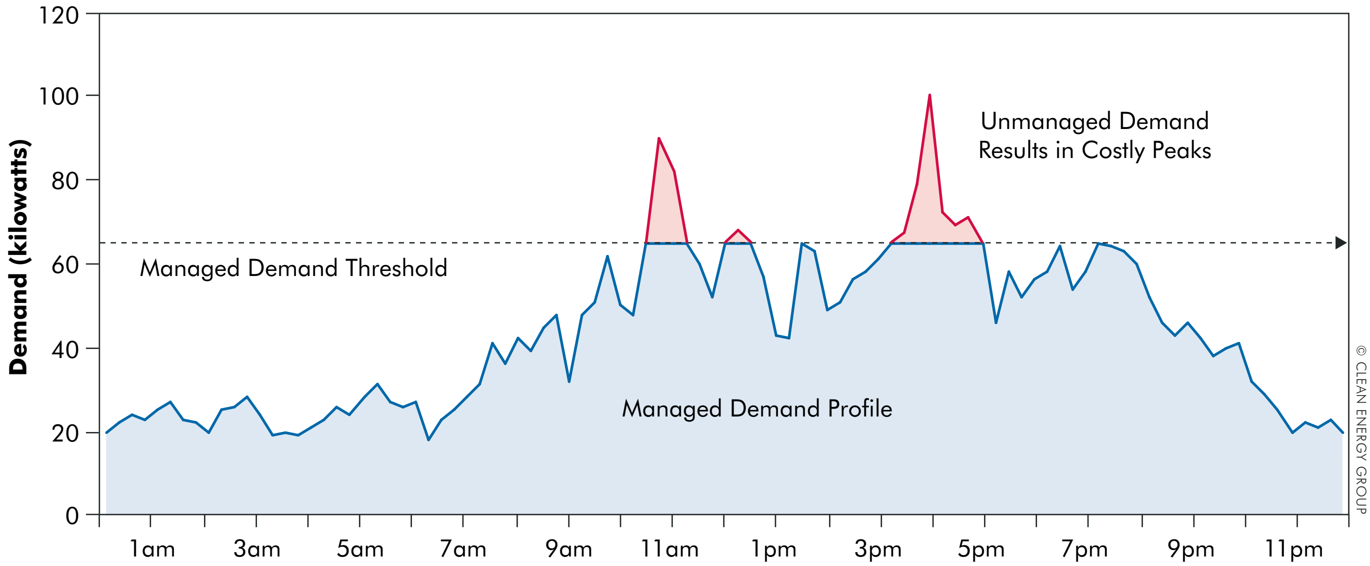
When a commercial customer's peak demand consistently occurs during sunny daytime hours, solar may help reduce costs by lowering customer demand for utility power. However, because solar is an intermittent resource, a few clouds at the wrong time could wipe out demand savings for an entire billing period. Because of this, solar is not an effective way to reduce monthly utility demand charges, and customers cannot rely on solar alone for consistent demand charge savings.[6]

Battery storage, on the other hand, can reliably deliver electricity demand reductions throughout a billing cycle, ensuring demand charge savings through an effective demand management strategy. (See Figure 3.)

While nearly all medium to large commercial customers in every state are subject to demand charges, there remains a lack of customer understanding about how these charges are structured and a lack of transparency about the range of utility demand charge rates across the country.

FIGURE 4

Energy Storage Can Reduce Customer Peak Demand Charges



Through the deployment of an energy storage system, peak demand can be effectively capped at a specified level—significantly reducing utility demand charges. Assuming a demand charge of $10 per kilowatt and peak demand reduction from 100 kilowatts to 65 kilowatts each period (as shown here), energy storage could reduce the customer's demand charge by $350 per billing period, amounting to an annual savings of $4,200.

This lack of customer understanding is especially unfortunate as demand charges often represent from 30 percent to 70 percent of a monthly commercial electric bill. But it's also understandable—until now, there were few options available to allow customers to act on that information. Now, with batteries, there is a technology that can be used to effectively and efficiently reduce demand charges. Figure 4 details how battery storage can be used for peak demand management.

As technology development outstrips customer understanding of complex rate structures, the resulting knowledge gaps pose significant barriers, these occur not only to commercial customers seeking new ways to reduce energy costs, but also to the continued growth of the clean technology sector as companies increasingly offer integrated solutions like solar paired with battery storage.

Due to these barriers and the relatively recent opportunities to reduce demand charges with energy storage, there are currently few well established markets for BTM storage. As of today, BTM storage is still a nascent, but fast-growing market in only a few states in the country.

Without additional incentives to boost market growth and a balanced approach to battery storage development that encourages BTM installations, the market potential for these customer-benefiting systems may remain fragmented and underserved, as solar was a decade ago.[7]

The Opportunities and Challenges

Several studies have explored the economic case for BTM battery storage as a demand-management solution for commercial customers.

An analysis of rate structures across 51 utilities performed by GTM Research concluded that storage begins to be a cost-effective demand management strategy at a demand charge rate of at least $15 per kilowatt.[8] Based on GTM estimates, the demand charge threshold for storage could drop as low as $11 per kilowatt by 2021.

Analysis by McKinsey & Company found even more favorable opportunities for energy storage.[9] The consulting firm determined that some customers could break even by investing in battery storage at a demand charge rate of about $9 per kilowatt.

By 2020, McKinsey believes storage could be an economically viable demand reduction strategy at demand charge rates of as little as $4 to $5 per kilowatt, which would include most commercial rates, and some residential rates, in the U.S. with a demand component.

Over five million commercial customers across the country may be able to cost-effectively reduce their utility bills with battery storage technologies today.

These numbers show a huge market potential for BTM storage across the United States. Clean Energy Group recently confirmed this potential in a first of its kind study with the National Renewable Energy Laboratory (NREL). Based on a survey of over 10,000 utility tariffs in 48 states, the NREL/CEG study concluded that more than a quarter of U.S. commercial customers may be eligible for utility tariffs with demand charges of $15 per kilowatt or higher.[10]

That means that over five million commercial customers across the country may be able to cost-effectively reduce their utility bills with battery storage technologies today. This represents not just businesses, but nonprofits, public facilities, and multi-family housing as well. So far, only a small portion of this potential market has been realized, with no more than a few thousand commercial systems deployed.

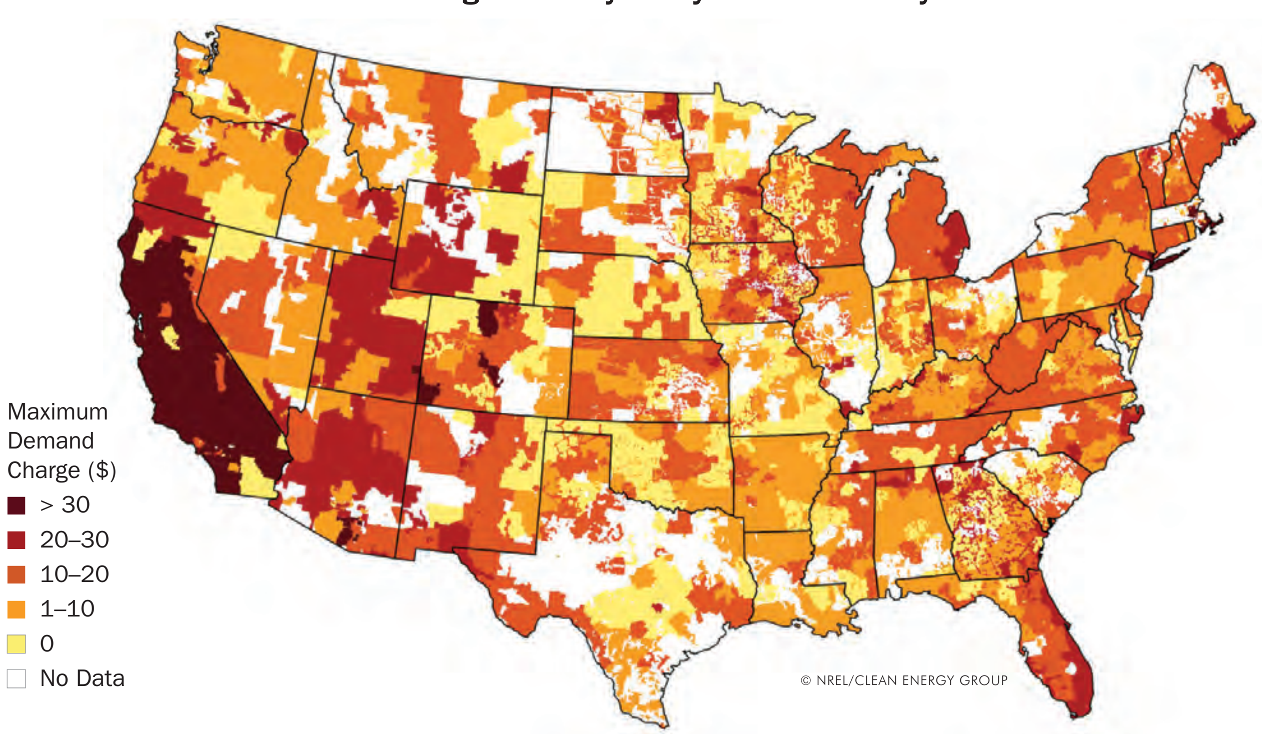
While the survey found opportunities for demand charge savings with batteries across the country, most of the BTM storage systems installed for demand charge reduction have been concentrated in California. This is not just due to the state's high demand charges. In fact, the analysis determined that economic opportunities for storage exist in states across all regions of the country including the Midwest, Mid-Atlantic, Southwest, and Southeast.

For example, along with energy storage leaders like California, New York, and Massachusetts, tens of thousands of commercial customers in Georgia, Alabama, Colorado, Kentucky, Michigan, Texas, Minnesota, and Ohio may be subject to utility tariffs with sufficiently high demand charges to make storage a viable economic investment. Figure 5 provides an overview of locations in the U.S. where commercial customers are facing high utility demand charges.

In other words, there is a future for clean energy with battery storage in states and regions that are not now considered clean energy leaders. Storage might be *the* enabling technology that could drive bill reductions and make renewable projects more economical to pursue in these markets. Anticipated future declines in battery storage costs will continue to enlarge the market potential in these and other states.

FIGURE 5

Maximum Demand Charge Rates by Utility Service Territory



Despite these opportunities, there are skeptics who challenge the reason why advocates should get behind efforts to use storage to reduce demand charges. These advocates are not necessarily against storage but, instead, see demand charges as an inefficient way for utilities to recover and bill customers for peak demand-related expenses. As a result, they view storage deployed for customer demand charge reduction as an inefficient way to reduce system demand.

A few responses to this are worth considering.

First, we take the utility world as it is right now and, like the companies already deploying storage, we advocate for cost-effective clean energy technologies that have market opportunities to capture today. That seems a smart advocacy strategy even if there are opportunities for different, more efficient rate design structures to advocate for and evolve over time.

Second, there is little proof that the current rate design structure in favor of demand charges is going away any time soon. In fact, a recent rate case in Massachusetts expanded the use of demand charges to more commercial customers and to residential customers with solar, an undeniable trend pressed by many other utilities across the country.[11]

And third, changes proposed by many utility rate reduction advocates include more time-of-use energy charges, which also favor the use of battery storage for cost savings over time.

For all these reasons, advocating for storage to reduce billions of dollars of utility demand charges is a pragmatic and potentially hugely successful enterprise for clean energy advocates to pursue.

The Actions

New market opportunities for BTM battery storage must be further investigated and verified. The survey of utility rate tariffs represents a critical first step in expanding and establishing markets in new regions; however, actual investment decisions will ultimately depend on building-specific energy usage profiles and other detailed, customer-specific information.

More work is needed to determine how many customers are subscribed to utility tariffs with significant demand charges and which of those customers use energy in a way that would allow storage to economically reduce demand. This on-the-ground work will require partnerships with local organizations and commercial customers interested in pursuing BTM storage solutions.

To accurately determine the economics of BTM battery storage, building owners and managers must have access to their property's detailed energy usage history. Detailed interval usage data is a key component in determining the cost-effectiveness of battery storage for demand charge reduction.

Unfortunately, many owners and managers have access to no more information than what they see on their monthly utility bills. This is often because, despite being billed for demand, many facilities are not equipped with smart meters that track and record customer energy usage at the level required for storage cost savings analysis. Even for those buildings that do have meters tracking interval-level demand, getting access to that data can be a frustrating and time-consuming process, as not all utilities are required or willing to readily share access to this data. And paying for utility meter upgrades or energy data loggers can be prohibitively expensive for many organizations.

The Green Button initiative is a good example of expanding customer access to utility data.[12] This type of open access needs to be implemented for any customer subject to demand charges. It seems common sense that, if a customer is paying for demand, they should have easy access to information that can help them reduce their demand. Utilities should be required to track interval-level energy usage for any customer on a demand or time-of-use rate; and they should have a simple, free or low-cost process for customers to access that data. In cases where this is not feasible, government support should provide funding for implementation of data loggers to track usage, particularly for public facilities and those serving low-income and vulnerable communities.

State policies, programs, and regulations must be put into place to facilitate market uptake. The reason California has the most established commercial BTM storage market in the U.S. is largely due to its enabling policies and programs that have allowed the use of battery storage to mitigate the state's high demand charges. Targeted state policies have accelerated the market uptake of storage built on a foundation of basic utility bill reduction economics.

The state has taken three key policy actions to boost its BTM storage market:

- ***Incentives:*** California has incorporated energy storage into its behind-the-meter distributed energy resources incentive program, the Self-Generation Incentive Program (SGIP). To date, the program has provided funding to more than a thousand commercial BTM storage projects. State regulators have also established an equity budget within the program, devoting 25 percent of remaining SGIP funding for battery storage projects located in low-income and disadvantaged communities.[13]
- ***Balanced mandate:*** California has taken a balanced approach in its utility energy storage procurement mandate, requiring that a minimum percentage of storage procurements be met by BTM systems. This balanced approach ensures that customer-sited battery storage projects benefit from the mandate by limiting market saturation by large utility-owned projects sited on the transmission and distribution grid. More than 40 percent of California's energy storage capacity is now located behind-the-meter, which, due to the excellent economic potential of BTM storage, is even higher than the policy stipulations require.[14]
- ***NEM inclusion:*** California regulators have enacted rules clearly stating that energy storage can be paired with solar systems participating in net energy metering (NEM) and laying out allowable configurations for NEM solar+storage systems. This level of clarity is essential to create fair and consistent market rules across multiple utility territories.[15]

Similar types of policy actions will need to be implemented in other states looking to cultivate emerging BTM storage market opportunities.

Individual, third-party, or aggregated BTM battery storage systems should have the same access to participate in utility and regional grid electricity market opportunities as traditional grid resources and larger utility-scale systems.

Lack of market structures and outdated participation rules currently inhibit BTM storage systems from providing many grid services. Changes will need to be enacted at both the utility and regional grid operator levels to allow for BTM storage to tap into these additional revenue streams.


Calabaza
Cebollas
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2

Top Ten Trends to Champion Battery Storage

Resilient Power

Providing Protection in Storms and Outages

"I went to church, and I'm not a church person. I sat there and said, 'Please bring the power back.'"[1]

Manuel Laboy Rivera, Secretary of Puerto Rico's Department of Economic Development

"The lack of power is the root of everything."[2]

Miriam Gonzalez, the owner of a restaurant in San Juan

Summary

Battery storage is increasingly an option for meeting power needs after disasters, like the unprecedented number this country has faced this past year. With power outages on the rise, the status quo energy systems have failed too often, resulting in death, damage, and prolonged suffering. Better technology solutions such as solar+storage are now viable alternatives to protect people from the dangers of power outages before, during, and after the next storm.

A sonnen battery powers a remote school in Orcovis, Puerto Rico. The school was without electricity for five months following Hurricane Maria.

The Issues

The U.S. electric grid is aging. At the same time, it's becoming more complex. And extreme weather events, ranging from hurricanes to ice storms to flooding, are becoming both more frequent and more damaging to the grid.

As more of our society becomes electrified—from electric-powered heat pumps and geothermal systems, to electric vehicles—the impacts of grid outages become even more severe.

No wonder, then, that power outages are increasing in frequency and severity. And, as more of our society becomes electrified—from electric-powered heat pumps and geothermal systems, to electric vehicles—the impacts of grid outages become even more severe.

According to the best available data from the Executive Office of the President, 679 power outages, each affecting at least 50,000 customers, occurred due to weather events between 2003 and 2012; and these events cost the U.S. economy an estimated $18 billion to $33 billion annually, in addition to damaging key transportation and medical infrastructure that are essential services for much of the nation's population.[3]

This accounts only for weather-related outages—it doesn't include outages due to non-weather events, which can include fires, earthquakes, falling tree branches, software errors, equipment failures, human error, terrorist and cyberattacks, and animals interfering with grid equipment (squirrels alone account for hundreds of outages per year).[4]

Of course, power outages are most harmful when they occur during a disaster, because they both contribute to the disaster and hinder efforts to provide emergency services when they are most needed. The recent hurricanes in Florida, Texas, and Puerto Rico exposed the vulnerabilities of the electric grid and sparked a nationwide discussion about the implications of power outages for public health and safety.

The disaster in Puerto Rico due to Hurricane Maria is now the largest and longest blackout in American history.[5] A month after Hurricane Maria made landfall in Puerto Rico, the majority of the island's 3.5 million residents still did not have access to power.[6]

The hurricane also crippled the island's $15 billion-dollar pharmaceutical industry, which supplies 10 percent of the United States' total medicinal production.[7] The storm damaged hospitals, knocked out medical refrigeration systems, wiped out internet and phone access, and prevented road access for 100,000 employees.

In addition to all of this, Puerto Rico's water treatment facilities shut down due to lack of electricity. This has led to an increase in water-borne diseases, as a quarter of the population was without clean drinking water.[8]

If natural disasters continue to become more severe, while nothing is done to improve power systems,[9] the problems exemplified in Puerto Rico will only continue to get worse. Increasing threats from climate change will create more outages to the power system. It is only a matter of time.[10]

As noted above, grid outages are not always associated with natural disasters, but when they are, their impacts are compounded. This is because critical services and facilities—emergency shelters, first responders, medical centers, communications and transportation hubs, fueling stations, water treatment plants, refrigerated stores of food and medicines—are subject to widespread power outages too. If these critical facilities are not supported with reliable and long-lasting backup power, they will not be able to deliver emergency services when they are most needed.

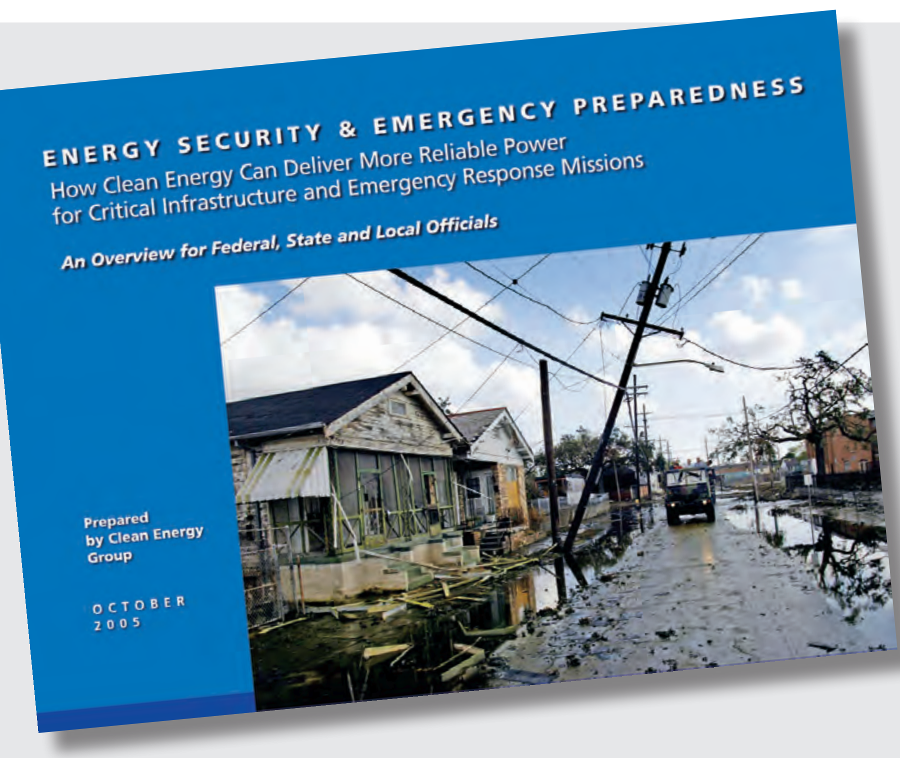
A home in Puerto Rico is spotted with the word "HELP" painted on its roof following Hurricane Maria.

Traditionally, backup power for critical facilities like hospitals has been supplied by diesel generators. But several recent disasters have shown diesel generators to be unreliable and prone to failure.

A white paper published by Cummins Power Generation after Hurricane Katrina devastated New Orleans noted that during and after that storm, "many stand-by generating systems located in basements and ground-floor levels failed immediately due to flooding. Generators that were not flooded soon ran out of fuel due to the inability of refueling trucks to deliver diesel fuel. Many other power systems failed to start altogether due to lax maintenance."[11]

The U.S. Department of Energy estimated that upwards of 50 percent of diesel generators failed at some time when Hurricane Sandy hit the East.

Similarly, during Superstorm Sandy, nearly 1,000 patients had to be evacuated from New York University's Langone Medical Center and Bellevue Hospital Center after diesel backup generators failed, plunging the hospitals into darkness. Although both hospitals had located their generators on high floors, critical components like fuel tanks and pumps were in basements, and these basements—despite being reinforced against flooding—were flooded.[12]



Energy Security & Emergency Preparedness:
How Clean Energy Can Deliver More Reliable Power for Critical Infrastructure and Emergency Response Missions

This report, prepared by Clean Energy Group in 2005 after Hurricane Katrina, provides an overview for federal, state, and local officials on how clean energy can deliver reliable power in emergencies. Critical public facilities should install on-site clean energy generation to reduce the risk from power failures. This document is intended to give state, local and federal officials a snapshot of what state clean energy funds and others are already doing to harden critical infrastructure, and demonstrate the potential to further enhance emergency preparedness. Many of the report's recommendations are still pertinent today. See *www.cleanegroup.org/ceg-resources/resource/energy-security-and-emergency-preparedness.*

The U.S. Department of Energy estimated that upwards of 50 percent of diesel generators failed at some time when Hurricane Sandy hit the East.[13] The same level of diesel failures has been experienced in Puerto Rico during the continuing blackout after Hurricane Maria hit the island.[14]

Destruction in New Orleans in the aftermath of Hurricane Katrina.

Fortunately, technology has progressed, and the venerable diesel generator is no longer the best we can do to support critical facilities and vulnerable communities. Battery storage combined with solar PV (solar+storage) provides a flexible and reliable system that scales easily, saves money, and doesn't rely on fuel deliveries to generate electricity.

Solar+storage systems can be configured to "island" when the grid goes down, meaning they continue to deliver power to their host facility. But unlike diesel backup generators, which sit idle 99 percent of the time, solar+storage systems operate year-round to provide daily benefits, saving money for their owners by lowering electricity bills and, in some cases, generating revenues through the sale of capacity and ancillary services in wholesale electricity markets.

Fortunately, technology has progressed, and the venerable diesel generator is no longer the best we can do to support critical facilities and vulnerable communities.

In numerous cases, solar+storage installations have shown that they can pay themselves off over just a few years, well within the lifespan of the equipment.[15] By comparison, diesel generators represent a sunk cost that will never deliver cost savings or revenues.

The resiliency performance of solar+storage is not just theory—there are numerous projects with track records to point to. For example, in 2015, a microgrid operated by San Diego Gas & Electric (SDG&E) powered the entire community of Borrego Springs, CA during planned grid maintenance, thus avoiding major service interruptions to the entire community of 2,800 customers.[16]

Similarly, a 2012 program to create solar+storage-powered shelters in Florida public schools equipped 112 schools with 10 kW of solar PV and a 40-kWh battery for each, at a cost of $74,000 to $90,000 per school.[17] When Hurricane Irma hit Florida in October of 2017, all 29 of the schools that were called upon as emergency shelters were able to self-power using their solar+storage systems. During normal operations, these solar+storage systems lower the schools' energy costs. Because installed costs for both battery storage and solar PV systems have fallen significantly since 2012, it's likely that similar systems installed today would be considerably cheaper, and the relative savings greater.

Solar+storage systems can also benefit multifamily affordable housing facilities, which are considered commercial customers by utilities, and often pay extremely high demand charges. Clean Energy Group has analyzed two such facilities in the Boston area, each of which pay more than $80,000 annually in demand charges. A resilient solar+storage system at one of these facilities would add reliable backup power while paying for itself in under six years through demand charge savings alone.[18]

Larger solar+storage systems show the same resiliency benefits and cost savings. For example, the Burlington Electric Department in Burlington, VT plans to lease a 1-MW/4-MWh battery to be located at the Burlington International Airport. Combined with an existing 500-kW solar array, the battery should be able to power the airport through an outage with no loss of services to customers. The utility plans to use the battery to reduce its capacity and transmission costs during normal operations, and it expects the system to pay for itself through these savings.

Burlington Electric Department plans to use the battery to reduce its capacity and transmission costs during normal operations, and it expects the system to pay for itself through these savings.

Similar systems have been built in Rutland, VT and Sterling, MA, and more than 100 resilient solar+storage systems are operating or in development across the country.[19]

The Opportunities and Challenges

If there is good news, it is that with new battery technology, more can be done to protect critical facilities and the communities they serve. Disasters often lead to unexpected and swift technology transformation. The calamitous collapse of Puerto Rico's electricity system might be the next example of that phenomenon.

Post-Hurricane Maria, several federal officials have acknowledged that energy systems in places like Puerto Rico should be upgraded with more resilient technologies, including solar+storage systems, not with more of the same old fossil-fueled systems that have already failed.[20] After the hurricane, Elon Musk, the peripatetic disruptor of multiple industries from autos to space travel, and now the electric power sector, sent Tesla batteries to Puerto Rico to be installed with solar as an emergency measure to provide power to critical facilities.[21]

He was not the only one. Sonnen, a German company with manufacturing facilities in the United States, also installed solar+storage systems in Puerto Rico[22] at emergency shelters and schools.[23] Their systems can provide critical power for cell phones, lights, and refrigeration.

If there is good news, it is that with new battery technology, more can be done to protect critical facilities and the communities they serve.

Beyond these short-term, emergency measures, Musk has said he could repower Puerto Rico's grid with solar plus battery storage,[24] an alternative that would make the island's electric system more resilient, more locally sourced, more independent, and less costly. And he said he could do it quickly, following his examples in American Samoa,[25] Australia,[26] and other islands now turning to distributed, onsite solar+storage to power homes and public and commercial buildings.

But deploying these technologies at scale will require more than willing suppliers: it will require a new federal approach to disaster recovery funding. This is starting to emerge in conversations about the relief efforts in Puerto Rico. For example, 19 U.S. senators have requested that future federal funding incorporate these new resilient power principles:

> We support efforts to reduce the use of imported diesel to generate electricity, increase the use of renewable generation resources, and modernize the design of the grid and the location of its power generation, which would help make the system less vulnerable to power outages. We are committed to the long-term rebuilding of these power grids in a way that is more resilient to extreme weather events, reducing the potential need for future disaster assistance, and prioritizes rebuilding with technologies like microgrids, utility-scale and distributed renewable energy, and other distributed energy resources. We believe that leveraging federal analytical capabilities within the Department of Energy and the National Labs could greatly improve plans to rebuild these grids. Rebuilding Puerto Rico's and the U.S. Virgin Island's electric grids with modern technologies will improve reliability and can help save consumers and taxpayers money, in addition to being a much more prudent use of federal dollars than simply rebuilding the grids back to their pre-storm condition.[27]

A greater focus on the potential for local microgrids and resilient power in Puerto Rico is now part of new public discussions about rebuilding the island's energy system.[28] And a recent report from the governors of New York and Puerto Rico recommended a budget of over $1 billion for the installation of hundreds of solar+storage systems in critical facilities on the island.[29]

Congress did pass an emergency response bill in early February 2018 that provided up to $2 billion in relief to rebuild the energy systems in Puerto Rico and the Virgin Islands.[30] In effect, the law provides $2 billion in federal funding for "enhanced or improved electrical power systems." There is no clear legislative direction from the language as to how much of the funding is for central station grid hardening and how much is for decentralized microgrids in the form of solar+storage building or community systems.

The budget law also appears to amend *The Stafford Act* to allow for reconstruction to a higher standard than before. The language states that repairs to "critical services" can be built "to industry standards without regard to pre-disaster construction of the facility or system."[31] This would support the report's underlying recommendation to "build back better," although without the accompanying level of funding required.

One might well ask why a calamitous natural disaster is required to prompt needed upgrades in our power systems.

One might well ask why a calamitous natural disaster is required to prompt needed upgrades in our power systems. If solar+storage is such a great technology, why is it not more widely used? Why are government programs and incentives still needed to move this market?

The answer is that, despite its promise, there are market failures and barriers that need to be addressed to bring this technology to scale.

For example, there are numerous benefits and values that energy storage offers, but that are not easily monetizable (that is, markets do not exist, or if they do, there are barriers to entry). Energy resilience itself is an example of this: widely recognized as a highly valuable attribute or service, there is now no market for it, and hence it is difficult to assign a value to it; and systems that could provide resilient power cannot easily charge for the service. If resiliency is assigned no economic value, its value in any calculation of project economics will be zero, which is the typical default today.

A solar+storage microgrid provides power to an off-grid home and business in rural Montana.

Another valuable service storage can provide is capacity, which is important to keep electric grids stable. Wholesale capacity markets exist in many areas of the country. Behind-the-meter (BTM) battery storage systems can be aggregated as a valuable capacity resource, yet there are very few existing aggregators for this technology; and without aggregators, individual small storage owners cannot meet size thresholds to enter the markets. In this example, valuable services that could be provided cannot reach the existing market.

Major challenges to deploying more solar+storage systems also include the regulatory structures that sometimes hinder the adoption of new technologies, such as energy storage, even when they are superior in performance to older technologies. For example, hospitals are required to install diesel or gas backup generators, and this reduces the likelihood that they will choose to install energy storage for resiliency. So long as this "lock-in" of established, sometimes inferior, technologies persists, it will slow the entry of more innovative technologies like battery storage.

Additionally, the very communities that need resilient power the most are often the least able to afford or finance solar+storage technologies.

Additionally, the very communities that need resilient power the most are often the least able to afford or finance solar+storage technologies. The most advanced resilient power systems are typically in place to protect facilities involved in financial transactions such as credit

Long-duration backup power for the police station and emergency dispatch center in Sterling, MA can be provided by solar PV and battery storage.

card processing centers, in banks, or in data centers where resiliency budgets are virtually infinite, and the costs of even momentary power disruptions run into the millions.

But poor and vulnerable communities rarely have the means to invest in such technologies, which are needed to protect life and health, and cannot easily attract financing. In affordable housing facilities and senior centers, budgets are often too small to support anything better than an old and unreliable diesel generator.

Finally, knowledge barriers for new technologies remain one of the most significant obstacles to adoption. Many customers that might benefit from solar+storage simply do not have the time, expertise or capacity to learn about new energy technologies. For this reason, convening, knowledge sharing, and technical assistance continue to be important activities.

The Actions

There are two types of actions needed in this resilient power field: 1) a set of actions for all communities for long-term resilience planning, and 2) those needed for short-term recovery transitions in places such as Puerto Rico that are facing the immediate after-effects of a disaster.

For long-term resilience and resource planning, communities should consider the following.

In general, states and municipalities should assess and address resiliency needs through energy planning, programs, and regulation as well as through disaster planning. To date, few such plans explicitly assess the backup power needs of mission-critical facilities. Planners should investigate new technologies such as solar+storage for use in critical facilities such as emergency response centers, hospitals, and wastewater treatment plants as well as their potential for year-round contributions to the power grid and to reduce consumer electricity costs.

Communities should call for the installation of new, more reliable forms of on-site electricity generation, such as solar+storage, at essential public safety facilities. There should be a focus on healthcare facilities, assisted living communities, schools, emergency shelters and other essential community service facilities where health equipment, refrigeration, communications and the like can be supported with solar+storage systems. This would provide the community with power protection in the next storm. Such a focus would conserve budgets and provide the largest resiliency benefit to communities.

Because battery storage is a relatively new technology and there is little experience with it, states and municipalities need to seek help to understand how the technology works and how to craft policies and programs to support its deployment. This is especially the case with homeland security and emergency management personnel and those managing critical facilities.

To recognize the value of resilience, municipalities and states should provide new customer incentives for clean, resilient power systems (grants and loans, financing, rebates, tax incentives), particularly those systems providing a public good, such as resilience for first responders, affordable housing, or emergency shelters.

A paper released by CEG and NREL found that when the resilience benefits of solar+storage are accurately accounted for, more systems become economically viable.[32] Utilities should also be required to increase resiliency, which can be done through portfolio standards, integrated resource plans (IRPs), procurement mandates, and grid modernization initiatives.

States and municipalities should add storage and resiliency adders or carve-outs to existing clean energy programs. The Solar Massachusetts Renewable Target (SMART) solar incentive comes close to this with an energy storage adder and a low-income community adder, but it does not have a resiliency adder.[33]

Resilient solar+storage demonstration projects supported by public programs should receive up-front, publicly-funded technical assistance. This ensures that the resulting projects are well designed, work as intended, and provide all the benefits the technology can provide.

For communities facing disaster recovery, the following federal and local actions are needed.

There must be long-term, permanent changes to *The Stafford Act*. This allows for the more resilient rebuilding of power systems, along the lines of the recent budget bill changes for Puerto Rico. This should be a high priority. The current law requires rebuilding energy systems to the same standard that failed, a requirement that is simply indefensible in this modern environment.[34] This more creative use of federal funds for resilient power should serve as a first step to create replicable federal models for future disaster recovery.

FEMA and other federal agencies should pre-position portable solar+storage systems at the ready for deployment in the next disaster. It is critical that the federal government focus more on distributed power systems like solar+storage in both immediate recovery and long-term rebuilding of power systems damaged from disasters.

Green Mountain Power's Stafford Hill solar+storage microgrid provides resilient power to an emergency shelter in Rutland, VT while benefiting the grid at other times.

More coordination is needed for disaster relief efforts. In Puerto Rico, private sector solar+storage companies were ready to help with near term support after the hurricane. But there was no systematic way to link critical facilities in need with the private-sector companies willing to help. In the future, perhaps some form of web-based platform to link these two sectors could be established as part of disaster recovery efforts; if successful, a more permanent platform could be developed for use in future disasters.

After the early-stage recovery systems are installed, there should be a focus on the long-term, market-based strategies for the installation of resilient energy systems in disaster areas, focusing on electricity cost-reduction opportunities and power resiliency needs to drive private-sector installations.

Especially in places like Puerto Rico, this should include workforce training to educate on-island solar installers about how to integrate battery storage into those systems.

If the federal government, states, and communities embrace these actions, perhaps more resilient electricity systems will be built that are able to withstand the next storm.

3

Top Ten Trends to Champion Battery Storage

Equity and Justice

Bending the Arc of the Technology Curve toward Vulnerable Populations

"Storage needs to compete on economics, and there's no getting around that. But the industry could gain from forging new alliances with stakeholders that have overlapping interests.… Environmental justice is a logical place to start, because storage is well equipped to tackle the environmental damage that often falls more heavily on poor or minority populations."[1]

Julian Spector, GTM2

Summary

Early adopters of innovative, disruptive technologies are typically the well-to-do and, so far, battery storage is no exception. Most of the economic benefits of storage are now realized by commercial utility customers who are saving money from these systems through electricity bill reductions. Very few of these projects are in disadvantaged communities; ironically, low-income customers need the benefits of solar and battery storage systems the most. Advocacy and policy must be directed to ensure that all communities benefit from these technologies now, not ten years from now.

At the McKnight Lane Redevelopment Project in rural Vermont, solar+storage systems at each of the 14 single-family duplex units provide low-income tenants with backup power and zero energy costs.

The Issues

While natural disasters and associated grid outages affect everyone, not all communities are equally harmed. Often, it is the poor, the elderly, and the disabled who are hit hardest, because they are less mobile, less able withstand the dangers from an outage, and less able to recover from a disaster.

Clean energy equity provided by solar+storage systems could ensure that all communities have access to the economic, health, and resiliency benefits.

Disadvantaged communities have fewer resources; they may not be able to re-locate to a hotel or temporary housing during or after a storm. And they tend to be underinsured, so it is more difficult for them to recover from property losses. If power outages disrupt the ability to go to work, the resulting disruptions in income hit harder in communities that have fewer economic resources.

In cities, low-income communities are often located in low-lying areas, making them more vulnerable to flooding. Evacuation is harder on the poor, who may have nowhere to go; and on the disabled and elderly, who may not be able to move safely.

And for those dependent on electricity for the refrigeration of medicines and for powering medical devices, the loss of electricity can have much more severe consequences than simply being left in the dark.[2]

Also, many poor, elderly, and disabled people live in buildings with electric bills that include the same kind of high utility "demand charges" for electricity facing large, private companies.

Solar PV and battery storage (solar+storage) can reduce demand charges on facilities that house and provide essential services to the economically or physically vulnerable.[3] Taming utility demand charges (which are on the rise) makes for a good strategy for helping affordable housing owners to manage their energy bills.

In addition to these direct economic benefits, solar+storage can power essential services during extended power outages. Such clean energy equity provided by solar+storage systems could ensure that all communities have access to the economic, health, and resiliency benefits that these technologies can provide.

Solar+storage systems are also possible drivers of local economic development. Savings from systems can be reinvested in affordable housing and community buildings. Local groups can own or lease solar+storage systems, leading to more community-led investment.

More installations of such systems in low-income communities and communities of color also can provide a semblance of equity in the energy system. Vulnerable populations should be first, not last, in line to obtain the benefits of new clean energy technologies.

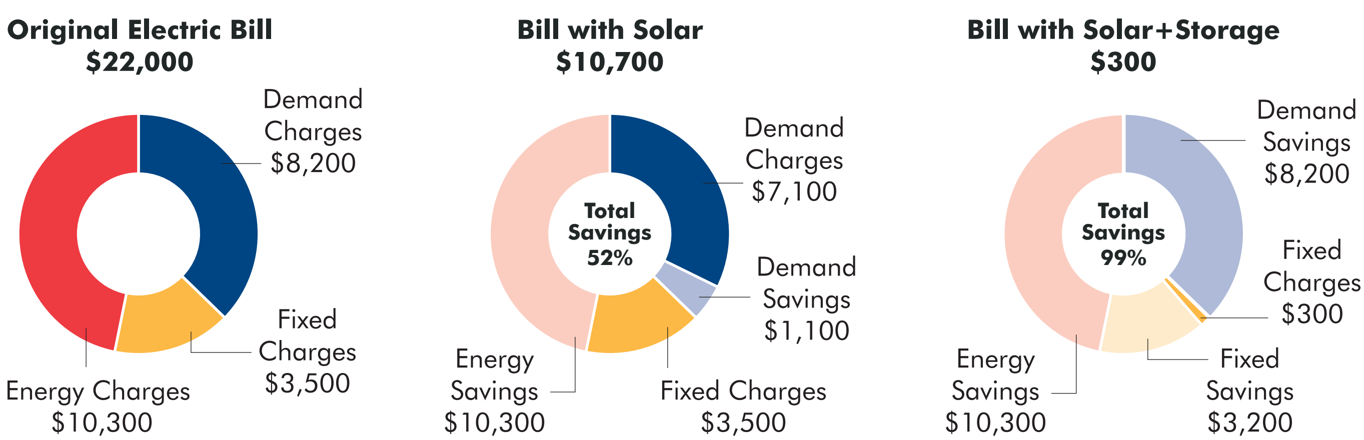
The key challenge is this: how can we bend the arc of this solar+storage technology trend toward public purposes now, not as a last resort but as a matter of market design and social justice? To capture this opportunity, we must first fully understand the drivers and limits of these emerging energy storage markets.

The Opportunities and Challenges

It is important to understand that installation of solar+storage technologies can serve building owners of affordable housing and community facilities mainly because batteries do a great job of reducing demand charges on their utility bills. Clean Energy Group's report, "A Resilient Power Capital Scan: How Foundations Could

FIGURE 6

Example of Impacts from Addition of Solar and Solar+Storage on Electricity Bills in Southerm California



This graphic summarizes the modeled building's original electric bill, electric bill and savings after deployment of solar, and electric bill and savings after deployment of solar+storage. Solar eliminates energy consumption expenses and lowers demand charges, saving $11,400. The addition of battery storage eliminates demand charge expenses and lowers fixed charges, saving an additional $10,300 per year. (Analysis from Clean Energy Group's *Closing the California Clean Energy Divide* report.)

FIGURE 7

Impacts of Clean Energy Technologies at Multifamily Affordable Housing in Southern California

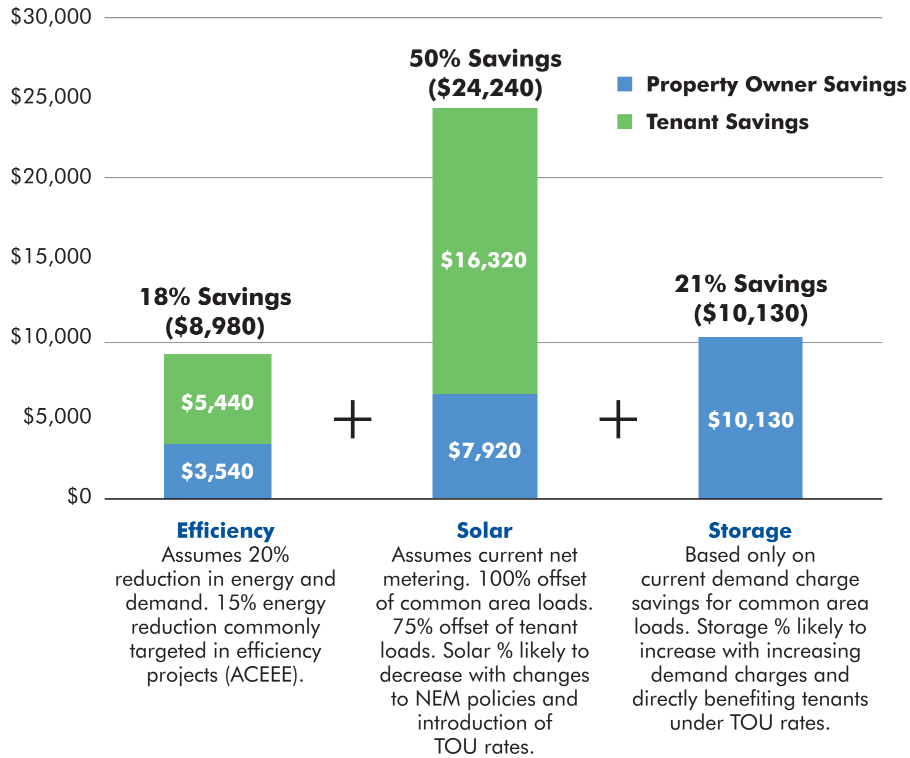
EXAMPLE

50-Unit Multifamily Affordable Housing in Southern California

Total Annual Electricity Bill for Owners and Tenants
$48,800

Total Annual Electricity Bill Savings from Efficiency+Solar+Storage
$43,350

Total Annual Electricity Bill Savings with all three technologies combined
89%



Use Grants and Investments to Advance Solar and Storage in Low-Income Communities," provides examples of the energy savings of solar+storage; see Figures 6 and 7 from the report.

Demand charges are the fees that utilities charge commercial customers (affordable housing owners and many community facilities are on the same rates as commercial customers). These charges are based on their highest peak power use over a billing cycle (usually a month or so), regardless of how much electricity they use.

It's like a charge on the highest, single power spike—about as popular as Uber's congestion pricing. In some places, demand charges can comprise over half the bill; and for an affordable housing complex or a senior center, that can be a lot. That makes reducing demand charges a huge savings opportunity for people who need to reduce their electric bills.

It is important to know that most solar PV systems are not usually configured to run independently from the grid—when the grid goes down, the PV systems do too. PV systems need battery storage, so they can island from the grid and continue to provide power when the grid isn't available.

While focusing only on solar in affordable housing or community facilities may offer some benefits, it is not enough to keep a facility powered during a power outage. Solar-only systems might bring about some reductions in energy bills due to less consumption of grid power, but they will do nothing to reduce demand charges or provide resiliency if the power goes out.

While energy efficiency and solar can reduce energy consumption, they do relatively little to reduce the demand charges that can be upwards of 30 percent to 70 percent of a total utility bill. And apart from the economics, it would be unfortunate to convey to that solar-alone systems will provide power in the next blackout. They will not.

To ensure that solar+storage technologies are deployed in low-income markets, advocates need to: 1) understand how energy technologies become mainstream and to leverage those trends, 2) address complex market dynamics in an early stage technology market, 3) provide sound analytical information, to support an informed environmental justice and philanthropic community, 4) create an interested and educated customer base in affordable housing sector (for both public and private building owners) and among state and community leaders, 5) advocate support policies to accelerate these individual efforts, and 6) to create new finance models to enable market development.

There are some promising new programs that will help low-income communities pay for solar+storage systems. For instance, in March 2018, San Diego Gas and Electric (SDG&E), a major California utility, proposed a $2 million pilot program to incentivize behind-the-meter energy storage at facilities serving low-income residents. The justification and design of SDG&E's program relies heavily on materials produced by Clean Energy Group in cooperation with other equity groups in the state.

Solar-only systems might bring about some reductions in energy bills due to less consumption of grid power, but they will do nothing to reduce demand charges or provide resiliency if the power goes out.

From SDG&E's testimony on the pilot program,

> As outlined in a report by Clean Energy Group, California Housing Partnership, and the Center for Sustainable Energy, additional incentives for storage are needed, and without them low-income customers will not be able to obtain energy storage and the benefits of resiliency….[4]

According to SDG&E's calculations, the proposed incentive of $1.20/watt represents the full cost of installing and maintaining the system for 10 years, and such storage systems must be paired with existing or new solar systems.

Today, new affordable housing complexes have begun to install solar+storage systems to reduce electric bills and provide resiliency. Marcus Garvey Apartments is home to the first solar+storage microgrid at an affordable housing property in New York City. A new battery system, which began operation in early 2017, stores power from solar panels, a fuel cell system, and low-cost, off-peak power purchased from the utility, Con Edison.[5]

NGOs and foundations have never created an advocacy movement to ensure equal access to a new clean energy technology that was just entering the marketplace.

When grid outages do occur, the microgrid will be able to island itself and provide up to 12 hours of power for several critical building loads during power outages, including outdoor lighting, the management office, security systems, and a community room. In the community room, the system is designed to power lighting, heating, refrigeration for medicines, and cell phone charging.

The Marcus Garvey project is expected to result in savings on both electricity and heating bills, as well as performance payments from Con Edison for participation in the utility's demand management program. The money saved on energy expenses will be used for programming that supports quality of life activities for the tenants of the 625-unit housing complex.

These new programs and projects are just a start. The magnitude of this challenge must be understood. NGOs and foundations have never created an advocacy movement to ensure equal access to a new clean energy technology that was just entering the marketplace. Instead, typically, arguments for equity and equal access come around years after a technology already has been established in the market, such as with energy efficiency or stand-alone solar.

Solar+storage must be widely adopted in the broader markets, while at the same time ensuring that its early markets are equitable and accessible to low-income communities. We need to tackle these two challenges at the same time.

The Actions

Federal, state, and local governments should provide more funding and policy support to deploy resilient power for public safety and community resiliency. Policymakers at the state level should set aside portions of battery storage incentives for low-income communities, as California has done. They should ensure that solar+storage incentives are targeted to benefit low-income communities. And they should expand their housing and energy programs to include solar+storage applications, as a cost reduction and resiliency measure.

Organizations advocating for vulnerable populations (and those populations themselves, to the extent possible) should demand equal access to these new clean energy technologies. This requires working on finance strategies, developing analytical software tools, creating a growing list of resources, providing leadership grants to community groups, and awarding technical assistance fund grants to planners and developers.

Banks, foundations, and socially responsible investors must find creative ways to finance solar+storage technologies to serve critical public needs.[6]

Solar+storage companies should aggressively expand their customer acquisition strategies to include solutions for affordable housing and buildings that serve seniors and vulnerable populations, as well as solar+storage applications for critical public facilities. Targeting battery storage benefits only to corporate savings will shortchange the technology's social promise.

A residential solar+storage pilot program in Imperial Valley, CA is expected to double the savings that could have been achieved by solar alone.


EMERGENCIA

4

Top Ten Trends to Champion Battery Storage

Public Health

Providing Greater Protection for Medical Care and Hospitals

"The storm damaged many of the island's more than 100 drug and medical device manufacturers. Puerto Rico produces about $40 billion worth of pharmaceuticals for the U.S. market, according to the Food and Drug Administration—more than any other state or territory."[1]

Alison Kodjak, Health Policy Correspondent, Science Desk

Summary

We are at a critical period where solar+storage solutions can, for the first time, be deployed at scale resulting in significant health benefits while improving economic conditions and addressing issues of equity and climate mitigation. This is the future of more resilient health care: using resilient and clean power systems that do not fail when they are needed, that are supported by renewable power and battery storage, and that help health care delivery systems do their job.

Destruction at Hospital Oriente in Puerto Rico following Hurricane Maria

The Issues

Battery storage paired with distributed generation, such as solar, in the health care system is a pioneering new idea, a breakthrough technology solution to the recurring problem of power outages and adverse health outcomes, both in normal times and in disasters.

In a 2014 global review of electricity outages, a National Institute of Health publication noted that "the impact of power outages on health is varied and far reaching. From the first call for help to the giving of complex clinical treatments, it is evident that healthcare is increasingly dependent on power."[2]

Battery storage paired with distributed generation, such as solar, in the health care system is a pioneering new idea, a breakthrough technology solution to the recurring problem of power outages and adverse health outcomes, both in normal times and in disasters.

The UK government has recognized electricity as "the most vital of all infrastructure services, because without it most other services will not function."[3] That has certainly been the case with health care and power outages in America over the last two decades, not only during disasters but also during long-duration grid failures.

In 1999, one of the worst blackouts to hit New York City crippled the Columbia University medical research center. Because its two diesel generators failed, the medical research facilities were without power for hours. As the school paper noted:

> Researchers were forced to throw away countless samples of bacteria, viruses, tissues and other chemicals after freezers which maintained the samples malfunctioned. Losses include human cell cultures prepared for research on Alzheimer's disease as well as human research tissue, DNA samples and brain bank tissues collected over the last 15 years.[4]

Clean Energy Group wrote a *New York Times* op-ed about the outage. In it, we asked, "what's the price of losing a cure for cancer because an outmoded diesel generator failed to work?"[5]

In 2003, the entire Northeastern part of the United States suffered a massive blackout that left 45 million people without power. According to reports, "hospitals had several internal problems, including loss of HVAC and water pressure, inability to sterilize instruments at certain facilities, and loss of refrigeration and cooking…"[6]

Doctors were unable to view X-rays using digital machines, register patients, and there were multiple reports of respiratory failures in community-based patients who lost power to their medical devices. After the outage, scientists reported an increased level of diarrheal illness from the consumption of meat or seafood that spoiled after the power went out.[7]

In 2005, Hurricane Katrina swamped New Orleans and knocked out power to the city's largest hospital, Memorial Medical Center. As reported in the Pulitzer Prize winning book "*Five Days at Memorial,*" 5,000 people were trapped in the hospital without power when it flooded and its generators failed.[8] The hospital was without lights, air conditioning, sewer systems and essential medical equipment. By the fifth day of the crisis, doctors and medical staff reportedly had to make decisions about euthanizing patients, all due to the lack of electricity in the hospital.

In 2008, Hurricane Ike hit Ohio as an extra tropical cyclone, causing the largest electrical failure in the state's history, and leaving two million people without power. Several of the state's hospitals lost their main power sources, forcing them on to generators. The population hit the hardest were home-bound people whose medical equipment failed, forcing them to seek alternative emergency housing such as shelters. And without power, many organizations providing home meals for the elderly could not prepare meals.

The Migrant Health Center located in Maricao, Puerto Rico is a nonprofit clinic providing medical services to everyone regardless of insurance or ability to pay. This clinic was the first location for the installation of solar+storage as part of the Solar Saves Lives initiative.

As a post-disaster report noted:

> These widespread multi-day power outages caused thousands of people to seek food and water at shelters, food banks and other charities, in what may have been the most serious public health need from the windstorm.[9]

In 2102, Superstorm Sandy knocked out power to eight million people, including all operations at NYU Langone Medical Center where, once again, the diesel generators failed to provide power in the storm.[10] It had to halt operations and transfer 215 patients to nearby hospitals. "Things went downhill very, very rapidly and very unexpectedly," Dr. Andrew Brotman, senior vice president and vice dean for clinical affairs and strategy of NYU told CNN.[11]

Residents and neighbors were "helping children in the NICU and PICU down the stairs, triaging patients and building teams of nurses, doctors and therapists to help the babies down nine flights of dark, wet stairs with all their intravenous lines and equipment."[12]

According to a summary of reports after the Langone disaster, "the power failure jeopardized both patient care as well as nurses' ability to communicate with each other, with leadership, and with their loved ones."[13]

In 2017, three major storms hit the mainland of the United States. Once again, the hurricanes in Florida, Texas, and Puerto Rico exposed the vulnerabilities of the country's electric grid and sparked nationwide discussion about the implications of power outages for public health and safety.

According to a summary of reports after the Langone disaster, "the power failure jeopardized both patient care as well as nurses' ability to communicate with each other, with leadership, and with their loved ones."

In a matter of months, Hurricanes Harvey, Irma, and Maria killed more than 250 people and forced thousands from their homes to seek refuge in temporary shelters.[14] The storms also damaged a significant portion of the electric grid that supplies power to millions of residents across the country and the U.S. Virgin Islands. In Florida, 160 nursing homes were left without power, including Krystal Bay Nursing and Rehabilitation Center in North Miami Beach, where generators and air conditioners failed, leading to sweltering temperatures and the tragic deaths of at least eight elderly residents.[15]

During Hurricane Harvey in Texas, many hospitals had to be evacuated, including the Citizens Medical Center in Victoria; its generators could not provide air conditioning, trapping 80 patients on site. (Several hospitals in Houston did better, with flood waters blocked by submarine doors installed after Hurricane Allison in 2001.)[16]

One month after Hurricane Maria made landfall in Puerto Rico in September 2017, the majority of the island's 3.5 million residents still did not have access to power.[17] Residents in nursing homes, hospitals, and affordable housing units experienced these power outages most acutely when they were left without reliable access to air-conditioning, food and medical refrigeration, and dialysis and oxygen units for several weeks.

A week after the disaster, 58 of the 69 hospitals on the island were without power, causing numerous fatalities.

Those who sought diesel generators to provide emergency power were faced with long waiting lists, while existing emergency diesel generators—when they worked—struggled to meet increasing demand with limited access to fuel supplies.

The hurricanes also crippled the island's $15 billion pharmaceutical industry, which supplies 10 percent of the United States' total medicinal production.[18] The storms damaged medical refrigeration systems, wiped out internet and phone access, and prevented road access for 100,000 employees.

A week after the disaster, 58 of the 69 hospitals on the island were without power, causing numerous fatalities.[19] During the hurricane, the death toll in Puerto Rico rose from an estimated 82 deaths per day to an average of 117 deaths per day during the two weeks following the storm.[20]

The power outages also crippled Puerto Rico's water treatment facilities, which were left inoperable without electricity. The outages caused an increase in waterborne diseases, which disproportionately affected a quarter of the population that was without access to clean drinking water.[21]

"Storm damage and power outages remain problems especially in rural areas where access is still difficult… the island's grid remains shaky and generators still keep one in five hospitals running, according to recent Federal Emergency Management Agency data. [According to FEMA], seventeen hospitals lacked phone service."[22]

As of mid-January 2018, four months after the storm, 467,600 businesses and residences—more than a third of the people in Puerto Rico—were still without power.[23]

Marines assess damage to the Ryder Memorial Hospital in Humacao, Puerto Rico following Hurricane Maria.

These outages have led to severe health problems, including illnesses such as diabetes and heart disease. Furthermore, "lack of clean water has led to skin rashes and gastrointestinal illnesses, and mold flourishing in storm-damaged buildings has made it harder to breathe for others."[24]

The disaster of Hurricane Maria in Puerto Rico is just the latest dramatic case study that demonstrates the tangible link between public health and electric power. But, to illustrate the larger problem with disasters and power beyond hurricanes, in the Pacific Northwest, officials are taking seriously the long-term power outage potential associated with the unstable Cascadia Subduction Zone and catastrophic earthquakes that would impact the entire region.

A multi-week or months-long power failure of that magnitude would be especially damaging to health care facilities:

> "…health care facilities would have limited backup power and face water shortages, making it difficult for them to treat patients admitted before the event and limiting their capacity to handle new cases."[25]

But it bears repeating that power outages at medical facilities do not occur only after disasters or widespread electricity system failures. The number of power outages continues to increase every year due the country's aging energy infrastructure, growing energy demand, and the fragility of backup generator systems.

Every day, power outages are a fact of life in America's health care system.

In the past year alone, multiple hospitals in the Orlando Florida area experienced computer system failures due to power outages. Another recent outage knocked out power to Simi Valley Hospital in California, affecting 1,300 patients. An electrical transformer fire interrupted all phone communications at Washington state's Coulee Medical Center. A car accident knocked out a power pole, leaving the Richmond Community Hospital to rely on faulty generators. Another outage risked patient care at the Kaiser Permanente Santa Rosa Medical Center, which had to utilize emergency generators. These are the common, power related problems affecting health care throughout the country.[26]

As a report from the National Governors Association confirmed:

> "…each state has unique threat vectors that could cause prolonged and widespread power outages, and each threat comes with its own unique consequences. Of particular concern are the potential effects on other critical infrastructure sectors like health care and emergency services that rely on electricity to function."[27]

The Opportunities and the Challenges

These realities necessitate a stable, resilient power supply that can provide reliable, clean power when operating under normal conditions while also meeting demand to power critical services during power outages. The good news is that resilient power supply already exists in the form of solar+storage systems.

Solar+storage systems can prevent or minimize deaths and public health crises caused by power outages by providing resilient power in critical community facilities.[28] They can mitigate greenhouse gas and local particulate emissions that spike when backup, emergency diesel generators are activated during emergencies.

Apart from the obvious opportunity to address power outages and create more resilient power systems, solar+storage systems can also save hospitals and medical centers money. The healthcare industry is under tremendous pressure to reduce operating expenses, including energy costs. A 2014 survey by the American Society of Healthcare Engineering (ASHE) showed that energy accounts for more than half the annual budget of a typical hospital facilities director—more than staff, supplies, and outsourced services combined.[29]

Large hospitals—those with 200,000 square feet or more—accounted for less than one percent of all commercial buildings and two percent of commercial floor space in the United States, but they consumed 5.5 percent of total delivered energy used by the commercial sector in 2007.

Based on a survey of more than 10,000 utility tariffs, a recent study by NREL and Clean Energy Group found that nearly 5 million commercial customers could have the potential to economically install energy storage for demand charge management.[30] Many hospitals pay high demand charges—the part of the utility bill that represents the monthly peak load—and these charges could be reduced with solar+storage, while also providing resiliency during power outages.

Hospitals are just beginning to explore use of solar+storage to reduce costs and provide resiliency in a health care setting. This has national implications for medical facilities that need to adopt new innovative power technologies in the future. Several states are pursuing new solar+storage, resilient power opportunities with their hospitals.

As part of post-Sandy resiliency programs, states such as Massachusetts have offered "resiliency incentives" for storage and other technologies in hospitals and other medical facilities. These developments illustrate a promising energy trend for the medical sector.[31]

In this direction, Boston Medical Center (BMC), the city's largest hospital, recently received a grant from the Massachusetts energy storage program to install a new system. Early modeling for the system indicated it could have simple payback of 7.97 years without subsidies; with inclusion of the state grant, the payback period is reduced to four years. If the project sells services into the frequency regulation market—which BMC is investigating and plans to do—the payback period is further reduced to three years.

The Actions

To achieve these goals, there needs to be cross-sector collaboration among environmental, equity, and public health professionals to address the benefits of resilient power.

Currently, the clean energy community is not well integrated as a policy or implementation partner in many public health and resilience initiatives as it might be, especially in new technology areas such as solar+storage, while the healthcare community is often underrepresented in policy venues concerned with energy systems planning and funding.

To encourage a systems-change in the energy sector to better prevent the life-threatening impacts of power outages on public healthcare systems, there must be a venue for open dialogue between the healthcare and clean energy advocacy communities.

Such a multi-sector collaboration must focus on new ways to understand the benefits of solar+storage to achieve public health goals and improve the overall well-being for the country's most vulnerable populations.

This work should jump-start a systems-change in the energy sector by integrating public health perspectives and considerations into scoping, planning, and implementation of renewable energy projects such as solar+storage systems for health facilities such as hospitals, senior centers and health clinics.

As noted, Massachusetts has focused on providing grants for solar+storage systems in hospitals. Collaboration would identify new policy areas such as dedicated state-level funding for solar+storage resilient power systems at medical facilities.

Additional collaboration would identify the social, community, environmental, and economic policies and programs that need to be in place to preserve health, well-being, and equity during and following long-duration power outages. The objectives listed above aim to develop an empirical, evidence-based approach to protect lives during and after grid failures and disasters.

For example, there are new efforts being developed for empirical research into the health impacts of the power outages in Puerto Rico, especially the effect of outages on home-based, electrical medical equipment such as ventilators and dialysis machines that failed during and after the blackout. Such a systems-wide approach could lead to smarter, more innovative, locally based solar+storage systems based at the community level for the next grid outage or disaster.


Milwaukee
M18

5

Top Ten Trends to Champion Battery Storage

Finance

From Mainstream to Low-Income Markets

"The energy storage industry needs better financing to break out of its early stages."[1]

Julian Spector, GTM Energy Storage

Summary

Low- and moderate-income (LMI) communities have lagged far behind commercial and upscale markets in implementing solar+storage technologies. Contributing to that challenge is a persistent financing gap. There are new ownership and finance models beginning to address the economic barriers to deploying resilient power technologies in disadvantaged communities, as well as market-building interventions that foundations and advocates could use to leverage additional sources of capital to advance solar+storage solutions in these markets.

Installation of a battery storage unit at the Marcus Garvey Apartments, an affordable housing property in Brooklyn, NY.

The Issues

There are two distinct markets that are central to a discussion of battery storage finance.

First is a broad market of different segments of creditworthy commercial customers able to access conventional financing; and second, there is a separate market of property owners and project developers seeking financing for affordable housing and community facilities in LMI communities.

In the larger commercial markets with strong utility rate structures and policies, we are starting to see significant commercial activity for battery storage that is supported by robust financing tools.

In the larger commercial markets with strong utility rate structures and policies, we are starting to see significant commercial activity for battery storage that is supported by robust financing tools.

A key finance tool commonly used by independent power producers for conventional power plants is non-recourse project financing. In these transactions, the credit risk is limited to the project itself; the project sponsor is not obligated to backstop the project's loan payments. Non-recourse project financing allows project developers that may not have large balance sheets to be able to access financing on commercially reasonable terms.

Now we're beginning to see more battery storage projects be developed with non-recourse project financing.[2] Least risky are those projects where loan payments are fully covered by payment streams under long-term power purchase agreements (PPAs) from investor-owned utilities. There is also an increasing number of projects that combine merchant revenues (non-contracted payment streams) with contracted utility PPAs. The more loan repayment relies on merchant revenues, the greater the risk and the higher the cost of financing.

In 2017, Macquarie Capital, with CIT Bank, closed on the first non-recourse project financing facility ($200 million) for a portfolio of behind-the-meter (BTM) commercial projects totaling 50 MW of battery storage systems. The projects were acquired from Advanced Microgrid Solutions and are located at commercial, industrial and government properties throughout Southern California.[3]

Through the acquisition of 80 percent of the start-up Green Charge by ENGIE (a French multinational electric utility) in 2016, Green Charge now has direct access to capital markets and nonrecourse debt to build out its BTM pipeline of commercial and industrial projects and expand into utility scale projects.[4]

These types of acquisitions are a clear sign of financial confidence in the energy storage market. And in the monopoly utility states without competition, large-scale energy storage projects are typically rate based, solving that financing issue. Captive customers are obligated to repay utility-scale storage projects through their electric bills.

This is also occurring in one state, Massachusetts, which is a competitive, restructured state. Massachusetts has allowed its electric utilities to rate base energy storage projects as a "non-generation asset." (It should be noted that where energy storage projects can be financed by utility ratepayers, it can create an emerging problem of utility market power that could undermine competitive, BTM markets.)

Outside of the vertically integrated monopoly states, new energy storage market activity is dependent in large part on firm and clear regulatory signals and state and federal policies.

The most active commercial storage market is in California and is driven by a three-legged stool of high demand charges, an aggressive utility storage mandate, and the state's Self Generation Initiative Program (SGIP) incentive.

Solar+storage is lowering utility bills and decreasing tenant turnover at this affordable housing community in Los Angeles County, CA.

That combination has resulted in an active market of new storage start-ups and other solar companies moving into the storage market with well-financed products and services on offer. A case in point is the partnership between Generate Capital, Sharp's Energy Systems and Services Group and SolEd (a solar+storage developer structured as a B Corporation focused on the municipalities, schools and non-profit organizations markets). Generate Capital has been able to secure California energy storage incentives for solar+storage systems to reduce utility costs for six California public schools.[5]

The low-income market is another finance story entirely. The dramatic success of clean energy technologies like solar PV over the last decade has largely bypassed disadvantaged communities.

In commercial markets, the key to being able to finance battery storage projects rests on policy. Strong state mandates and incentives, coupled with federal incentives like the paired solar+storage investment tax credits (ITC), have opened a path for financing portfolios of storage projects. If other states want to see their storage markets develop and bring in finance players into that market, they need to implement similar storage policies.

The low-income market is another finance story entirely. The dramatic success of clean energy technologies like solar PV over the last decade has largely bypassed disadvantaged communities.

Contributing to this lag in market uptake is a persistent financing gap. Solar+storage projects are vastly underrepresented in affordable housing and community facilities across the country.[6] Current models of financing clean energy systems do not sufficiently serve low-income communities, if they serve them at all. That is, there is a lack of capital to invest in these systems in these markets.

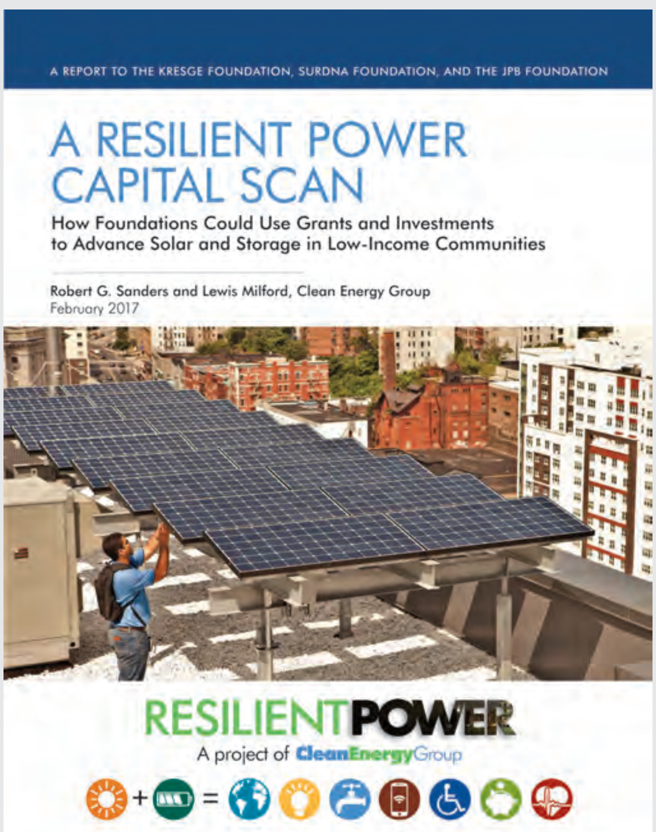
Why is it that solar+storage projects that could reduce utility bills and create more resilient power systems for people who need the benefits the most[7] are unable to reliably access financing?

Many nonprofit property owners serving low-income communities are viewed by lenders as having limited cash flow to service additional debt, making it difficult to access financing for energy upgrades.

Additionally, nonprofit owners of affordable housing or community facilities have difficulty accessing solar+storage tax equity markets. Tax-exempt entities have little if any tax appetite and the tax equity investors that have purchased low-income housing tax credits (LIHTCs) for affordable housing projects have little experience with how solar+storage projects and their ITCs perform in multifamily housing.

In the case of stand-alone solar PV systems, third-party ownership and lease financing models have greatly expanded the market for solar PV by providing no-down payment, 100 percent financing. But in many instances, it has also obligated property owners to long-term leases with recurring payment escalators and unclear bundled operating, management, and financing costs—which present an especially tricky problem for LMI customers or property owners who may have little ability to absorb increasing costs. For these and other reasons, residential direct ownership of PV systems overtook solar leasing in the United States in the last quarter of 2016.[8]

To overcome some of these financing obstacles in low-income communities, in 2017 Clean Energy Group issued a report, *A Resilient Power Capital Scan*,[9] that identifies multiple barriers to financing solar+storage technologies in low-income markets and proposes a broad range of investment opportunities that foundations and socially minded investors can use to address these barriers.



A Resilient Power Capital Scan:
How Foundations Could Use Grants and Investments to Advance Solar and Storage in Low-Income Communities

This report, commissioned by The Kresge Foundation, Surdna Foundation, and The JPB Foundation, identifies market barriers to deploying solar+storage technologies in low-income markets, and proposes more than 50 grant and investment opportunities that socially minded investors can use to target those barriers. The report identifies five market barriers to integrating solar+storage in low-income communities and recommends a broad palette of options for foundations interested in different market efforts. The report can be downloaded at *www.cleanegroup.org/wp-content/uploads/Capital-Scan-Feb2017.pdf*.

The report makes the following observations:

- There are too few completed projects in the LMI space for other interested building owners to evaluate. That lack of replicable completed projects makes scale hard to achieve.
- Property owners and advocates are still largely unaware of the economic, health, and community resilience benefits of solar+storage. This constrains demand for financing.
- There are insufficient performance data. Building owners and lenders want to be able to analyze a track record of successful project development and operation over time.
- There is too much uncertainty regarding how project pro formas compare with actual operations, information that is important in financial underwriting and structuring PPA and energy service contract terms.
- It is difficult for many behind-the-meter building-specific projects to reliably access tax credit investment.
- In general, there is a chicken-and-egg issue facing the current LMI market: Predictable access to well-structured finance is needed to justify the work of developing projects, but investors aren't willing to commit capital without the assurance of a ready pipeline of financeable projects.

Property owners and advocates are still largely unaware of the economic, health, and community resilience benefits of solar+storage. This constrains demand for financing.

The Opportunities and Challenges

How the ownership of solar+storage assets is structured will affect the financing options that are available to an LMI housing developer. The good news is that there are several new financing options emerging in the LMI marketplace.

In Clean Energy Group's March 2018 report, *Owning the Benefits of Solar+Storage: New Ownership and Investment Models for Affordable Housing and Community Facilities*, four new ownership and investment models were discussed that promise to extend the benefits of solar+storage to affordable housing owners and residents, as well as community facilities, beyond the direct ownership model.[10]

First, as a baseline status quo option, there is the *immediate direct ownership model*. The solar+storage system is purchased and owned outright by the property owner. In this model, a solar+storage developer designs and builds a turnkey system to be owned by the property owner, and the owner retains the greatest flexibility and control over the economic and use benefits of the solar+storage system. The net metering, solar

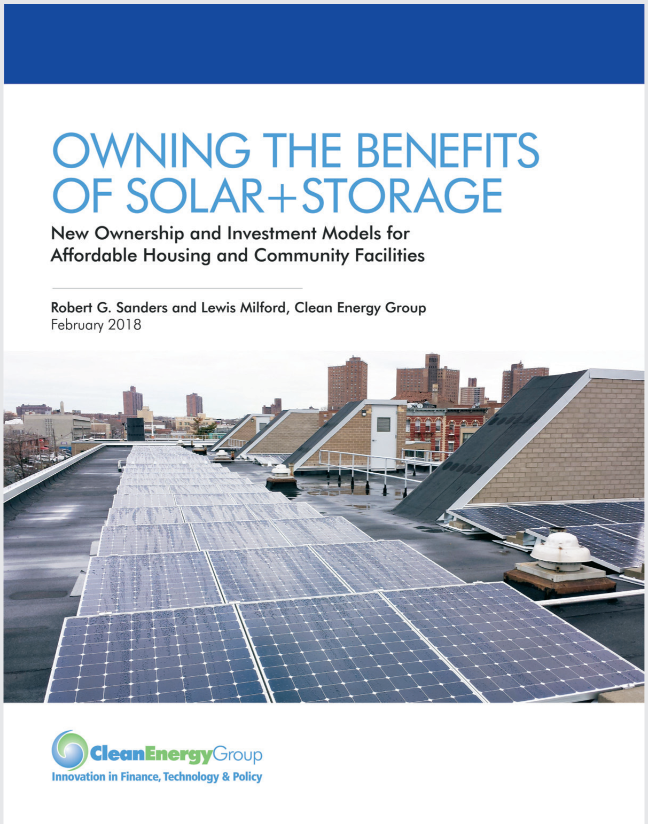
A battery storage unit is combined with rooftop solar at the Marcus Garvey Apartments in Brooklyn, NY.

renewable energy certificates (SRECs), and utility bill savings of solar and energy storage systems are retained by the owner.

As tax-exempt organizations, government and nonprofit entities are unable to take the tax incentives associated with solar+storage systems. These tax benefits may include ITCs, LIHTCs, and accelerated depreciation (Modified Accelerated Cost Recovery System, or MACRS).

Second, there is the *third-party ownership flip*: A third-party entity initially owns the solar+storage assets until the tax equity investor's tax incentives have been fully used, at which point ownership of the project assets flips to the property owner. The third-party entity (either a special purpose entity created for the specific project or a third-party project development entity) raises tax equity investment to supplement the grants and incentives that have been awarded to the project.

Solar+storage equipment can be installed without any upfront capital cost to the property owner. The third-party ownership of solar+storage assets does not interfere with the existing capital stack for the real estate property, so no consents are required by existing mortgage lenders, and the project does not need to coincide with a capitalization event.



Owning the Benefits of Solar+Storage:
New Ownership and Investment Models for Affordable Housing and Community Facilities

Current clean energy financing models do not sufficiently serve low-income communities. As a result, solar+storage projects are vastly underrepresented in affordable housing and community facilities, meaning that low-income communities are unable to enjoy the benefits of clean, affordable and resilient power.

This paper, prepared by Clean Energy Group, describes emerging finance models to address the energy equity challenge and to level the financing playing field. It explores additional ownership and financing options for solar+storage projects and low-income communities beyond direct ownership and conventional leasing models. It makes a simple point: there are ownership and financing strategies that can provide many of the economic and other benefits of direct ownership, while overcoming some of the risks and barriers that direct ownership may entail for many project developers. The paper can be downloaded at *https://www.cleanegroup.org/wp-content/uploads/Owning-the-Benefits-of-Solar-Storage.pdf*.

Third, there is the *third-party ownership flip using an affiliated entity*: Instead of the assets being transferred to the property owner/housing developer once the tax benefits have been fully utilized, they are transferred to an affiliated public purpose entity. Initially, the affiliated entity would retain one percent ownership of the solar+storage assets, and the tax equity investor would own the remaining 99 percent. The affiliated entity would enter into PPAs with the individual property owners and tenants on favorable terms throughout the economic life of the project.

Once the tax benefits have been fully utilized by the tax equity investor, 100 percent ownership of the assets flips to the affiliated entity. Construction and permanent financing to leverage the tax equity investment for the project can be obtained by either the owner/developer or the affiliated entity. The owner/developer and the affiliated entity could serve as co-developers for the solar+storage project, for which they share in the development fee.

Fourth, there is the *C-PACE model with third-party ownership*: Property Assessed Clean Energy (PACE) financing secures the loan payments through a priority lien assessment on real estate property, providing third-party owners/tax equity investors with additional security and long-term debt sources for solar+storage projects. State and local incentives and favorable financing—including 20-year tax credit bond financing such as Qualified Energy Conservation Bonds (QECBs)—can be used to reduce the cost of financing and increase the project's economic benefits.

These economic benefits are then passed on to the property owner through improved power purchase agreement (PPA) pricing and terms, sometimes using a "prepaid PPA" model (an option that may no longer be financially feasible under the 2017 end-of-year U.S. tax-cut bill).[11,12]

Once the investment tax credits have been fully used, ownership of the solar+storage equipment can be flipped to the nonprofit property owner or affiliate.

Once the investment tax credits have been fully used, ownership of the solar+storage equipment can be flipped to the nonprofit property owner or affiliate.

Fifth and last, there is the *utility-ownership or third-party ownership under a utility-contracted payment for services agreement:* If energy demand congestion is relieved in key grid circuits, the utility is indifferent to whether the project is located adjacent to a low-income community property. When the grid is down, the solar+storage system is available to provide resilient back-up power for adjacent critical energy loads and public services. Utilities may choose to own the solar+storage systems outright.

But in many states, utilities are not permitted to own generation sources. An alternative ownership model that is being developed is for third-party providers to own solar+storage systems and sell energy, capacity, or ancillary services from solar+storage systems into wholesale markets or with payment-for-services utility contracts.

This may involve aggregating energy storage systems to create larger energy services offerings, something a single property owner or business may not otherwise be able to do. This model has been deployed in commercial markets and could be extended to multifamily affordable housing and community facilities.

The Actions

A two-pronged approach is needed to meet the challenge of scaling solar+storage deployment in LMI communities.

$ **New financial resources and interventions are needed to address financing gaps and leverage external investment so that projects can be implemented, and portfolio owners and project developers will commit their resources to developing prospective projects.**

$ **Support is needed for organizations that have demonstrated an ongoing commitment to developing their capacity to build project pipelines.**

$ **A uniform, scalable financing product for LMI projects is not immediately apparent at this stage in the market's development. Instead, support should be given to project developers and financial intermediaries that are pursuing flexible "pilot" financing approaches for deploying solar+storage systems**.

Excellent work is being done in developing new financing products, underwriting terms, and development/construction risk mitigation protocols for LMI solar+storage projects, notably New York City Energy Efficiency Corporation (NYCEEC), NHT Renewable, Urban Ingenuity and Generate Capital.[13]

In *A Resilient Power Capital Scan*, more than fifty grant and investment interventions are proposed that foundations and impact investors could consider to accelerate the financing and deployment of solar+storage technologies in LMI communities. Some of these include:

- Storage developers have developed thousands of behind-the-meter battery storage systems for commercial customers. Favorable financing—including equity investment—for companies that are prepared to expand their market focus to include LMI and MUSH (municipalities, universities, schools, and hospitals) markets would be a means of accelerating deployment in these markets.
- Support for the creation, outreach, and initial operations of a new or repurposed legal entity to aggregate multiple portfolio owners' solar+storage tax credits to create a scaled investment opportunity for investors.
- Support for analysis and pre-development costs to create business models and value sharing with utilities interested in solar+storage in LMI communities to defer capital investments in transmission and distribution.

Via Verde, or the Green Way, was the winner of the New Housing New York Legacy Project (NHNY) competition, an initiative that set out to bring innovative, sustainable design to affordable housing.

- Provide a source of ten-year project financing or credit enhancement so third-party project developers can prove out utility and community resiliency benefits of solar+storage until utilities can gain approval to own the systems themselves.
- Provide debt service reserve funds and other credit enhancement to support initial projects of strong portfolio owners.
- Provide credit enhancement and/or capital to support commercial and "Civic" PACE (PACE financing for tax-exempt property owners) financing for multifamily affordable housing (including public housing) and nonprofit-owned community facilities projects.
- Provide funding to build pipeline-development capacity that supports program related investments (PRIs) and other investment in community resilient power projects. However, PRIs to advance solar+storage technologies will have difficulty getting traction in this emerging LMI market without sustained support for capacity building for project developers, property owners, and community advocates. This needed support includes technical assistance, data collection and analysis, and information sharing.
- Provide market building grant funding. Philanthropic and local/state support is needed to create an adequate policy, incentives, and regulatory frameworks to leverage financing and investment for solar+storage project development in LMI communities.

$ **As an overall recommendation, there is a serious storage "capacity gap" among low-income communities, advocates, and affordable housing owners that must be addressed.** Solar+storage is a new, complex technology that requires a level of energy sophistication that often is missing in small nonprofits, among affordable housing building owners, and in public agencies. Foundations should consider developing a significant "capacity fund" to serve LMI storage markets if they want to see serious uptake of the technology for those most in need.

6

Top Ten Trends to Champion Battery Storage

The Future of Solar

It's Storage

"Virtually all quarters agree that the real future for solar—and much of the energy industry—depends on electricity storage, which banks solar power for when the sun isn't shining."[1]

Ivan Penn & Russ Mitchell, *Los Angeles Times*

"Pairing solar and storage is here and now."[2]

Bernadette Del Chiaro, Executive Director, California Solar & Storage Association Summary

Summary

As more solar PV is connected to the grid, eventually leading to oversupply and solar curtailment, its value to the grid decreases. By transforming solar into a flexible, responsive, dispatchable resource, energy storage can preserve the value of solar to the power system. It can insulate solar customers from adverse changes to solar policies and utility rate structures that could jeopardize the value of their clean energy investments.

Reslient solar+storage system is paired with a backup generator at the headquarters of Boulder Housing Partners, the city's public housing agency in Boulder, CO. The system includes a 7.7-kW solar PV array, and 45 kW of AGM Lead Acid Batteries.

The Issues

Solar energy generation has grown exponentially over the past few years, a trend that shows no signs of slowing anytime soon. This is particularly true for states with strong renewables generation and emission reduction policies, like California, Massachusetts, and Hawaii.

This is good news for climate and environmental protection, but along with success comes new challenges.

For the electric grid to function properly, energy supply must be kept in constant balance with energy demand. Both an oversupply and undersupply of energy can result in serious problems, like widespread outages.

The U.S. Energy Information Administration (EIA) reported that in March 2017 utility-scale solar briefly served 40 percent of California's electricity demand. Along with rooftop generation, EIA estimated that more than 50 percent of mid-day electricity demand was met with solar.[3] That's a big accomplishment for a state committed to 50 percent renewable generation by 2030.

During that same period, wholesale electricity prices in California dropped below zero. Negative pricing sounds like a positive thing for consumers, but it points to two major obstacles facing solar growth in California and other states with relatively high renewables penetration: oversupply and value deflation.

Oversupply can happen when intermittent solar and wind produce enough electricity to push demand for traditional baseload generation below forecasts. For the electric grid to function properly, energy supply must be kept in constant balance with energy demand. Both an oversupply and undersupply of energy can result in serious problems, like widespread outages. When production by inflexible traditional generators, like coal and nuclear plants, can't be pushed any lower, negative pricing and renewable generation curtailment occur.

Curtailment means that some portion of the solar energy generation gets cut off, essentially wasting free, clean energy. In 2017, the president of the California Independent System Operator, which manages the state's electric grid, warned that the grid operator may be forced to curtail as much as 8 gigawatts of power at certain times during the spring season, mostly solar.[4] That's a lot of lost clean energy.

Oversupply and curtailment are big factors in the second major issue facing renewables growth, value deflation. The fact is, that as more and more solar comes online, producing energy at the same time, the value of that generation to utilities and the grid declines.

> ***As more and more solar comes online, producing energy at the same time, the value of that generation to utilities and the grid declines.***

This is most evident when curtailment occurs. With high enough levels of curtailment, the value of solar could decline to the point where additional installations are no longer worth the cost.

Until recently, the sunny daytime hours were when the California grid experienced much of its highest demand for electricity. Now, as solar production has carved out the net-daytime load, that peak demand for electricity has largely shifted to the evening hours.

This peak transition is illustrated by California's infamous "duck curve." It shows a steep decline in net energy demand as solar production ramps up in the morning, and an even steeper increase in energy demand in the early evening as solar production winds down and people return home from work.[5]

Microgrid testing and analysis at Idaho National Laboratory.

These large fluctuations in demand create balancing concerns for grid operators, which are often solved by inefficiently ramping expensive natural gas "peaker" generation up and down. But ironically and troubling, these trends are likely to intensify in states that have made the most progress on solar policy, leading them to reevaluate these policies.

States and utilities are responding to declines in the grid value of solar by adjusting net metering policies and imposing new rate tariff designs, leading to solar value deflation for homeowners and businesses as well.

California is responding by shifting most of its utility customers to time-of-use utility rates, where the highest prices for electricity occur when the sun isn't shining. The state has also applied small charges to solar energy that is exported to the grid and allowed utilities to increase the demand charges applied to commercial customers.

As noted in Clean Energy Group's May 2017 report, *Solar Risk: How Energy Storage Can Preserve Solar Savings in California Affordable Housing*, the combination of these measures could result in more than a 50 percent drop in solar savings for some California utility customers who have invested in solar.[6] (See Figure 8.)

Hawaii, with the highest rooftop solar penetration in the country, has taken similar steps. In 2015, Hawaii became the first state to dismantle its solar net metering program. The following year, the Hawaii Public Utilities Commission approved a pilot time-of-use rate program where electricity prices can jump by a factor of more than four times higher as the sun begins to set.[7] Today, with limited solar exports allowed, most Hawaiian customers must invest in energy storage if they want to install a solar system.

This might be the most important issue in solar policy in a decade—without storage, the future economic value of solar is at risk.

This might be the most important issue in solar policy in a decade—without storage, the future economic value of solar is at risk.

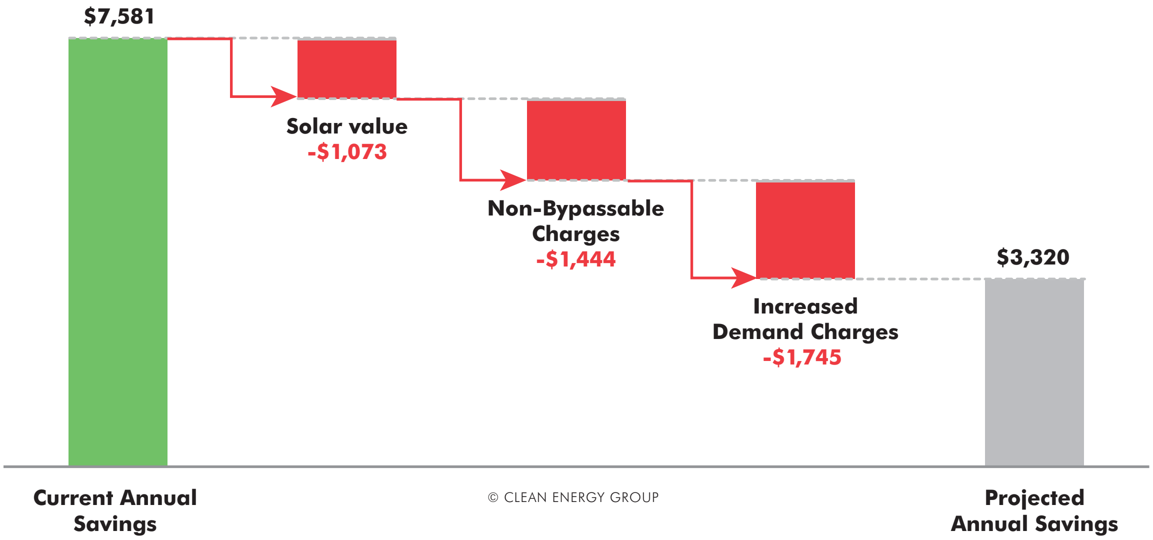
The Opportunities

That solar should be paired with battery storage is now a virtual consensus policy.

The National Renewable Energy Laboratory (NREL) raised similar concerns on solar+storage when evaluating what it would take for California to achieve

FIGURE 8

Proposed Changes Reduce Property Owner's Annual Savings from Solar by $4,262, a 56% Loss



The combined impact of shifting time-of-use pricing periods, non-bypassable charges, and proposed higher demand charges would reduce the annual bill savings delivered by a commercial solar system in San Diego by 56 percent. The annual savings shown in this chart represent a 52-kilowatt PV system producing 75,000 kilowatt-hours per year for an affordable housing property with an annual peak demand of 35 kilowatts billed under the San Diego Gas & Electric TOU-AL rate tariff.

50 percent solar penetration by 2030.[8] In order to keep solar curtailments at a reasonable level and keep the cost of solar electricity production competitive with traditional gas generators, the study found that California would need an additional 15 gigawatts of energy storage—that's more than 11 times California's groundbreaking storage procurement mandate of 1.3 gigawatts.

Another report from NREL found that solar and storage can complement and enhance each other's value when considering the replacement of natural gas peaker plants, a topic covered more extensively elsewhere in this report.[9] According to NREL's study, higher penetrations of PV, similar to those seen in California today, produce a "peakier" net load shape on the system, which in turn creates more opportunities for shorter duration energy storage systems to meet those peaks in demand. As stated in the report, the "potential of energy storage continues to increase with increasing PV penetration." This analysis shows yet another synergistic economic relationship between solar and storage technologies.

Pairing solar with storage for behind-the-meter systems serving homes and commercial customers can act as a hedge against changes in state net metering policies and evolving utility rate tariffs.

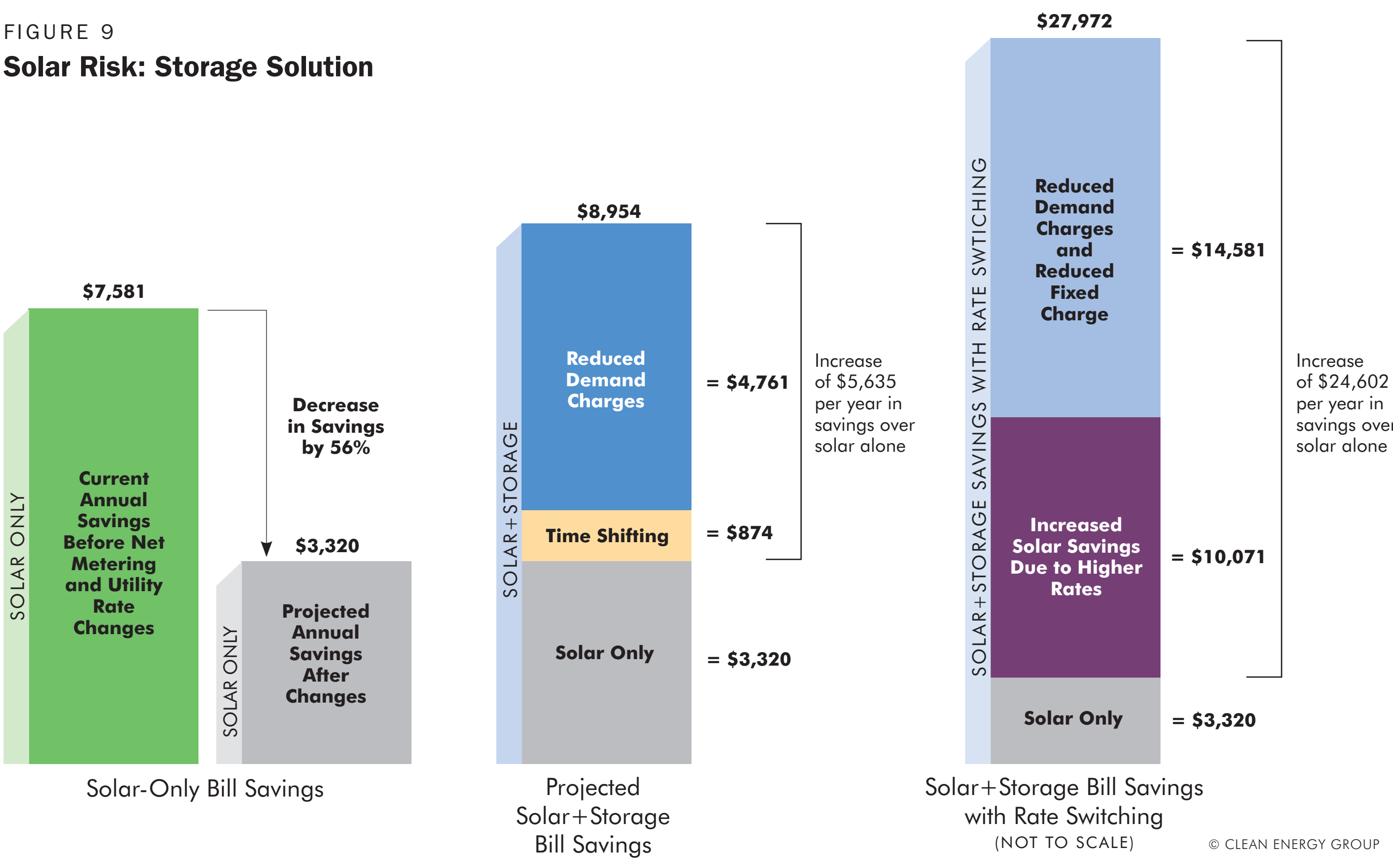
In addition to enhancing and preserving the value of solar at the grid level, battery storage can also protect the value of solar for consumers.[10] Pairing solar with storage for behind-the-meter (BTM) systems serving homes and commercial customers can act as a hedge against changes in state net metering policies and evolving utility rate tariffs.

The bottom line for customer-sited solar+storage is this: the same analysis that estimated a 50 percent drop in solar value for customers under new California rules and rates also found that storage could completely reverse those losses, in some case delivering more than eight times the annual savings of solar alone. (See Figure 9.)

According to analysis by Navigant Research, global revenue from energy storage deployments supporting the integration of renewable generation will top $23 billion by 2026.[11] This impressive growth is expected for both utility and customer BTM installations, with BTM battery storage anticipated to account for about two-thirds of new storage capacity. Despite this positive outlook and continued battery storage cost declines, Navigant found that storage deployments are still hampered by a lack of consistent policies, market opportunities, and financing options across regions.

FIGURE 9

Solar Risk: Storage Solution



Adding energy storage can reverse the negative impacts on solar bill savings due to net metering changes and proposed utility rate tariffs, which could reduce savings by more than 50 percent. Storage unlocks additional savings through time-shifting solar to be used during peak electricity pricing periods and reducing, or in some cases eliminating, demand charges.

The Actions

To ensure that storage becomes an integrated part of the solar equation before issues like oversupply and curtailment arise, all clean energy policies and market signals need to be established and aligned to recognize the added value that storage can bring to a solar project.

States need to consider policy options to incorporate storage value into future solar projects. Some states have already proposed or implemented measures that would reward solar projects that include energy storage. Hawaii's Community-Based Renewable Energy program has been designed to incentivize renewable power that can be dispatched to correspond with peak grid demand. Under the program, projects will earn a premium for power exported to the grid between 5 p.m. and 9 a.m.[12]

Similarly, measures introduced in California, Massachusetts, and Arizona have proposed creating a clean peak standard that would require utilities to deploy a specified percentage of clean energy during periods of peak demand.[13] Massachusetts is also approaching solar+storage in a different way, by including an energy storage adder for paired projects in its new Solar Massachusetts Renewable Target (SMART) program.

States should consider utility rate design to boost the uptake of solar paired with storage. As has been done California and Hawaii, implementation of time-of-use rates or critical peak pricing that more accurately reflect the varying wholesale cost of energy can give solar owners an economic incentive to store solar production during daytime hours and discharge it later when electricity prices may be higher.

States adopting these types of policy measures and market adjustments should pair them with extensive consumer outreach and education efforts. Individuals, businesses, and communities will need access to information about how changes to state solar policies and utility rates could impact their solar investments, and how storage can help mitigate against future uncertainties in the value of solar.


TESLA

7

Top Ten Trends to Champion Battery Storage

Emission Reductions

Replacing Fossil-Fueled Peaker (and Maybe Baseload?) Plants

"I can't see a reason why we should ever build a gas peaker again in the U.S. after, say, 2025. If you think about how energy storage starts to take over the world, peaking is kind of your first big market."[1]

Shayle Kann, senior adviser to GTM Research and Wood Mackenzie

Summary

Storage could replace existing and new, uneconomic gas-fired peaker plants, especially in congested urban distribution areas, in the coming years. Over the long term, whether solar+storage could operate as an economic, baseload firm resource is a critical and contentious issue in clean energy policy. Both of these opportunities call for more systematic work on storage—to understand how market-based, declining cost and longer duration discharge trends impact whether storage and renewables could significantly reduce fossil fuel emissions from the power system by mid-century, a key decarbonization target.

The Mira Loma Battery Storage Project in California can store up to 80 megawatt hours, enough energy to power 15,000 homes for four hours.

The Issues

Today's electric power system is built on a foundation of baseload power, largely coal, nuclear, and gas, supported by more flexible, predominately natural gas-powered plants to meet peak demand, known as peaker plants. Recent market trends suggest some combination of renewables and battery storage could economically compete to replace some or all our existing fossil-fueled fleet in at least two ways.

First, today there are economic opportunities for storage to compete directly with high-cost, infrequently utilized gas peaker plants, especially in heavily congested sections of the grid. In that market—consisting of nearly 800 gas combustion turbines in operation across the country—storage could start to replace and retire this fossil-fueled fleet now and over the next several years.[2] But no coordinated analytical and advocacy strategy is now in place to support and accelerate that transition.

Recent market trends suggest some combination of renewables and battery storage could economically compete to replace some or all our existing fossil-fueled fleet in at least two ways.

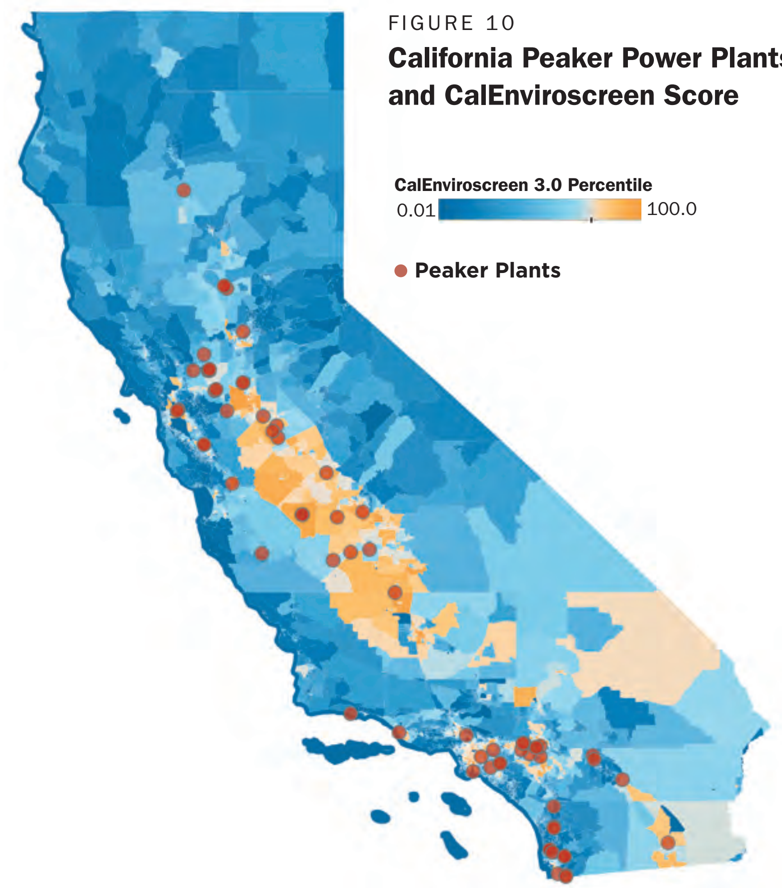
Second, and this is a much more debatable and long-term proposition, current market activity suggests that renewables and storage could start to operate like firm power and displace or cause the retirement of some existing baseload, carbon-based generation. That prospect—and the role of storage—is subject to a highly contentious debate over whether renewables can fully replace fossil-fueled electricity generation in the long-term energy future. In turn, that renewables debate depends on whether storage costs can realistically decline and also provide long duration power to the point it and renewables can compete with baseload power. Some advocates and analysts even argue that there will be no need for what has traditionally been known as baseload power as the world transitions to a cleaner, more dynamic energy system.[3]

This report addresses the near-term peaker replacement opportunity in some depth. The long-term baseload discussion is largely outside the scope of this report, but it is summarized enough to frame the options going forward—mainly to argue for smarter analytical rigor on the question of how innovation and cost declines will shape the role of storage in the future, and why models need to reflect current market activity on those issues.

As to the nearer-term opportunity, natural gas peaker plants are more expensive to run than baseload generation and are typically less efficient, so they tend to emit

FIGURE 10

California Peaker Power Plants and CalEnviroscreen Score



Natural gas peaker plants are more expensive to run than baseload generation and are typically less efficient, so they tend to emit hazardous pollutants at a higher rate than other conventional gas plants.

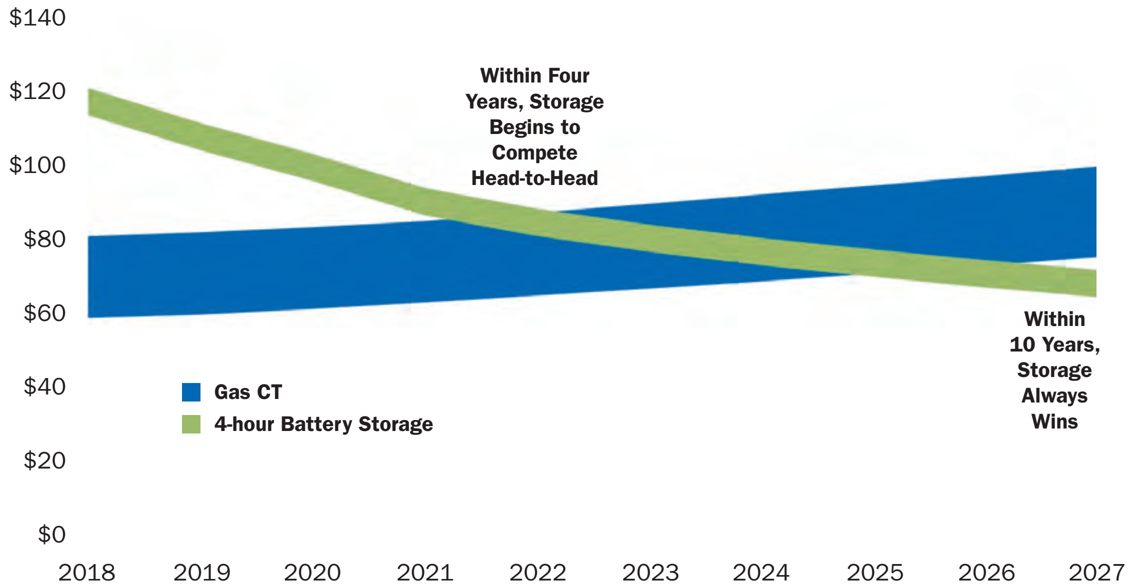
Half of all peaker plants in California are located in the state's most disadvantaged communities. These communities have been identified by the California Environmental Protection Agency as being disproportionately burdened by multiple sources of pollution and home to vulnerable populations that may be more sensitive to pollution.

multiple pollutants at a higher rate than other conventional gas plants. Even worse, peakers are often located in or near disadvantaged communities and called upon to run on days already experiencing poor air quality conditions.[4] A California study found that more than 80 percent of the state's existing peaker plants are located in the state's more disadvantaged communities.[5] (See Figure 10.)

Recent analysis from the national laboratories suggests that storage "could replace peaking capacity in urban areas."[6] Researchers at NREL found that, in some cases, storage could be a viable cost-effective alternative to a natural gas peaker plant. While batteries have a higher up-front capital cost, they have lower operating costs due to avoided fuel costs, avoided peaker start-up costs and deliver additional benefits to the grid by performing other valuable services.[7]

Other researchers have confirmed this market trend of peaker replacements with storage in the near future, though all pick slightly different near-term dates for when storage could reach competitive cost parity.

FIGURE 11
Peaker Plants at Risk from Storage in the Next Few Years



Source: GTM Research/Wood Mackenzie[8]

As of early 2018, some analysts say peakers are at risk from storage in the next five years:

> "Beyond the early 2020s, as the cost structure of storage systems declines to levels that make them cost-competitive with gas peakers, there is the likelihood of an exponential increase in storage deployment. This will have the effect of reducing the need for gas peakers, putting at risk a sizable portion of [that fossil fleet]."[9]

GTM Research estimates that declining battery prices will result in natural gas peaker development becoming increasingly rare over the next few years, possibly ending altogether within 10 years.[10] (See Figure 11.) It says that the U.S. will need to add about 20 gigawatts of peaking capacity over the next decade. Storage could account for at least half of that capacity, possibly more if batteries costs decline faster than expected.[11]

Bain & Company agrees, estimating that, by 2025, battery storage could be cost-competitive with peaker plants, and that's without even considering the many additional values streams that storage could access.[12]

Similarly, according to analysts at the investment company Raymond James & Associates, there is likely to be an exponential increase in energy storage deployment in the early 2020s as cost declines make batteries an economic alternative to gas peakers.[13]

Finally, other researchers from the University of Texas stated, with some reservations about whether storage cost reductions will occur in time, that "going after peaker plants will likely be the first major play (besides infrastructure deferments) that batteries make into the markets."[14]

And to confirm the popular economics of this trend, the *Wall Street Journal* in early 2018 gave this replacement opportunity a comprehensive press treatment. A lead piece stated that, "giant batteries charged by renewable energy are beginning to nibble away at a large market: the power plants that generate extra surges of electricity during peak hours."[15]

Declining battery prices will result in natural gas peaker development becoming increasingly rare over the next few years, possibly ending altogether within 10 years.

This movement to replace peaker plants appears to be on strong economic ground and is likely to be an area where storage will be quite active in the coming years.

As to baseload replacement, the future is unclear at best and is subject to a great deal of dispute, mainly among climate technology modelers.

However, it is hard to ignore current market activity in this space, which suggests that solar paired with storage is starting to beat out fossil fuel capacity providers across the country in some jurisdictions, an economic competition unimaginable only a few years ago.

In Hawaii, the utility serving Kaua'i contracted for 28 megawatts of solar with 100 megawatt-hours of batteries at a power purchase price of 11 cents per kilowatt-hour, lower than fossil-fuel generators could deliver.[16]

Tucson Electric Power in Arizona set a mainland record for solar paired with storage with a 20-year power purchase agreement rate below 4.5 cents per kilowatt-hour for 100 megawatts of solar and 120 megawatt-hours of storage.[17]

Based on data reported by Xcel Energy, the Colorado utility received a median price of 3.6 cents per kilowatt-hour for energy from more than 50 proposed solar developments paired with storage.[18]

In 2016, PG&E announced plans to replace the 2.3 gigawatts of generation capacity from California's last nuclear power plant with a mix of renewables, energy storage, and efficiency measures.[19]

And in New Mexico, the state's largest utility issued a request of 456 megawatts of renewables and battery storage to help reach its goal of becoming coal free by 2031.[20] Utilities across the country are exploring similar opportunities.

This isn't to say that batteries aren't facing opposition as alternatives to traditional power plants. It's true that, while batteries can meet many of the same peak demand needs as a natural gas peaker plant, they are different types of technologies and batteries are limited in some ways that gas peakers are not.[21] Batteries can only deliver peak power over a predetermined duration of time, whereas a gas plant with fuel can run indefinitely.

It seems to be the case that the dispatch duration of battery storage—a key to success in baseload disruption—is more of an economic barrier than a technical issue.

However, lithium-ion battery storage projects are already advancing beyond their initial 4-hour duration limitation, with projects in development for 8-hour batteries and proposed projects that could deliver up to 10 hours of peak energy.

It seems to be the case that the dispatch duration of battery storage—a key to success in baseload disruption—is more of an economic barrier than a technical issue. That is, with cheaper and cheaper storage, it will be economically possible to cost-effectively deliver stored energy over longer and longer time frames, which makes it possible to firm up more and more intermittent renewable power.

Batteries also have some distinct advantages over traditional plants, such as the ability to avoid a single point of failure through distributed storage resources; they can be sited closer to loads, which avoids interruptions due to transmission line failures; and they avoid the price volatility of fuels like natural gas, particularly when batteries are charged by renewable energy.

The Opportunities and Challenges

The benefit of replacing fossil-fuel power plants, both peakers relatively soon and possibly baseload further down the road, with renewables paired with storage are clear—no greenhouse gases and no local toxic emissions. Additionally, batteries can be deployed more quickly than traditional resources, can be sited in many more locations, and have the flexibility to provide many more services than fossil-fuel power plants.

Aerial view of thick summer smog in urban downtown Los Angeles, California.

This is more than theory, as energy storage stepped in to reliably deliver peak capacity after a major gas leak at California's Aliso Canyon natural gas storage facility. The state deployed 100 megawatts of storage across several sites in a matter of months, avoiding feared blackouts during the summer peak season in 2016.[22]

That success may have been just the beginning for California.

In early 2018, the California Public Utilities Commission approved a resolution requiring the utility Pacific Gas and Electric (PG&E) to look for battery and clean energy based alternatives to three existing gas-fired power plants. Instead of offering the gas plants lucrative must-run contracts to keep them operating, PG&E must use some combination of batteries and other non-fossil fuel resources to meet peak demand going forward.[23]

Efforts to build a new gas plant in Oxnard, California were also derailed recently when the California Independent System Operator determined that storage and distributed generation could do the job just as well.[24] The balance in favor of the plant shifted when analysis showed that solar+storage could deliver the same reliability and grid stability as a gas plant, but without the unwanted emissions. Solar+storage could also be deployed more quickly than a traditional power plant, and the resource

Tesla Powerpacks and solar panels on the island of Kaua'i, Hawaii.

could be dispersed throughout the community, allowing local residents and businesses to see direct economic benefits from the development.

In fact, a wave seems to be building to close these aging gas peakers—and to reconsider new ones—in California. In early March 2018, NRG announced it would retire three peakers in that state, while four other gas plant proposals were put on hold as state regulators consider clean energy alternatives.[25]

This trend is likely to build over the coming years. According to a recent NREL report, at California's current level of 11 percent solar penetration, battery storage could replace up to 3 gigawatts of peaker plants in the state. At 17 percent solar penetration, battery storage could replace up to 7 gigawatts of peakers. That would continue the movement to replace the 272 natural gas combustion turbines currently active in the state that represent 20.6 gigawatts of peaking capacity.[26]

While California is leading the way, this power plant replacement trend isn't limited to the Golden State.

In late January 2018, solar paired with battery storage directly beat out bids from natural gas peaker plants in response to a request for proposals (RFP) from another Arizona utility, Arizona Public Service Electric Company. The RFP, which was open to any technology, was looking for solutions capable of delivering power during the utility's peak demand period between 3 p.m. and 8 p.m.

The winning bid was submitted by First Solar for a 65-megawatt solar installation combined with 50 megawatts/135 megawatt-hours of battery storage. A spokesperson for First Solar commented that the company expects this type of solar+ storage project model to become "very common in many of our markets."[27]

Taking the case even further, in an unprecedented move, the Arizona Public Service Commission in March 2018 placed "a temporary moratorium on new natural gas infrastructure" pending a case by case review. In that new project level review, the Commission indicated it wanted "an independent analysis comparing the present and future costs between the specific natural gas procurement and alternative energy storage options."

Needless to say, this kind of regulatory action could completely change the game for consideration of how storage should compete against gas plant development, if such actions become common in other jurisdictions.[28] And there is a lot of room from storage to grow in this sector, as the Energy Information Administration reports that just thirteen battery storage projects are now operating as peaker plants across the country.[29]

So, apart from its growing building-level and utility applications, renewables with battery storage could assume the role of reliable, on-demand power—replacing dirty peaker plants where storage costs today are close to competitive.[30]

So, apart from its growing building-level and utility applications, renewables with battery storage could assume the role of reliable, on-demand power—replacing dirty peaker plants where storage costs today are close to competitive.

But there is a longer-term opportunity that might or might not come to pass: whether renewables and storage can begin to operate like a baseload plant. Some believe they could start to replace our existing coal and nuclear plants, as well as replace new natural gas plants that are the default option to bridge the gap left by coal plant retirements.

Indeed, a new international study says that the cheapest and most effective way to achieve a 100 percent global clean decarbonized energy transition by 2050 is through a mix of renewable power backed by battery storage.[31] It is the first emissions study to incorporate real-world cost reduction trends in battery technologies, leading to a newly optimistic case for decarbonization of the current fossil fuel energy system.

To give a sense of how quickly and widespread this transition to incorporate energy storage could be, currently some utility executives are the leaders behind this pro-renewables and storage argument.

Storage is important for emissions reductions because it could be the flexible, enabling technology that can overcome the intermittency issues that plague renewable wind and solar. For the truth is that wind and solar do face significant barriers due to their variable generation and time-constrained nature.

Energy storage is the essential enabling technology that can shape and firm energy production by these intermittent renewable resources for integration onto the grid.

To give a sense of how quickly and widespread this transition to incorporate energy storage could be, currently some utility executives are the leaders behind this pro-renewables and storage argument.

On an investor call in early 2018, Jim Robo the CEO of Nextera, which manages utilities such as Florida's largest electricity provider, Florida Power and Light, stated that, early in the next decade, wind and solar, without incentives, will deliver energy at a cheaper cost than existing coal or nuclear facilities. Robo told investors:

> As the world's leader in wind, solar+storage development, we are uniquely positioned for the next phase renewable development that pairs low cost wind and solar with a low-cost battery storage solution to provide a product that can be dispatched with enough certainty to meet customer needs for firm generation resource."[32]

The recent capacity auctions from utilities in Colorado and Arizona described above also show that the costs of solar+storage power are already lower than the average cost of running coal plants in their states.

But whether solar+storage could ever operate as competitive baseload power is hardly a universally agreed upon view.

Some climate advocates have a less optimistic view of whether renewables with storage ever could serve as a baseload resource.[33] A recent report from Lazard also indicated its view that solar+storage technology "will not be capable of meeting the baseload generation needs of a developed economy for the foreseeable future."[34]

However, an important study released in early 2018 by noted climate experts at Caltech and other institutions described a future scenario where wind and solar technically could power at least 80 percent of the electric system with high reliability—assuming storage costs decline significantly:

> In particular, our results highlight the need for cheap energy storage and/or dispatchable electric generation. Determination of the most cost-effective strategic combination depends on future costs that are not well-characterized at present. Regardless of the levelized cost of electricity from solar or wind power alone or in combination, our examination of 36 years of weather variability indicates that the primary challenge is to cost-effectively satisfy electricity demand when the sun is not shining, and the wind is not blowing anywhere in the U.S.[35]

Microgrid testing and analysis at Idaho National Laboratory.

Local studies of this sort are also now emerging. A March 2018 study by Synapse Energy Economics indicated that the Los Angeles Department of Water and Power could repower their electric system with 100 percent renewables by 2030. That conclusion depends on a significant, parallel investment in energy storage—in the 2-3 GWh range—especially for a distributed renewables strategy.[36]

The models, as can be expected, often predict excessively high future costs for storage based on current costs, therefore pricing out the potential for storage and renewables to compete against baseload plants.

These reports are part of the ongoing debate about whether renewables uptake can be cost-effectively deployed to reduce emissions and replace fossil fuel plants in the next few decades. The models, as can be expected, often predict excessively high future costs for storage based on current costs, therefore pricing out the potential for storage and renewables to compete against baseload plants. The Caltech study importantly focused on the future storage cost reduction needs, once it established the technical case for renewable generation.

As a general matter, unlike the Caltech study, it's important to recognize limitations of many such models. A recent article concluded that such climate models "systematically underestimate" the role of solar in climate emissions reductions—and enabling storage—as compared to the cost reductions seen through innovation and actual deployment experience.[37]

In this regard, it also seems important that the recent market data in the past year showing extraordinarily significant cost reductions for solar+storage replacement capacity in utility RFPs alone must play a role in future modeling. If it does not, there will be situations where the models ignore the markets, which is not a good result for smart advocacy and policymaking.

And it is important to recognize that modeling the technology trajectory for energy in three or four decades is tricky territory. Predicting technology innovation trends has proved to be a parlor game filled with historic examples of silly and wrong statements about why cars, phones, computers and the internet would never achieve market entry, or not become cheap enough to compete against former incumbent technologies.

We must be cautious with ironclad predictions about how storage innovation and costs will play out into the 2050 time frame, a key period for climate stabilization, especially given the rapid cost-decline trends for storage now appearing for the first time in energy markets. And relying on such prognostications to develop current policies is even more complicated.

In all cases, it seems a good idea to be humble about this technology prediction enterprise. It might be wise to avoid a premature conclusion that energy storage technology innovation in the decades to come will "never" compete with existing, incumbent technologies.

Despite all this uncertainty and the prevalence of dueling climate models, what is certainly clear is the need for more analytical work in this space that is based on current and future economic data on energy storage markets.

Instead, it might be a better use of time for advocates to focus on accelerating the adoption of key storage technologies now, so that needed cost reductions come about in time to make renewables more reliable and cost-effective.

Put another way, we need to be wary of a professed certainty about how storage technology cost and adoption curves will or will not evolve, especially as storage is subject to manufacturing cost efficiencies new to the energy space. As a recent Santa Fe Institute meeting about technology noted, "predicting the future of technology even five to ten years out is often little more than a guessing game."[38]

Despite all this uncertainty and the prevalence of dueling climate models, what is certainly clear is the need for more analytical work in this space that is based on current and future economic data on energy storage markets. Not having definitive answers to these key questions about the future technical and economic role of storage in clean energy policy—especially around the opportunity to reduce or replace peaker and baseload plants—is a critical missing link in the current debate over which technology combination can lead to a decarbonized future.

While storage policy advocacy is needed, advocates on both sides of the replacement debate also need access to independent and deep analytical work to develop a solid economic and technical foundation about the role energy storage could play in our long-term energy future. Developing consensus on unbiased analyses regarding the economic and environmental benefits of role of storage going forward should be an important goal for advocates who care about a defensible climate emissions strategy.

These competing views about the future energy system are what makes battery storage advocacy so important to launch now. Resolving these questions could be a key to developing effective climate policies.

Utility workers making repairs near the State Capitol in Montpelier, VT.

The Actions

With battery technology prices continuing to decline, the biggest hurdle for widespread power plant replacement with storage and renewables is determining a systematic program of policy and market design. Policymakers need to acknowledge their responsibility to plan for solar+storage as a key replacement strategy for existing power plants. To date, these replacement efforts have been driven by local opposition, not policy.

States should follow California's lead on power plant replacement by prioritizing storage policy with legislation that requires utilities to evaluate storage, efficiency, and distributed generation when considering resources to meet peak demand power needs.[39]

Regulators in Washington State have also directed utilities to incorporate energy storage into their future planning processes.[40] States like Massachusetts have imposed mandatory greenhouse gas emissions reductions for the power sector, which should be used as a tool to require the development of renewables paired with storage to reduce emissions to meet future reductions requirements. More states will need to adopt similar policies to encourage utilities to explore solar+storage alternatives to traditional power plants.

Analysis also needs to be done to evaluate the costs and capability of storage-backed renewables to replace individual power plants—especially developing a peaker plant model that can be used in utility resource decisions. This was done at a high level in the case of the Oxnard plant, and obviously drives several recent utility solicitations. But no standard methodology has been developed to replicate the process in a meaningful way for other proposed and existing power plants.

In most parts of the country, it will take detailed, regionally-focused analysis to convince utilities, companies, and regulators that renewables and storage can serve as a viable and cost-effective alternative to fossil-fueled power plants. Policymakers should require that utilities use up-to-date data on solar+storage costs and performance metrics in any resource planning process or replacement analysis to reflect accurate economic and market conditions. These analyses should consider the total lifetime costs and benefits of a system, not just a comparison of upfront capital investments.

Advocates opposing existing traditional power plants need access to the right economic and technical tools to make the case for replacement technologies in fights over peaker and other power plant replacement strategies.

Climate advocates, whether proponents of renewables, nuclear energy, or carbon capture and storage, should agree on a common position regarding the role of storage and future storage analysis in any climate mitigation scenario. Whether a 100 percent renewables scenario or some other hybrid technology combination, such as nuclear or carbon capture and storage, comes into play to combat climate change, battery storage is likely to play a significant role. Foundations need to understand the stakes at play in the modeling debate, and how well it does or does not reflect market trends in the storage space. Agreeing on a sound economic and technical game plan for storage analysis—and what role it will play in numerous energy scenarios of the future—is in everyone's interest.

8

Top Ten Trends to Champion Battery Storage

Utility Markets

The Emerging Role of Large-Scale Energy Storage Systems

"Energy storage is the next step for our industry. We've been doing one thing for a hundred years, it's time to do something different."

Sean Hamilton,
General Manager, Sterling Municipal Light Department

Summary

Without energy storage, generation and transmission must be overbuilt to accommodate rare demand peaks and maintain grid stability while integrating high volumes of variable resources like solar and wind. Energy storage can help to solve these problems, while providing valuable grid services as a least-cost alternative that pays for itself. These benefits can be provided by batteries installed behind customer meters as well as on utility distribution grids.

Sterling Municipal Light Department's General Manager Sean Hamilton points out a battery stack in the 2 MW energy storage system that is paired with solar PV to bring cost savings and resiliency to the utility's customers in Sterling, MA.

The Issues

The existing power grid has not fundamentally changed in 100 years: it is still organized around big central generating plants and one-way flows of electricity, with instantaneous balancing of generation with consumption.

Consider the implications of that last sentence. In our society, we store every other critical commodity—food, water, fuel, heat, raw materials—but we have little to no capacity to store electricity. Because of this, production of electricity must be adjusted to exactly equal demand every second of every day. In other words, without storage, the electric grid is the world's biggest just-in-time delivery system.

This has enormous consequences for the overall efficiency of the power grid. Without the ability to store electricity, generation and transmission assets must be sized to meet demand peaks that only occur a few times each year. This means that our current systems are enormously overbuilt, and ratepayers pay for this inefficiency.

According to the *State of Charge* report issued in 2016 by the state of Massachusetts, from 2013 to 2015, the top 10 percent of hours of demand for electricity generation, on average, accounted for 40 percent of the state's annual electricity spending, or over $3 billion.[1]

In other words, nearly half the cost of the electricity system is devoted to meeting demand peaks that occur only a small portion of the time. This is not only a problem in Massachusetts, but in other parts of the country as well.

To understand why this is so, it is important to realize that many fossil-fueled electricity generators are paid when they are not actually generating power. These "peaker" plants, typically small plants fueled by natural gas, command high prices to be on standby in case demand for electricity should spike.

This makes gas peakers among the most expensive generators of electricity; they are also highly polluting.

The name for this "standby" power is "capacity." In areas with organized wholesale electricity markets, capacity is among the most expensive services utilities must purchase (and these costs are passed along to ratepayers). In New England, the cost of capacity tripled in two years, from $3.15/kW-month in 2016–2017, to $9.55/kW-month in 2018–2019.

According to ISO-New England, the annual cost of capacity paid by New England ratepayers will increase accordingly, "from a historical annual average of about $1.2 billion . . . to a projected annual average of about $3.1 billion from June 2017 through May 2021."[2]

Sterling Municipal Light Department's battery storage microgrid is saving the utility's rate payers $400,000 per year.

Along with capacity, utilities must pay for transmission—the poles and wires that allow electricity to travel from the generator to the customer. Just like a water hose, a transmission line can only carry so much electricity at once. If transmission is not sufficient to meet demand, it is said to be "constrained." Transmission constraints can keep power generated upstream from reaching customers who need it downstream.

Capacity and transmission costs together are like demand charges for utilities. And, like demand charges on a commercial customer's bill, they can be managed with energy storage.

In ISO and RTO markets, utilities pay annual capacity charges, often based on a single regional peak-demand hour each year. And they pay transmission charges, often based on a single regional peak-demand hour each month. By keeping their power purchases low during these 12 critical hours each month, utilities can reduce capacity and transmission costs for the entire year. Energy storage is a perfect technology to provide this service, because it can store electricity to be used during peak demand spikes.

This has been demonstrated by the Sterling Municipal Light Department (SMLD) in Sterling, Massachusetts.[3] The SMLD had seen the cost of capacity and transmission rise from $500,000 in 2010 to $1.2 million in 2017. Facing further steep increases as capacity costs were about to triple, the utility installed a battery storage system at one of its substations to hold costs down.[4]

In addition to lowering costs for its municipal ratepayers, the Sterling battery system is helping the utility integrate its large solar resource and providing backup power to the town's police station and emergency dispatch center.

Sterling's battery storage system is now saving the municipal utility nearly $400,000/year, meaning the system, which cost $2.5 million, will pay itself off in just over six years—in only 2.5 years, if state and federal grants are counted against system costs.[5]

This is mostly due to capacity and transmission cost savings, but the utility is also using its battery system to engage in arbitrage—buying grid power when it is cheapest, for example at night, and using it to offset purchases of more expensive power during the day.

In addition to lowering costs for its municipal ratepayers, the Sterling battery system is helping the utility integrate its large solar resource and providing backup power to the town's police station and emergency dispatch center. On the regional grid, Sterling's energy storage system helps to flatten the New England demand curve for electricity, making the grid more efficient for all.

These results have been replicated by other New England utilities and confirmed by a Sandia National Laboratories study.[6] Sandia concluded that Sterling exemplified the best known economic case for battery storage in the nation.

The Sterling example illustrates a fundamental fact about energy storage: its highest value lies in the provision of capacity, not energy. In most markets today, efforts to deploy energy storage should focus primarily on capacity services, like demand charge management and frequency regulation, rather than energy services, like arbitrage and reductions in generation curtailment. The latter can be important added services in a storage benefit stack but are unlikely to make up the core services that storage provides to pay its way, at least in the foreseeable future.

The Opportunities and Challenges

It's important to understand that utilities need not own the energy storage resource, as in the Sterling example, to get these results; utilities can contract with third-party storage owners to purchase battery services. In fact, the batteries need not even sit on the utility side of the meter.

Similar results can be obtained by allowing utilities (or resource aggregation companies) to remotely access smaller batteries in customers' homes and commercial properties. By aggregating many smaller, distributed batteries, utilities or third-party aggregators can achieve the same cost savings, while simultaneously, customers can use those batteries behind the meter to lower their own costs and provide resilient power services to their own critical loads.

This has been demonstrated by Green Mountain Power in Vermont and by Southern California Edison in California, both of which have customer-sited battery programs.[7] And it has been shown that siting storage behind the customer's meter allows it to provide a greater variety of services and benefits than siting it on utility substations.[8]

McKnight Lane Affordable Housing battery storage units in Waltham, VT, provided by Green Mountain Power, offer residents backup power for their all-electric, net-zero homes.

Similarly, utility-scale storage services can be provided to utilities by independent third parties, just as merchant generators sell electricity onto the grid. This is important, because merchant energy storage providers can offer many services, and often these services can be "stacked," meaning that battery owners can sell various services into various markets.

Thus, an independent storage provider might sell capacity reduction services to a utility, resiliency services to a large commercial/industrial customer, and frequency regulation services to the grid operator. Stacking services this way makes energy storage more economical, and more beneficial to society.

Energy storage can also take the place of expensive utility equipment upgrades. This is known as "T&D (transmission and distribution) Deferral," and it can save enormous amounts of money. As an example, in 2016–2017, Con Edison in New York was faced with the need to replace a substation, at a cost of $1.2 billion. Instead, the company developed the Brooklyn-Queens Demand Management project, a combination of battery storage, demand response and distributed resources that together rendered the new substation unnecessary. The cost of all these advanced technologies and distributed resources was $200 million, less than one-fifth the price of the planned substation—and the distributed resources will provide more benefits.

In addition to its many other services and benefits, energy storage can provide ancillary services to the grid. These are electricity services, such as frequency regulation, that are needed to keep the grid stable. Many electricity services markets have historically been closed to independent and distributed providers, but some have been opened by the Federal Energy Regulatory Commission (FERC). For example, in 2012, FERC order 755 required grid operators to pay faster, more accurate providers of frequency regulation a premium for their service.[9] This created a temporary but significant market for grid scale energy storage in PJM, the wholesale electricity market that serves the northern mid-Atlantic region, with the result that more than 265 MW of grid-connected storage were installed there in just a few years.

At this writing, a new FERC order (Order 841) directs grid operators to revise all wholesale energy services market rules to make these markets accessible to energy storage, taking the operational attributes of storage into account. Once these market rules are updated, storage developers will gain access to a much broader array of markets in those areas of the country where grids operate under FERC jurisdiction.[10] However, large regions of the nation do not have regulated markets of this type, and in these areas, it is difficult for storage to sell such services (and it can be difficult even to determine what such services would be worth).

The Actions

Utilities, especially municipal utilities and electric co-ops, should be encouraged to consider energy storage as a cost-saving alternative to more expensive and polluting technologies. This can be achieved in various ways—for example, through the IRP process or via regulation for regulated utilities, or through state grants and incentives.

Policymakers and regulators should mandate that regulated utilities acquire storage as an asset to reduce grid congestion and peak pricing. Such a mandate has been successful in California, which now has the largest storage market in the country.[11]

Policymakers must ensure that the ownership, attributes, and benefits of energy storage are shared with consumers and utility customers; investor-owned utilities should not be the only owners and beneficiaries of storage systems. Where utility procurement of energy storage is required, as in California, there should be a cap on utility ownership and a carve-out for behind-the-meter systems to create competitive markets with third-party providers. And in any such policy efforts, customers must be able to interconnect behind-the-meter (BTM) storage systems in a non-discriminatory fashion with utilities and realize the economic benefits. Advocates will need to step in to fight this battle on behalf of consumers.

Independent grid operators should open wholesale electricity services markets to energy storage, as required by FERC Order 841. This includes behind-the-meter and third-party systems. And, FERC should go a step further and require that aggregated distributed storage be made eligible for participation in energy markets—something Order 841 does not do. While energy storage is not explicitly barred from participating in many energy markets, specifications such as resource performance requirements can effectively make it impossible for storage systems to qualify. As stated by the outgoing head of GTM Research, “Energy storage doesn’t need big subsidies. It just needs to be eligible to compete.”[12]

9

Top Ten Trends to Champion Battery Storage

Electric Vehicle Charging

Prices and Power Outages at Public Charging Stations[1]

"A major buildout of fast-charging stations likely would help drive greater adoption of electric vehicles, experts say. But it's extremely difficult for public charging stations to turn a profit because of volatile fees, called demand charges, that many electric utilities charge their commercial customers."[2]

Areg Bagdasarian, energy analyst

Summary

Public fast charging stations for electric vehicles face some of the same utility "demand charges" that are now prevalent in most commercial building rates. Conventional ratemaking likely will not lower demand charges to levels that will be acceptable to the public, which will not tolerate variable, high rates for charging their electric vehicles. Similarly, charging stations will be subject to the same power outage problems facing the electric grid. On-site battery storage at charging stations could be the technology solution that addresses both the demand charge and power outage problems, results that require dedicated policy and market development strategies to be put in place.

The implications of EV charging, power outages, and battery storage is a topic that needs more analysis.

The Issues

The future of electric vehicle (EV) charging stations, especially those with high power, quick charging technologies known as direct current fast chargers (DCFC), must be ubiquitous, reliable, and cost effective in public places easily accessible from major roads and highways.

While there are many issues that must be resolved to create that infrastructure, two major challenges are getting too little attention, and that might undermine those long-term goals. And for both, batteries—onsite energy storage—could provide some unexpected solutions.

If the future of clean transportation will be electric vehicles, utility demand charges are a major market barrier that must be addressed for the success of that energy transition.

Recent evidence shows that electricity costs at DCFC stations will be largely driven by utility demand charges in many regions. These might make EV charging costs exorbitant in some utility territories, inhibiting customer acceptance of EV operating costs.

This problem was identified in a recent report ("EVgo Fleet and Tariff Analysis") by Rocky Mountain Institute (RMI).[3] According to the report, which was funded by EVgo, utility demand charges are "a significant barrier to the development of viable business models for public DCFC [direct current fast charger] network operators."[4]

The RMI report indicated that demand charges for some public charging stations constitute nearly all its operating costs:

> With today's EV market penetration and current public DCFC utilization rates, *demand charges can be responsible for over 90% of electricity costs,* which are as high as $1.96/kWh at some locations during summer months. (Emphasis added.)

In one example from the RMI report, the charging infrastructure company EVgo had a charger that generated a monthly bill of $1,938, of which $1,362 was demand charges. That's likely a very unprofitable charger. According to the RMI author, this means there is "no business case" for public charging with such high utility demand charges.

Electric car getting charged in Montreal during snowstorm.

If the future of clean transportation will be electric vehicles, utility demand charges are a major market barrier that must be addressed for the success of that energy transition. But that's not all.

Electrifying the transportation system also exposes vehicle transit to the same power outage problems that plague the electric power system, where there are thousands of outages a year across the country. If EV charging stations are unreliable and susceptible to frequent electric power loss, EV owners will not accept the risks of driving and finding stations out of service, without electric power needed to recharge their cars.

In-depth analysis or comprehensive studies on the problem of EV charging stations and power outages are not readily available, and few reports about this issue have written by advocates for this technology option. It is odd that such a consequential problem is not receiving any serious attention. The best coverage that we could find was a 2009 article in *The New York Times* that asked, in the context of electric vehicles, "what if there is a blackout?" The expert from a new start-up gamely answered, "a long blackout is unlikely."[5]

With EV transportation, we are importing all the power outage issues from the electricity sector to the transportation sector. That shift is a major one that deserves a great deal more attention, and the lack of analysis is more than problematic. If the entire transportation fleet is to be electrified, as has been proposed, the existing, growing problem of power outages in the electric generation sector should be a key issue in the discussion about transportation electrification. That does not seem to be the case.

For both demand charges and power outages, the conventional solutions are not satisfactory. As to high demand charges and fuel costs, many experts simply say utility rate design will solve the problem. In the case of charging station resiliency in the face of power outages, there seems to be no attention paid to it in the literature.[6]

The Opportunities

People with EVs will want reasonably priced electricity to be offered at times of their choosing at the public charging stations of the future. They will want the same ease and accessibility of the current fuel delivery system, the gas station, at EV charging stations. They also will want stations to run all the time and to provide power for their vehicles at reasonable costs. In both cases the installation of onsite battery storage could solve those problems in ways preferable to some proposed solutions.

On the question of utility demand charges, many reports indicate that this can be addressed with new forms of rate design. According to the authors of the RMI report, the cost of fast charging should be equivalent to the cost of gasoline, and new forms of rates should reflect that cost:

> As state legislators begin to craft legislation defining the role of utilities in deploying, owning and operating electric vehicle charging stations . . . it is critical that utility tariffs for EV charging support, rather than stifle, the shift to EVs. Utilities, their regulators, and EV charging station owners and operators must work together to provide all EV drivers especially those without home and workplace charging options access to reliable EV charging at a rate competitive with the gasoline equivalent cost of $0.29/kWh. Put another way, it should be possible for DCFC operators to sell power to end users for $0.09/mile or less, while still operating a sustainable business.[7]

Some rate design proposals suggest that utilities should use a variety of time variant pricing in rates, or utilities should simply eliminate demand charges for public charging stations.[8] A good summary of this issue by the Lawrence Berkeley National Lab captured the sentiment for rate design solutions, which relies in part on pricing to encourage drivers to charge their EVs at low peak hours—suggesting public chargers would be best use at night or other low peak hours when demand charges are lower. Such "time of use" pricing would:

> …encourage drivers to charge during hours when the electricity grid has spare capacity or to alleviate local distribution-level constraints, rather than exacerbating the system-wide peak demand.[9]

This is the view of many advocates for EV charging infrastructure. The RMI report noted here suggests that the operating costs should be recovered entirely out of these volumetric rates rather than demand charges. In other words, many advocates are arguing for an entirely new rate treatment for EV charging stations that do not typically now apply to peak load demand charge recovery in buildings across the United States.

The choice of waiting an hour or paying three times the normal rate—just to power their EVs when they need to—will be unacceptable to most vehicle owners.

This type of approach, based on time-of-use rates where the cost of charging a vehicle varies widely throughout the day, may be an acceptable solution for slower charging devices, those commonly found at homes and businesses. If a vehicle is going to be plugged into a charger for hours at a time, overnight or while at work, consumers may choose not to charge their EVs during a few high-cost hours.

But this type of rate solution is unlikely to work for DCFC, when people are in route and need their vehicle charged up within minutes. The choice of waiting an hour or paying three times the normal rate—just to power their EVs when they need to—will be unacceptable to most vehicle owners.

In case theoretical rate design schemes may not work for fast charging infrastructure, it might be useful to look at technology solutions like battery storage that could be employed if such new ratemaking is not forthcoming and utilities continue to impose demand charges for public charging stations in the future.

In the first instance, it is difficult to see how these rate solutions alone would work in practice.

Curbside electric car charging station.

First, expecting customers to use public charging stations only at night time or at other low peak-demand hours seems to be a basic non-starter for building out the market based on customer choice and accessibility. Customers will expect a certain level of consistency in electricity pricing throughout the day and from location to location when charging their vehicles, as there is with gasoline pricing today.

Expecting customers to use public charging stations only at night time or at other low peak demand hours seems to be a basic non-starter in building out the market based on customer choice and accessibility.

Second, based on what we know about demand charges for building applications and utility rates, variable rates are not the solution adopted in any state to deal with demand charges at the commercial and industrial level. Perhaps that is why advocates are assuming utilities would voluntarily or be forced to abandon the use of demand charges for EV stations in favor of volumetric rates.

Third, analysis by the National Renewable Energy Laboratory has indicated that, even at low levels of EV adoption, clustering of residential vehicle charging could result in significant increases to localized peak demand, which would require upgrades to the electricity distribution system.[10] This means that if a few EV owners in a neighborhood decide to charge their vehicles at the same time, the system could become over-loaded without expensive upgrades to infrastructure. Rate design provides no solution to this problem.

The non-rate solution hinted at in the Berkeley Lab report is the one that seems to make the most sense, and that is on-site storage.

The only reliable way to reduce demand charges and bring the cost of EV charging down to reasonable levels is through on-site battery storage—the same solution that is used to reduce demand charges in commercial building applications. Even if utilities were convinced to abandon demand charges and, instead, embrace a time-varying rate structure, battery storage could be used to help ensure a consistent charging price for customers.

The only reliable way to reduce demand charges and bring the cost of EV charging down to reasonable levels is through on-site battery storage—the same solution that is used to reduce demand charges in commercial building applications.

The solution would be for each public charging station to be equipped with on-site battery storage and, in some cases, solar, in the same way that buildings are now seeing such systems installed. Of course, this does raise issues about siting, available space, and related questions about whether these locations could be suitable for such onsite applications.

This storage solution has been advanced most recently by McKinsey consultants in a 2018 analysis:

> Demand charges can be as little as $2 per kilowatt all the way to $90 per kilowatt; paradoxically, they tend to be higher in states where BEVs [Battery Electric Vehicles] are more popular, such as California, Massachusetts, and New York. In a high-charge state, with no cars charging at the same time, the monthly demand charge could be $3,000 to $4,500. For the BEV owner, that could translate into $30 to $50 per session, plus the cost of the actual energy. *Customers just will not pay that. There is a way to resolve this conundrum: stationary battery storage.*[11] (Emphasis added.)

McKinsey notes that there is a pressing need to expand the existing fast charging stations in the country quickly, which now total fewer than 2,000 stations. Solving this economic problem is critical to get those stations to scale and to support future EV markets across the country. Right now, there are more than 150,000 gas stations in the country, so closing the EV charging station gap must happen soon if the EV market is to take off and compete with gasoline powered vehicles.

In a recent filing by a coalition of advocates for an EV charging station infrastructure plan, a demonstration project with one or two on-site storage for public charging stations was proposed.[12] To create more accessible and affordable public chargers, storage will have to become an embedded design feature, and planners should be encouraged to move beyond demonstration project strategies.

The added benefit of battery storage and solar PV, in addition to cost reduction, is that on-site solar+storage could help alleviate the problem of power outages.

The added benefit of battery storage and solar PV, in addition to cost reduction, is that on-site solar+storage could help alleviate the problem of power outages. Customers simply will not tolerate the unavailability of electricity when they need it to re-charge their cars. They will not accept power outages at EV charging stations, period.

And apart from average customers, there is a risk that all critical-use transportation such as ambulances, fire trucks, police cruisers, and virtually every other mode of transportation requiring reliable service could now be subject to the vagaries of power outages and disruptions in the electrical service to EV charging stations.

It is unacceptable to leave those risks unaddressed. This is especially so given the amount of revenues at issue.

Americans spend around $325 billion per year on gasoline.[13] If the entire gas power car fleet were converted to electricity, and utilities were to acquire that revenue in the form of electric sales from EV charging, it would essentially double the electric utility revenues (now about $381 billion) they now enjoy.[14]

Whether those numbers turn into a roughly equal transfer of revenues, the point remains: there is enough money to build a resilient charging system to avoid these problems. Onsite storage at EV charging stations should be a essential feature of system design to address reliability for critical transportation services.

The Actions

Policymakers should encourage the industry leaders who are moving to install on-site solar+storage as technology solutions to reduce or eliminate demand charges at public charging stations. To date, several providers such as Tesla and Volkswagen and have indicated they plan to install on-site technology solutions to address the problem, rather than to rely only on future favorable rates as the solution.[15] One new European partnership announced in early 2018 states that "customers will from now on be able to combine photovoltaics, power storage and electric vehicle charging."[16]

Policies should be designed to encourage on-site storage as a design feature in DCFC systems going forward, including system design costs with storage and solar, for both utility price control and reliability. Public incentives and other policy options should be adopted to encourage such far-reaching technology solutions on site.[17]

Policymakers and EV infrastructure planners and consultants must better understand real world prices from demand charges and analyze how storage paired with DCFCs could reduce EV charging prices for customers. Further, these technology options should be addressed in tandem with the real-world analysis of time-of-use rates or other volumetric pricing proposals—and the effect on market uptake with customers asked to charge at low peak times under that new rate regime.

Siting for EV charging stations with on-site storage should be aligned with electric power storage implementation plans and policies—so public EV infrastructure and storage systems can be co-located with commercial and industrial, community, affordable housing, and other public energy storage systems in buildings.

Any state decisions relying on public analysis using public funds must consider how EV charging infrastructure design is subject to the risk of power outages and incorporate that analysis in both funding and design decisions. This is a serious matter that deserves much more attention at the state, regional, and federal level. Studies should be conducted of how power outages could affect system reliability for public EV charging. At a minimum, charging stations serving critical transportation services should have on-site storage as a mandatory design feature.[18]

10

Top Ten Trends to Champion Battery Storage

International

Becoming a Global Market

"[T[he global energy storage will double six times between 2016 and 2030, rising to a total of 125 gigawatts/325 gigawatt hours.... Eight countries will lead the market, with 70 percent of the capacity to be installed in the US, China, Japan, India, Germany, UK, Australia and South Korea."[1]

Bloomberg New Energy Finance

Summary

The energy storage market is a global work in progress. Early markets in many countries all face the same start-up issues as with any relatively new energy technology. This is a perfect time for advocates and others to work together across borders to address similar technical, market, and policy issues. Coordination and consensus around ways to support the emerging market could accelerate progress across the globe. At present, no such international or multi-national collaboration exists. It should be an important element of any future storage advocacy.

A new battery storage solution for offshore wind energy will be piloted in the world's first floating wind farm, the Hywind pilot park off the coast of Peterhead in Aberdeenshire, Scotland. Statoil will install a 1MWh Lithium battery-based storage pilot system in late 2018.

The Issues

Battery storage is an international phenomenon. It is expected to grow to 40 GW by 2020.[2]

A McKinsey and Company report recently looked at storage developments globally and concluded that:

Battery storage is entering a dynamic and uncertain period. There will be big winners and losers, and the sources of value will constantly evolve.

> [S]torage is starting to play a broader role in energy markets, moving from niche uses such as grid balancing to broader ones such as replacing conventional power generators for reliability…
>
> Battery storage is entering a dynamic and uncertain period. There will be big winners and losers, and the sources of value will constantly evolve depending on four factors: how quickly storage costs fall; how utilities adapt by improving services, incorporating new distributed energy alternatives, and reducing grid-system cost; how nimble third parties are; and whether regulators can strike the right balance between encouraging a healthy market for storage (and solar) and ensuring sustainable economics for the utilities. All this will be treacherous territory to navigate, and there will no doubt be missteps along the way. But there is also no doubt that storage's time is coming.[3]

In addition to the U.S., these developments are occurring around the globe, from Europe, Australia, Asia, Africa and South America. While a lot of attention was focused on California, a state that has done more to nurture storage than any other region, there was plenty of action in Asia, Europe, and Australia.

Tesla focused most of its attention on Australia in the second half of the year; residential storage developers continue to see Germany as the market to watch; and China is emerging as a global electric-vehicle behemoth.[4]

As an end of 2017 round in international energy business activity stated:

> …when you look at the activity in 2017, a pattern emerges.

Over the past year, we've seen a number of major European energy companies—and some Japanese, American and Israeli ones as well—buy into the proposition that providing distributed energy technologies and services to their customers will be a significant part of their futures.

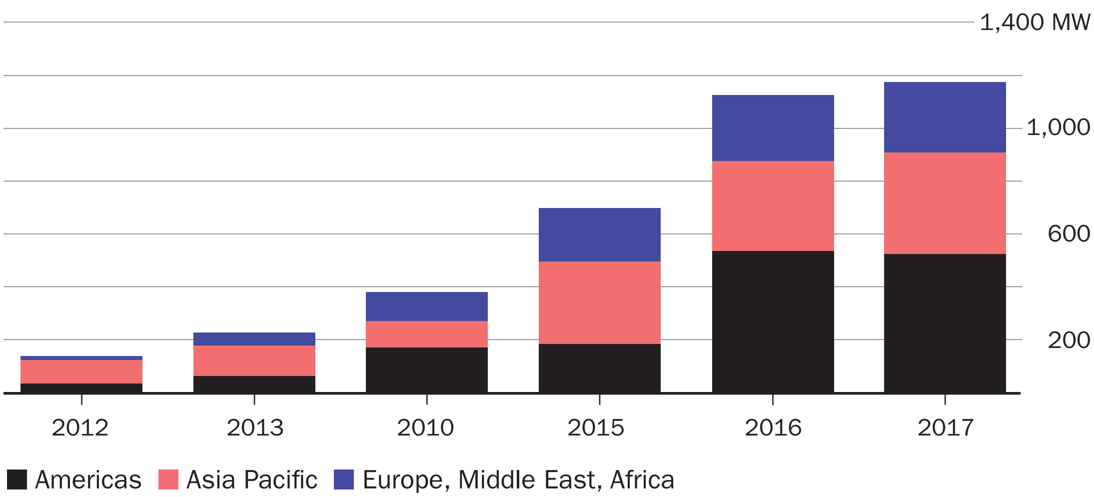
This pattern stands out most clearly in the big European energy giants' shopping spree this year, starting with Enel's purchase of Demand Energy in January[5] and closing with Centrica's purchase of REstore in November.[6]

In between, we've seen Total, E.ON, Engie, and Shell also make significant acquisitions ranging from demand response and electric-vehicle management to energy storage and the connected home.[7]

Figure 12 shows the story of global development in storage.

FIGURE 12

The World Is Moving to Energy Storage



Grid Energizer—more batteries are coming online to backstop wind and solar energy worldwide.

Source: Bloomberg New Energy Finance[8]
Note: Installations include utility-scale and behind-the-meter batteries.

And there seems to be heightened interest among the international environmental and energy community about the climate emissions benefits of increased storage and renewables development through 2050.

But oddly enough, how storage plays a role in the decarbonization discussion too often has been left to skeptics and contrarians, combining attacks on renewable energy transition scenarios with efforts to minimize the positive role of storage can play to solve energy problems. More thoughtful analysis and action are needed to help develop consensus around these long-term issues regarding the role of storage in the future energy system.

The Opportunities and Challenges

Despite this market activity and environmental interest, there is little coordinated activity among energy advocates or foundations around this international opportunity for storage. This is the case even though there are markets outside of the U.S. struggling with many of the same energy storage market development issues that face domestic companies, policymakers, and advocates.

Despite this market activity and environmental interest, there is little coordinated activity among energy advocates or foundations around this international opportunity for storage.

At best, discussions around policy and markets for storage globally occurs sporadically and episodically at technology conferences dominated by industry players with little participation by NGOs or policymakers. It also appears that storage is not a top priority of many international parties to the climate negotiations and related technology forums. A greater focus on storage in those forums might well advance related renewable energy and climate mitigation discussions in a more aggressive manner.

At present, there is no international network of energy storage experts to expand access to energy storage information and implement a framework that enables storage technologies to reach a broader market. As result, the environmental and NGO communities are missing an opportunity to shape international climate and technology discussions about how to create favorable policies, and have conversations about the role of storage in the global clean energy future.

Without dedicated market information-sharing opportunities across national boundaries among policymakers, with input from advocates and industry, the speed of change will be hampered by lack of data and a failure to adopt lessons learned and best practices.

It goes without saying that international exchange of information, policy directions, market intelligence, and basic know-how could go a long way towards moving these technologies to market. In this early stage of market development such international cooperation, combined with a national effort, could be one of the most effective ways to make a difference.

What is missing so far is any international approach to accelerate movement of the energy storage market. This gap suggests the need for a coordinated global network of interested parties that would have both a public and private market focus. With no effective network of NGOs, state energy leaders, and industry working together to learn from these early markets and adopt strategies, both public and private purposes with these emerging technologies will not be served.

With the demise of effective U.S. action on climate, it is more important than ever that non-federal actors engage in clean energy technology partnerships. Energy storage technology is among the most important to accelerate clean energy uptake and to reduce climate impacts.

A solar-powered, village-level microgrid provides electricity to an off-grid village in India.

The Actions

International exchange opportunities for energy storage policymakers would benefit the market. Frequently, countries take different policy approaches to clean energy (for example, feed-in tariffs are popular in Europe but not used as much in the U.S.). An international policy exchange would allow for policymakers to share ideas and experience across national borders. It would also help decision makers to stay current on major tax incentives, rebates, and market supports. With coordinated policy exchange opportunities, a compilation of policies and model legislation as well as an ongoing dialogue on policy proposals to support energy storage markets could be a reality.

As the first international study on emissions using updated storage economics shows, there is a great deal to learn about how storage with renewables can reduce global greenhouse gas emissions reductions.[9] As far as we know, the study cited here is the first emissions scenario done anywhere with sound storage economic data from current cost curves in real markets. A global effort to develop better analysis and strategies using current storage market economics would go a long way to resolving the contentious debate over whether renewables alone can address climate change, with or without other technologies such as carbon capture and storage or nuclear.[10]

An open-source database on energy storage market trends would help consumers and policymakers make informed decisions. This effort would keep participants abreast of market evolution in various countries and regions, as it affects distributed and utility scale energy storage. This would include electricity pricing, ancillary services markets, installed system costs, and related market developments.

A global effort for standardization and consensus on performance standards is needed. As the distributed storage field becomes more populated, there will be an increased need for agreed-upon performance and safety standards, and testing protocols. We should seize the opportunity to create an international effort early, before markets become fragmented.

The creation of a database on international energy storage programs would assist policymakers and stakeholders. This database would track distributed storage programs and deployment progress around the globe.

Overall, it is time to establish an international network of energy storage NGOs and other experts to expand access to energy storage information and implement a framework that enables storage technologies to reach a broader market. The network would develop a strategy to help shape climate and energy policy, support the energy storage industry, and develop successful financing models.

An experimental storage system at the Romande Energie-EPFL solar park in Switzerland.

Emerging Issues

In the Early Transition

"Energy storage is hot. Energy storage is gaining huge momentum with rapidly expanding companies, full commercialisation of technologies, declining costs and increasing customer adaptation. These signal its growing impact on the energy transition."[1]

EURELECTRIC Conference, December 2017

In this fast-moving field of energy storage at the cusp of a technology transition, there are emerging issues that we have not addressed in the first part of this report. Some are too new to understand the implications fully, while others might not turn out to be issues at all.

We list some of those here. And having done so, we are likely still missing some items that others might find need attention; while for others, such as advocates involved in these areas, likely have more nuanced responses—or flat-out opposition—to how we have addressed these topics. All of which argues for engaged, coordinated advocacy on storage where these issues can be explored.

For now, at least, here are some remaining challenges and opportunities we see arising in the future regarding the development of the battery storage market. We don't address them in the same way as the other trends we've covered earlier, with issues and actions, but rather simply flag them for future consideration and analysis.

Portland General Electric's Salem Smart Power Center includes a large-scale energy storage system.

Residential Usage

This report has not yet addressed what often first comes to mind among people thinking about battery storage: can I use it in my home? We have not written in any detail about residential battery storage for several reasons.

For the most part, battery storage is not economical today in the U.S. in most residential applications; people in individual homes are not typically subject to utility demand charges or time-of-use rates that would justify the added expense of storage (although this is starting to change in some parts of the country). Moreover, as noted here, the most common purpose for batteries might be resiliency, but it's not factored into any economic analysis, and people tend to go for lower cost diesel generators if outages are the primary concern.

But this could all change soon, based on some current trends. New reports indicate there were over 4,000 residential storage units in place, mainly off-grid, as of mid-2017.[2] According to a recent IRS ruling, homeowners can take advantage of the 30 percent investment tax credit for battery storage paired with new or existing solar systems, as long as the storage system is 100 percent charged by solar (which could be a problem for some uses).[3]

A residential battery storage unit.

In addition to individual home solar+storage applications, developers are starting to install battery storage with solar PV in huge housing developments, where economies of scale can result in cost savings across hundreds of new homes.[4] Telsa has plans to install battery storage systems in 50,000 homes in Australia and operate the independent systems together as a "virtual power plant."[5]

In addition to individual home solar+storage applications, developers are starting to install battery storage with solar PV in huge housing developments, where economies of scale can result in cost savings across hundreds of new homes.

Some utilities in the U.S. are offering leased battery systems in homes that could be used for resiliency but where a utility can call on the system to reduce grid costs.[6] Some already think residential solar+storage is "ready for prime time" based on several new business models.[7]

Also, as noted above, there is some indication that residential customers, at least those that have behind-the-meter (BTM) energy systems like rooftop solar, could become subject to demand charges or similar "reliability" charges, which could make residential energy storage more attractive. The reason for this concerns a controversy about whether customers who "net meter" excess electricity are paying their fair share of the costs of maintaining the grid.

Traditionally, the value of solar has been provided, in large part, by net metering excess generation to the grid. But recently, net metering rates have begun to drop in some areas of the country, and utilities have started to push for extra "reliability" charges on net metering customers. In 2016, Massachusetts granted the utility Eversource the right to assess a monthly reliability charge on all net metering customers, and in its recent rate case, the utility did exactly that. As a result, Eversource solar customers are now subject to residential demand charges, among the first in the nation.

If the future value of net-metered home solar PV systems continues to decline, pairing those systems with storage would be a way to preserve their value, because it allows the homeowner to increase self-consumption by storing excess solar generation in the battery and using it when the sun is not shining, thereby offsetting purchases of electricity from the grid at retail rates.

This reduced use of the grid power is sometimes called "grid defection" and has been identified by some observers as a first step in a predicted "utility death spiral." Essentially, these observers say that utilities will continue to raise rates to make up

Battery storage is also coming to manufactured modular housing, which when paired with solar can significantly reduce low-income residents' electric bills and keep homes powered during an outage.

for grid defection, but higher rates will only push more customers to self-generate electricity—thereby creating a downward spiral of electricity demand for utilities.

In addition to traditional housing, battery storage is also coming to manufactured modular housing, which when paired with solar can significantly reduce low-income residents' electric bills and keep homes powered during an outage; such homes could be a key part of rural development in remote places subject to periodic hurricanes and outages.[8]

Zero Net Energy

There is a growing movement toward buildings and, at a larger scale, cities that produce as much energy as they consume, known as zero net energy (ZNE).

California is currently leading the way on ZNE, with some cities already mandating ZNE development and the state requiring near ZNE for all new residential construction by 2020 and new commercial buildings by 2030. Unfortunately, many of these well-intentioned goals and policies are being put in place without recognizing that ZNE buildings can still have a significant impact on the electric grid.

Simply producing or procuring an amount of renewable energy equal to total energy consumption in no way ensures that power supply will match demand. A study prepared for the California Public Utilities Commission accessing the grid integration costs of residential ZNE development, found that, at a certain level of ZNE penetration, energy storage would be required to mitigate the negative grid impacts of increasing levels of distributed solar.[9]

As ZNE policies are developed and implemented, the real-world impacts to the grid must be evaluated and the incorporation of storage should be considered and encouraged for its ability to mitigate integration issues.

Wind and Storage

Like solar, wind is an intermittent, non-dispatchable resource. But unlike solar, wind (at least onshore wind) tends to generate more electricity overnight, when demand for electricity is low, and less during the day, when demand is high. This has led to wind

curtailment and the under-development of high wind resource areas; because there has been no good way to store nighttime generation for use the next day, the utility of building additional wind farms has been limited.

The Bear River Band's wind+solar+storage system is the first renewable hybrid microgrid installed by a California tribe.

Nevertheless, traditional wind turbines have been paired with battery storage, such as the 153-megawatt Notrees wind facility in Texas, which recently upgraded its batteries to a 36-megawatt lithium-ion system.[10]

Now, we're beginning to see energy storage play a major role in new offshore wind development as well in Europe and in the U.S., with several projects proposing to incorporate batteries to boost project economics and improve grid stability and reliability.[11]

With prices for lithium-ion batteries dropping, longer duration lithium-ion systems are now feasible and are beginning to be deployed; an example is the new 8 megawatt/ 6-hour duration lithium-ion battery system being developed by National Grid in Nantucket, MA.[12]

Longer duration storage systems will be a better fit with wind energy, which requires bulk storage overnight; and the evolution of battery storage for this purpose will not only reduce curtailment of wind generation, but it will help to move storage from a short-term "peaker" function to a longer-term "baseload" function.

Tesla Powerpacks at the Hornsdale Wind Farm in South Australia.

Developing state-level policy regimes to encourage further development of the wind+storage combination seems a worthwhile goal of future work.[13]

Power-to-Gas

Recent comments by former Department of Energy Secretary Steven Chu noted the limitations of battery storage technologies. In response, the head of the Energy Storage Association, Kelly Speakes-Backman, while defending batteries on several fronts, agreed that batteries are capable of providing daily storage but that long-term, seasonal storage will require different technologies, like power-to-gas (P2G).[14]

P2G, along with batteries, was also included as an essential component to the global 100 percent renewables analysis by Energy Watch Group.[15]

P2G is a technology process that converts electrical power to a gas fuel for storage or transportation through existing gas infrastructure. This conversion is done through electrolysis, which splits water into hydrogen and oxygen. The resulting hydrogen can then be directly used as a fuel source or turned into a form of natural gas through a process of methanation.

Because renewable generation can vary greatly by season or experience fluctuations in generation lasting multiple days or even weeks, longer duration energy storage is seen by many as an essential component in achieving high renewable penetration goals.

Some experts believe that P2G could fill the long-term storage gap that is unlikely to be met by existing battery technologies. Such long-term storage will be key to allowing renewables to fully replace what is considered baseload generation today.

However, P2G technologies have suffered from poor conversion efficiencies, meaning that much of the original energy is lost in the process of converting energy to gas and back again. And, as Ms. Speakes-Backman pointed out in her response, "under present market designs and public policy, there is not a market for seasonal storage."

Transmission & Distribution (T&D) Deferral

In a recent press release announcing an aggressive energy storage procurement target and the investment of public funds, New York's Governor Cuomo notes, "New York faces a number of energy-related challenges including upgrading its aging energy infrastructure, which carries with it an estimated $30 billion price tag over the next 10 years." Given the nation's aging energy infrastructure, similar costs may be faced in many states.

Energy storage has long been noted for its ability to take the place of traditional substation and poles-and-wires upgrades.

Energy storage has long been noted for its ability to take the place of traditional substation and poles-and-wires upgrades. A Brattle Group report for a Texas utility draws a direct connection between lowering peak load on the grid—an increasingly common use of storage—and achieving T&D investment deferrals.[16] The estimated value of this service varies, but the scale of the opportunity is large: for example, a single substation upgrade in ConEd's Brooklyn-Queens service territory was slated to cost $1.2 billion. Instead, the utility elected to solve the problem using a combination of storage, distributed generation and demand response, at one-fifth the cost. The program has been successful enough that ConEd is now expanding it into other neighborhoods.

While individual projects such as the Brooklyn-Queens Demand Management project offer savings in the millions, what has not been calculated is the scale of this savings opportunity for energy storage nationwide. So, although we have not dedicated a separate section of this paper to the topic of T&D deferral, it represents a major potential energy storage market, which should be characterized and quantified.

Safety

As with any new energy technology installed in a building or near population centers, energy storage fire and safety considerations must be addressed. To date, codes and standards, along with such basic needs as information and training, have lagged behind the development of energy storage technology, and this has created barriers to deployment in some jurisdictions. However, there are now significant efforts at the municipal, state, and federal levels to address this need.

To date, codes and standards, along with such basic needs as information and training, have lagged behind the development of energy storage technology, and this has created barriers to deployment in some jurisdictions.

At the state and municipal levels, New York City's Fire Department (FDNY) has taken the lead on developing new fire and safety codes for installation of lithium-ion batteries within buildings. FDNY is collaborating with the New York State Energy Research and Development Authority (NYSERDA), the National Fire Protection Association, insurance companies and utility Consolidated Edison.[17]

At the federal level, Pacific Northwest National Laboratory and Sandia National Laboratories are leading the effort to develop codes and standards for battery safety. The two labs have held conferences and on-site training workshops, and have published reports such as the *Energy Storage System Guide for Compliance with Safety Codes and Standards*[18] and the *Energy Storage System Safety: Plan Review and Inspection Checklist.*[19] And The National Fire Protection Association has just completed a draft version of NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*.[20] The draft, which is available for public comment, is scheduled for release in its final version in 2020.

From the industry standpoint, battery vendors have incorporated safety measures into their products, from physical barriers to chemical fire suppression systems. Numerous studies are being undertaken to determine the most effective systems for various battery chemistries and configurations.

Battery storage is typically deployed close to energy consumers—think of batteries in cell phones, computers, and cars. As battery storage scales up and is used to address increasing numbers of applications in homes, communities and on the grid, it will be important for safety practices, codes, and standards to grow in tandem. Safety concerns should not be a barrier preventing the widespread adoption of energy storage.

Portable Emergency Generators

This report has devoted considerable time to discussing stationary solar+storage for resiliency and disaster recovery, but given that one cannot prepare for every possible disaster in every location, it may be sensible for disaster recovery agencies to keep a stock of portable solar+storage emergency generators that can be easily transported wherever there is need.

Indeed, FEMA and similar regional/state agencies typically have such a store of portable diesel generators on wheels. However, as already noted, diesel may no longer be the technology of choice for such applications, especially in remote areas or during prolonged grid outages, when local fuel supplies will be swiftly depleted and fuel deliveries may not be possible.

Technicians from SunCommon in Waterbury, VT and other Northeast solar companies install solar panels and battery systems in three portable Solar Outreach Systems to be used in Puerto Rico to provide power for portable devices, to filter clean drinking water, and to light community gatherings in areas still without power after Hurricane Maria.

An example is the predicted Cascadia Subduction earthquake: studies have indicated that a major quake in the Pacific Northwest could leave coastal cities without power and cut off from overland fuel deliveries for months.[21]

Under such circumstances, self-powering, portable solar+storage generators might be the only viable technology that could supply long-term, temporary power to these communities. Small versions of portable solar+storage generators are already commercially available for niche markets such as camping, and the U.S. military has experimented with larger portable solar+storage generators for use in forward operating bases.

Since the components and technical knowledge already exist, it shouldn't be difficult to design a portable solar+storage system that could be airlifted in to serve remote communities and those struck by natural disasters. This is a niche market that deserves more attention from emergency planners and the storage industry.

Supply Chains and Recycling

Lithium-ion batteries are made with precious metals that include cobalt, nickel, and graphite. Of course, these materials are not limited to stationary battery storage, with lithium-ion batteries now playing a central role in much of modern society, from phones to computers to vehicles.

CBS News ran a recent report that showed the truly deplorable conditions where underage children mine cobalt in The Congo by hand.

The environmental integrity of materials extraction and battery manufacturing processes for these applications is a valid concern to many.

A central issue is the environmental impact and labor injustices related to the mining of raw battery materials around the world. The extraction of cobalt is a significant area of concern.

Cobalt represents the most expensive raw material component of a lithium-ion battery. Sixty percent of the world's cobalt supply is originally sourced from The Democratic Republic of the Congo, where thousands of miners, some of them children, work in so called "artisanal" mines with little oversight and few safety measures.

CBS News ran a recent report that showed the truly deplorable conditions where underage children mine cobalt in The Congo by hand.[22]

Flow battery at Idaho National Laboratory's microgrid test bed.

Some companies, such as Apple and Tesla, have reportedly made efforts to improve the ethical sourcing of materials used in their batteries, but the process has proved to be challenging. It goes without saying that more needs to be done to improve the conditions of miners in The Congo and other impoverished regions of the world. It is not clear that the companies have a serious or enforceable plan to eliminate these sourcing problems at this point.

Batteries can also benefit from reuse and recycling. Several electric vehicle manufacturers, including Daimler and Nissan, are exploring the second-life use of EV batteries in stationary storage applications, to lower waste and emissions by extending the useful life of their batteries.[23]

Recycling is another alternative to battery disposal. While lithium-ion recycling is still in its early stages, there's optimism that recycling could significantly reduce the total lifetime emissions of batteries. Umicore, which acts as Tesla's European partner for battery recycling, has reported that it can recover 70 percent of the greenhouse-gas emissions produced during the original battery material extraction and refining stages.[24]

Tesla is also constructing a recycling facility at its massive Gigafactory in Nevada, which will "safely reprocess all types of Tesla battery cells, modules, and packs, into various metal products for reuse in new cells."[25] Along with reducing waste, recycling of battery materials will result in less need for new raw materials extraction and processing.

The bottom line is that there is much more work that must be done by advocates and policymakers to reduce the environmental footprint of batteries used in all applications, from cars to laptops to phones to stationary storage. Cleaning up this supply chain should be a top environmental and moral priority of all affected electronics manufacturers.

Lithium-Ion Lock-In

In this new energy storage industry, there is a pervasive sense that the dominant technology has not yet been developed. Every day it seems there is a new battery chemistry announced that will challenge the presumptive dominance of the lithium-ion battery, whose position is based on its ubiquitous use across all sectors, including electric vehicles, energy production, and home use.

It could be that other chemistries will survive the competition with lithium-ion technology. But lithium-ion's cross-cutting presence, with economies of scale driving down production costs, is hard to beat.

At present, lithium-ion technology occupies a 94 percent battery market share.[26] That's why it is difficult to bet on the competition, especially for general purpose applications in the utility and BTM power markets.

Lithium-ion is not a perfect technology by any means, but it needn't be; like solar PV—which has only reached energy efficiencies of about 20 percent—lithium-ion technology doesn't have to be perfect. It only must be good enough, and cheap enough, to seize the dominant position in the market.

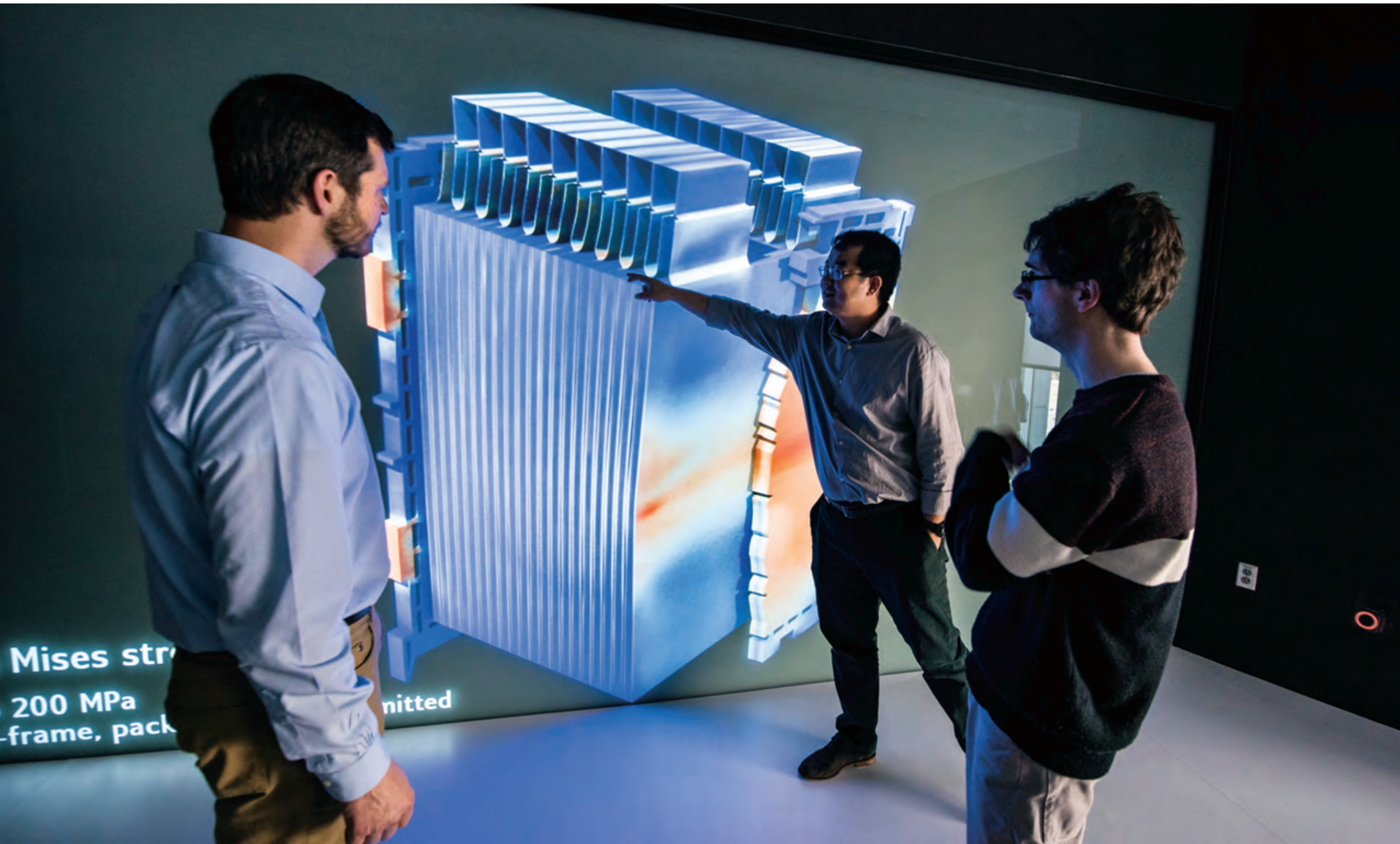
Once it has achieved critical mass, as the incumbent technology, it will be hard to dislodge. Many market observers now feel that lithium-ion is fast approaching this dominant position, and that the window of opportunity for other chemistries is closing quickly. (Many people close to this issue use the following as a standard: as soon as the banks learn how to finance a new technology like lithium-ion batteries in power generation, it is hard to beat. Once the financing risks are addressed by banks, the path to the dominant position becomes much easier.)

Having said this, it could well be that other chemistries will compete in niche markets that require special storage attributes. For example, flow batteries offer a unique decoupling of power and energy attributes, along with other advantages, such as long-duration discharge and a high level of safety.

However, even established battery technologies such as sodium-sulfur are struggling to compete with the market dominance of lithium-ion. According to the U.S. Department of Energy, sodium-based chemistries accounted for only 4.8 megawatts announced, contracted or under construction in 2017, as compared with more than 333 megawatts of lithium-ion batteries. Flow batteries accounted for less than one percent.

In the end, it is not always the case that the best technologies win, but rather that the dominant technologies generally win if they outcompete on performance and cost and establish a strong first mover position in multiple markets. That's what lithium-ion and its supporters have done quite successfully in the last decade.

NREL energy storage researchers evaluate simulation stills of a lithium-ion battery in the ESIF 3-D visualization room.



Electric Vehicles and Grid Support

One of the early arguments in favor of electric vehicles is that it would be possible to use the combined storage capacity of cars to support utility grid operations, so called "vehicle to grid" storage use. That the utilities would be able to call on those siting EVs and use the power storage in the car batteries in aggregate to provide grid support and other services.

It is generally recognized that using car batteries in this fashion could violate the car's existing warranties.

Based on some recent criticism and industry comments, it might be wise to temper the enthusiasm for that approach. It is generally recognized that using car batteries in this fashion could violate the car's existing warranties. Indeed, some warranties already expressly preclude such use; for instance, the Nissan Leaf 's warranty has disclaimed coverage for "misuse, such as overloading, using the vehicle to tow, driving over curbs, *or using the vehicle as a power source*."[27]

There are also serious degradation and interconnection costs that make it likely unfeasible.[28] A recent study suggested that car-to-grid powering would degrade the battery life down to five years.[29] That could be an insurmountable obstacle to this proposition. Perhaps that will change, but it's worth taking the obstacles to this proposition seriously.

Having said that, there is a healthy debate about whether used EV batteries could be deployed for grid and building storage purposes after a car battery's useful life had ended, as they might well have about 70 percent of their useful life remaining then. Whether they could compete with newer and better suited energy storage options at that time is one of the issues.

Electrified Air Transportation

Another form of transportation other than car that might be electrified in the future is the airplane. The future of air flight might also be electric. As a recent article noted, "in the French Alps last summer, a plane set seven new world records."[30]

The two-seater aircraft climbed more than 20,000 feet in under two minutes and reached speeds of 142 miles per hour. It flew nonstop for 300 miles." And the cost was surprising: "during a 62-mile stretch of its historic flight, the plane used about 25 kilowatts of electricity for a total energy cost of just over $3."

As the same article noted, "airplanes release around 500 million tons of carbon dioxide into the atmosphere each year." This plane burned no fuel and produced no emissions. This is important: it might be possible to complete avoid transport emissions by using batteries to propel planes.

But some say this future is more than 30 years away, as getting batteries to an acceptable flying weight is more challenging than in cars.[31]

But some say this future is more than 30 years away, as getting batteries to an acceptable flying weight is more challenging than in cars.

Of course, the air safety of batteries also would have to be resolved before this fully is adopted as a future path for storage.[32]

PURPA Eligibility

In states with vertically integrated utility monopolies, customers typically have few options to purchase power or acquire energy resources from non-utility parties. This has represented a major obstacle to the development of non-utility-owned solar and other renewable markets in such states.

This Arizona home was transformed by a microgrid installed by CleanSpark that includes non-toxic, efficient energy storage from SimpliPhi Power.

Hartley Nature Center in Duluth, MN installed a battery storage system to compliment an existing solar PV array in order to provide backup power during power outages and serve as a community shelter.

The same issue applies to battery storage, a technology that frequently depends on customer access to a third-party provider where the utility has no interest in selling storage assets to their customers.

One of the few ways for customers to acquire energy storage in such monopoly states could be through the Public Utility Regulatory Policy Act or PURPA, a 1970s era law that slightly opened markets for third-party providers to sell renewable energy systems directly to customers.[33] Under PURPA, the utility is required to enter into long-term contracts to buy renewable power from third-party "qualified facilities" (QF), if their rates are just and reasonable as approved by a utility commission. But, oddly enough, after almost forty years, there is an open question whether PURPA applies to stand alone energy storage or only storage powered by renewables. In 1990, FERC issued a decision that suggested storage is a "renewable resource" eligible for PURPA "must purchase" requirements under the law.[34]

But a law firm working on these issues questions that decision and notes that "there is no definitive precedent to date on whether battery storage satisfies the requirements for QF status, either alone or as part of a solar system. FERC staff has informally provided mixed guidance."[35]

In any case, whether PURPA provides for storage, either as a stand-alone resource or when powered by renewables, is yet another open issue requiring resolution if this storage market is to scale.

Blockchain Power

Not to be confused with its application for Bitcoin, blockchain is a new idea in an emerging consumer energy world.[36] In this "peer to peer" future, power generated and stored by local renewables and battery storage could be traded and exchanged with other local customers. Put simply, blockchain is the exchange method where customers on a community microgrid could buy and sell PV power to each other. Some early blockchain pilots involving solar+storage are in place in the U.S. and in Europe. In a Brooklyn microgrid pilot, people log on to an app to see who is producing solar and then purchase that output directly from the local producers. The PV system is integrated with battery storage, allowing output to be shifted to non-peak times of day.[37]

The international battery company sonnen is working on a similar solar+storage blockchain project in Germany. The system allows PV producers to sell their excess solar power that is stored in sonnen batteries to other customers.[38] The blockchain network already has thousands of customers signed on the exchange. A similar pilot is underway in the UK at a community housing project. Forty houses are hooked up to the system for energy trading. Although no price details are available, it is designed to provide low cost energy to address fuel poverty in the UK.[39]

Many are optimistic that blockchain with renewables and storage could transform the way energy is managed on the grid, and change its structure over time to be more accommodating to distributed power.[40] The economics and market uptake of these trading regimes is really at its infancy, with many new startups in this space.[41]

Many are optimistic that blockchain with renewables and storage could transform the way energy is managed on the grid, and change its structure over time to be more accommodating to distributed power.

The trend is worth watching in real time to find out its long-term significance, especially whether the complex world of energy trading can be converted into a financially sound community-level business of multiple transactions among local producers and consumers.

The Federal Role

Thus far, the federal role in supporting and promoting changes in the way electricity systems work has been limited. Because of this, states have taken the lead on solar+storage, with some early-adopter states moving quickly to adopt new policy and programs, while others do little. The result is a patchwork quilt of state incentives, policy and regulatory structures, which presents a difficult landscape for developers and technology innovators.

There are some areas in which federal intervention has been crucial. For example, a series of FERC orders, from 2011 to the present, have helped to open ISO/RTO markets to energy storage, require equitable pay for performance, and knock down interconnection[42] barriers. These orders have had outsized market impacts in some regions; for example, FERC Order 755, which required that grid operators pay more for faster, more accurate frequency regulation services, resulted in a short-term boom in grid-scale energy storage installations in PJM, the wholesale energy market that

The Flex manufactured battery enclosure, 1 MW, 1 MWh rating, using lithium ion batteries from LG, at the Battery Energy Storage System, owned and operated by NREL for grid integration research at the National Wind Testing Center.

serves much of the mid-Atlantic region, from Washington, DC to Pennsylvania. There are now more than 265 MW of grid-connected energy storage in PJM.

FERC continues to be an important player in the way regulated markets treat energy storage. Just recently, it finalized the long-awaited Order 841, which directs independent grid operators to update market rules that may present barriers to storage.[43] Under Order 841, as noted earlier, grid operators must now take the characteristics of storage resources into account and adjust market rules to facilitate their participation. This is anticipated to open wholesale markets to much greater participation by energy storage resources, in that it applies in many areas of the country and across many different electricity services markets.[44] However, it will depend on how the Order is implemented by wholesale market grid operators.

Another area where federal support has been critical has been the extension of the federal Investment Tax Credit (ITC), traditionally used to support solar installations, to include energy storage paired with solar. So long as the storage device is charged with renewably generated energy, it can receive the ITC and accelerated depreciation, both very valuable tax benefits. However, the ITC is scheduled to sunset over the coming years, and an effort to establish a separate, dedicated tax incentive for energy storage recently failed to gain the support of Congress.

While all these activities are important, the federal government could do much more to support the use of new technologies such as solar+storage to transform the nation's energy systems.

A third area of federal activity is direct federal support for project deployment, technical support and basic R&D, which is conducted at national laboratories. Support for demonstration projects has been provided by the U.S. Department of Energy–Office of Electricity through the Sandia, PNNL and ORNL national labs, while other labs such as NREL have engaged in market analysis. In 2012, DOE created the Joint Center for Energy Storage Research, an energy innovation hub, led by the Argonne National Laboratory, that is exclusively devoted to researching next-generation batteries (beyond lithium-ion).

While all these activities are important, the federal government could do much more to support the use of new technologies such as solar+storage to transform the nation's energy systems. A dedicated federal tax credit for storage remains an elusive policy tool.

The Right to Storage

In March of 2018, the Colorado legislature passed what could be historic legislation on energy storage. It enacted a "right to storage" law. The law would give every consumer a statutory right to own and operate battery storage without the interference of utilities or others to prevent the exercise of that right. The utility commission is ordered to issue rules to implement the law.[45]

This is the first state in the country to create such a statutory right to energy storage technologies. It is a simple legislative solution that could have significant implications for storage and other clean energy technologies.

To our knowledge, this is the first state in the country to create such a statutory right to energy storage technologies. It is a simple legislative solution that could have significant implications for storage and other clean energy technologies, if implemented well and broadly.

First, the legislation acknowledges the importance of energy technology, and why utility customers of all kinds should have an equal right of access to the benefits of energy storage. It comes down squarely on the side of consumers, rather than utilities, in the inevitable conflict of who owns, operates and controls energy storage technology going forward.

Second, it's a clever and efficient way to overcome the many obstacles that we have seen utilities create for solar, such as hindering net metering and applying unfavorable time-of-use-rates. With a right to storage, the consumers' needs should predominate in any future rule setting around storage markets.

Third, this could have implications for environmental justice and equity. If read broadly, as it should, laws like this providing equal access should apply to all consumers, not just those well-off who can afford to buy the technology. Rights to storage should mean that all public programs in support of storage incorporate energy justice provisions to ensure that low-income and diverse populations have equal access to the benefits of energy storage technologies.

Finally, this law gets at one of the fundamental challenges in modern society—the growing technology divide between the haves and the have nots—as well as the basic need to have access to technological innovations that can help the vulnerable to survive and prosper. Some have said that access to information technology should be a right.[46] The United Nations has declared that internet access—or the "freedom to connect"— is a basic human right.[47] Others argue that cybersecurity should be a basic human right.[48]

There have been numerous proposals to make clean energy more just and equitable, with various recommendations to implement those goals at the state and local level. There have been state efforts for "equal access" to solar.[49] And there have been some strong efforts to ensure that public funding programs be equitable in nature, that there be an allocation of clean energy funding targeted specifically to low-income communities, as California energy storage programs have done, which was detailed earlier in this report.

However, the right to storage concept has not yet made much statutory progress in the field of clean energy, which is why this approach could be significant. This could be a fundamentally new way to ensure the clean energy benefits of new technology are equally shared, and not undermined by utility or other interests. It is an area worth further advocacy and action.

Conclusion

Shaping the Policy Future

"Policy takes time to catch up with technology."[1]

Kelly Speakes-Backman, CEO, Energy Storage Association

It's rare to have an opportunity to shape an energy technology market as it is emerging, especially to create the rules so that its climate, equity, economic, and environmental benefits are front and center of the policy debate.

Imagine that you were a policymaker in the period 1880 through 1920, where you could shape the direction of the energy power and transportation markets as Edison and others fought to make light bulbs, transmission lines, electrical standards, customer products, and ways to finance their technologies.

We live today, over a 100 years later, with the results of their unregulated market approach to technology development.

At this moment, battery storage is the new technology innovation that can be shaped by advocacy and policy, as it is emerging in force on the national and international stage.

This report is designed to set the table for that conversation now, before the policies are fully proposed, the interests are hardened and aligned, the arguments are made, and the debates are too settled for further conversation and persuasion.

Above all, this report is intended to awaken the environmental and foundation community to this new opportunity.

Green Mountain Power's Stafford Hill solar+storage microgrid in Rutland, VT provides resilient power during emergencies while benefiting the grid and GMP ratepayers at other times.

Environmental advocates and foundations have spent the last thirty or more years designing and refining and defending rules and public funding for energy efficiency and solar technologies.

Now the third pillar of the clean energy technology platform is ahead of us. It will require a similar level of dedicated philanthropic support, NGO engagement, policy advocacy, state intervention, industry partnerships, financial creativity, and careful thought.

It will also likely engender heated debate with allies and adversaries, contested claims of merit and demerits, and disputes over whether models fit markets, and whether facts are facts.

But it will be worth it.

The issues outlined here are not the only challenges battery storage advocates need to resolve for the technology to take its much needed place in the clean energy marketplace. But they are a start.

It's now up to foundations and other advocates to shape the arc of this technology toward clear and committed public purposes.

Energy Storage Resources

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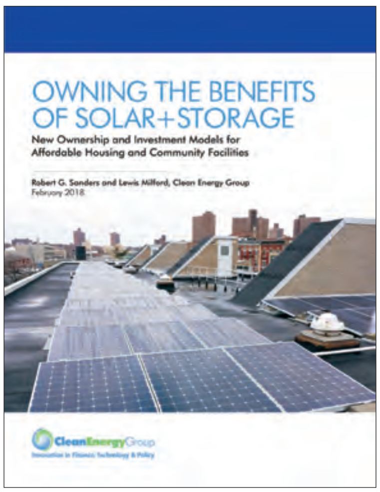
REPORTS

Clean Energy Group undertakes original economic and technical research and analysis about market opportunities and barriers to widespread adoption of solar+storage systems. The sections of from this report will be updated periodically on Clean Energy Group's website at *www.cleanegroup.org/ceg-projects/energy-storage*.

Recent publications include:



Owning the Benefits of Solar+Storage: New Ownership and Investment Models for Affordable Housing and Community Facilities

This paper explores additional ownership and financing options for solar+storage projects and low-income communities beyond direct ownership and conventional leasing models. *February 2018*

Valuing the Resilience Provided by Solar and Battery Energy Storage Systems

Researchers from NREL and Clean Energy Group found that placing a monetary value on the ability of solar+storage to avoid losses during grid outages can significantly impact project economics and system design. *January 2018*

Identifying Potential Markets for Behind-the-Meter Battery Energy Storage: A Survey of U.S. Demand Charges

The first public survey of utility rates details economic potential for commercial behind-the-meter battery storage market across the United States. *August 2017*

Solar Risk: How Energy Storage Can Preserve Solar Savings in California Affordable Housing

This analysis finds that energy storage can effectively hedge against proposed changes to California's solar policies and utility rates that could drastically reduce the value of solar. *May 2017*

A complete list of Resilient Power Project publications is available in the Clean Energy Group Publications Library on its website at *www.cleanegroup.org/publications-library*.

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The Resilient Power Project hosts periodic webinars on topics related to the importance and benefits of resilient power.

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NEWSLETTERS

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Solar+Storage E-News: This weekly electronic newsletter provides updates on the latest news and developments related to solar+storage technology, finance and policy, in the U.S. and internationally.

Read past issues of these free e-newsletters and subscribe to receive upcoming issues at *www.cleanegroup.org/ceg-projects/resilient-power-project/newsletters*.

TOOLKIT

The Resilient Power Toolkit is designed to help users gain a better understanding of resilient power systems, and to learn how to approach the planning and development of a resilient power installation. Resources include descriptions and links to key reports, guides, webinars, and online tools developed by Clean Energy Group and other organizations. Resources are broken down into the following topic areas: technology, economics, finance, project evaluation tools, and project development. Visit the Toolkit at: *www.cleanegroup.org/ceg-projects/resilient-power-project/toolkit*.

PROJECT MAP

The U.S. Resilient Solar+Storage Projects Map shows resilient power installations currently deployed or in development across the United States. The map is interactive, and projects can be searched and sorted by location, development status, project type, services provided, and more. To qualify for inclusion, a project must have the ability to operate independently from the grid to support critical electric loads in the event of a power outage, and be primarily composed of clean energy technologies, such as solar PV and battery storage. Visit the map at: *www.cleanegroup.org/ceg-projects/resilient-power-project/map*.

FEATURED INSTALLATIONS

Clean Energy Group maintains short profiles of resilient power installations, in the categories of affordable housing, emergency shelters, critical community services, and community microgrids. Each profile includes a project description, installation details, project photos, links to additional resources, and more. Browse the Featured Installations at: *www.cleanegroup.org/ceg-projects/resilient-power-project/featured-installations*.

For more information and resources on resilient power and energy storage, visit:

- *www.resilient-power.org*
- *www.cleanegroup.org/ceg-projects/energy-storage*
- *www.cesa.org/projects/energy-storage-technology-advancement-partnership*

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Endnotes

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TOP TEN TRENDS

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market that exists today throughout the country. Not focusing on storage because it reduces existing utility demand charges that some advocates and energy experts don't see as optimal rate-making is odd strategy. It's like saying it's counterproductive to use energy efficiency to reduce utility rates that are artificially inflated or suspect. It ignores today's reality. Also, the cumulative effect of customer level peak reduction will grow over time to reduce system peaks, with the attendant economic and environmental benefits from reducing overbuilt energy systems.

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> Our study has important implications for research and policymaking. First, that models consistently underestimated potential of solar energy—if continued—has implications for the future as decision-makers might treat PV too reluctantly. *Specifically, policymakers might fail to address the integration challenge and insufficiently plan for adequate grid and storage infrastructure.* As a result, low-carbon energy sources could be under-deployed, imposing economic and societal costs, while instead energy system planning might rely too much on other, possibly more problematic, low-carbon technologies such as CCS and nuclear.
>
> *Second, the nature of PV upscaling is changing, with the long-term potential at high penetration rates depending less on technological costs of PV but increasingly on the system integration costs, with storage (and less so demand response) being an important contribu-tion at high PV shares. Hence, realizing high PV scenarios requires not only support policies for fostering technological learning of PV, but also concerted programmes to* accommodate large shares of PV in the power grid by modernizing power market regulations, expanding transmission grids, and *scaling up storage technologies (emphasis added).*

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Section 9: Electric Vehicle Charging

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need of review that it was worth writing our views now. We welcome any competing views on these topics to sharpen our understanding going forward.

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10 There is an ongoing debate on this topic among environmental colleagues. David Roberts has summarized the literature on this topic reasonably well. (See, Roberts, David, "Is 100% Renewables Realistic? Here's What We Know," *Vox*, April 17, 2017, *www.vox.com/energy-and-environment/2017/4/7/15159034/100-renewable-energy-studies*.) Much of this debate is a one among climate colleagues who are modelling various scenarios to get to a fossil fuel-free future, so it's important to take their efforts seriously. Some have concluded that a renewables-only future is not a reasonably cost-effective solution, and they argue for a broader suite of alternative low carbon technologies, including nuclear and carbon capture and storage (CCS). They may well have an argument, that delivering reliable power through a 100% renewables future alone may not be economically feasible, but the studies underlying these scenarios, when it comes to energy storage often: (1) rely on the *wrong technology*, such as pumped hydro rather than batteries technologies, to project future costs that turn out to be too high to be meaningful, or (2) rely on the *wrong costs* for battery storage either by ignoring current cost reduction pathways, or by failing to acknowledge the many cost saving and revenue generating opportunities for batteries in electricity markets. In either case, these studies often result in conclusions that inflate the future costs of storage as a cost-effective option with renewables to reduce emissions, thus making the non-renewables alternatives look more cost-effective by comparison. What's more, the studies often fail to distinguish between situations where battery storage could support major renewables integration with shorter-term duration storage technologies, as compared to much longer-term duration, seasonal storage needs not feasible with today's battery technologies.

However, a recent relevant study by Nathan Lewis at Caltech (with Matthew R. Shaner et al) is an important advance toward more sensible projections in this field, especially about the role of energy storage in future renewable integration scenarios. (See: Shaner, Matthew R, et al, "Geophysical Constraints on the Reliability of Solar and Wind Power in the United States," *Energy Environ. Sci.***,** 2018, The Royal Society of Chemistry, February 27, 2018, DOI: 10.1039/c7ee03029k, *http://pubs.rsc.org/en/content/articlelanding/2018/ee/c7ee03029k#!divAbstract*). The study concludes that renewables systems with batteries that can store solar electricity for 12-hour durations could reliably meet up to 80% of the electric power system demands by 2050; that alone is an extraordinary finding – achieving an 80% renewable energy system with existing lithium-ion storage technologies. Battery projects now being bid into market are committed to delivering up to 10-hour durations; getting to 12-hour durations is a reasonably achievable, incremental economic improvement. The study concludes that to go further and reach a 100% renewables scenario, more longer-term, seasonal storage is needed, and that is not now economically feasible. (See the "Emerging Issues" section on "Power to Gas" for a discussion on this long-term storage technology issue.)

The debate over the findings from these types of studies is a critical one about whether renewables and energy storage could reliably replace fossil-fuel baseload plants in the future and bring about a decarbonized energy sector. Regardless of the conclusions the studies reach, recent finding all appear to confirm one critical point: getting the energy storage solution right is a key linchpin to answer the question whether a future energy system can be powered by renewables at significant levels. Unlike the approach of some studies, the solution is not likely to be an either/or answer**,**but a continuum of time durations where existing and future combinations of storage technologies can provide support to various future levels of renewables integration. As noted elsewhere, this paper is not written to grapple with this complete fossil-fuel replacement problem in any detail. Instead, it has been written to point out that, if storage is so critical to these long-term, future solutions, more work must be done now to reliably study and analyze current trends in cost and performance of battery technology to support a more robust and honest debate about storage's role in enabling renewables integration in future climate emissions scenarios.

EMERGING ISSUES

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View of power outages in downtown Manhattan following Hurricane Sandy.

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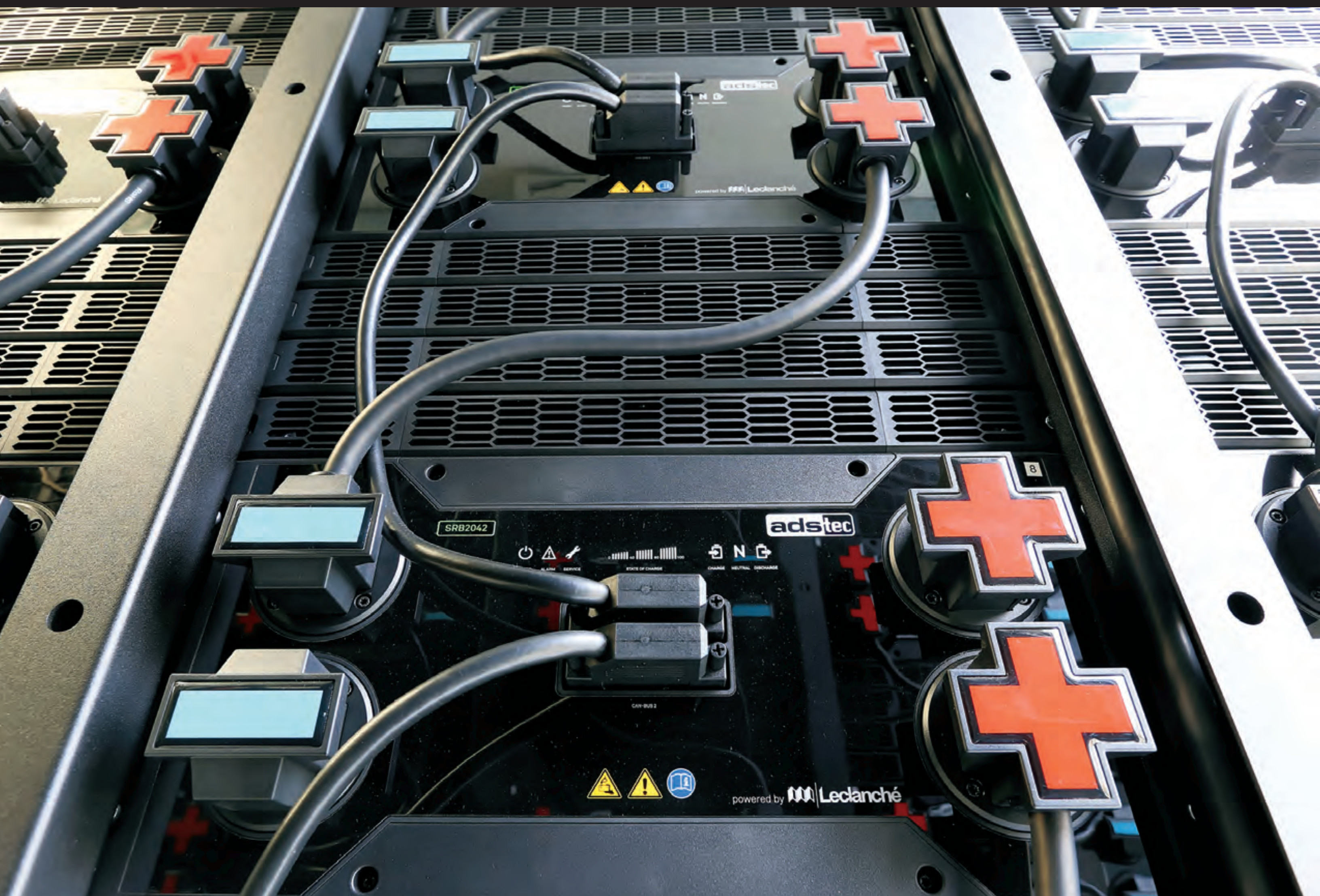
How Activists and Foundations Can Champion Battery Storage to Recharge the Clean Energy Transition



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