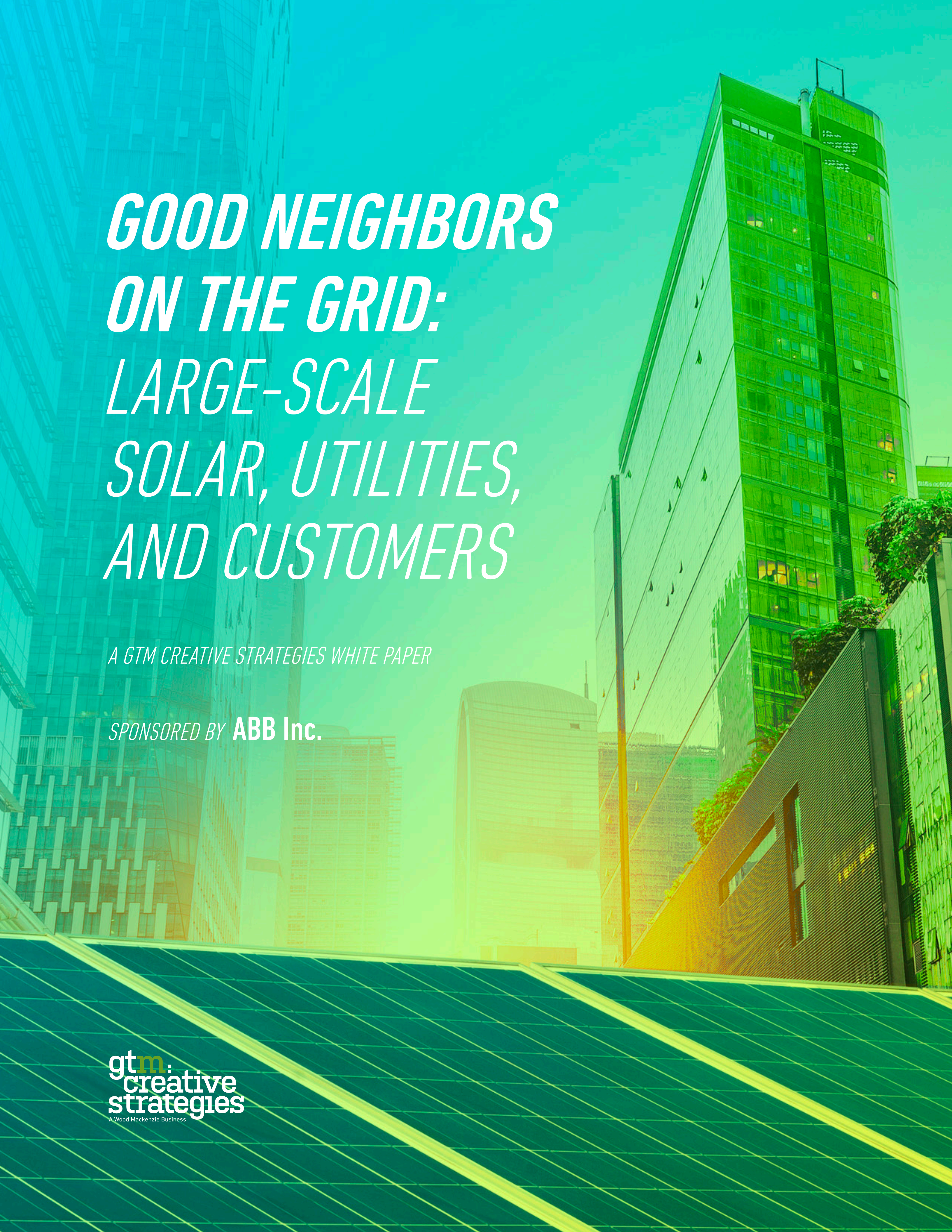

GOOD NEIGHBORS ON THE GRID: *LARGE-SCALE SOLAR, UTILITIES, AND CUSTOMERS*

A GTM CREATIVE STRATEGIES WHITE PAPER

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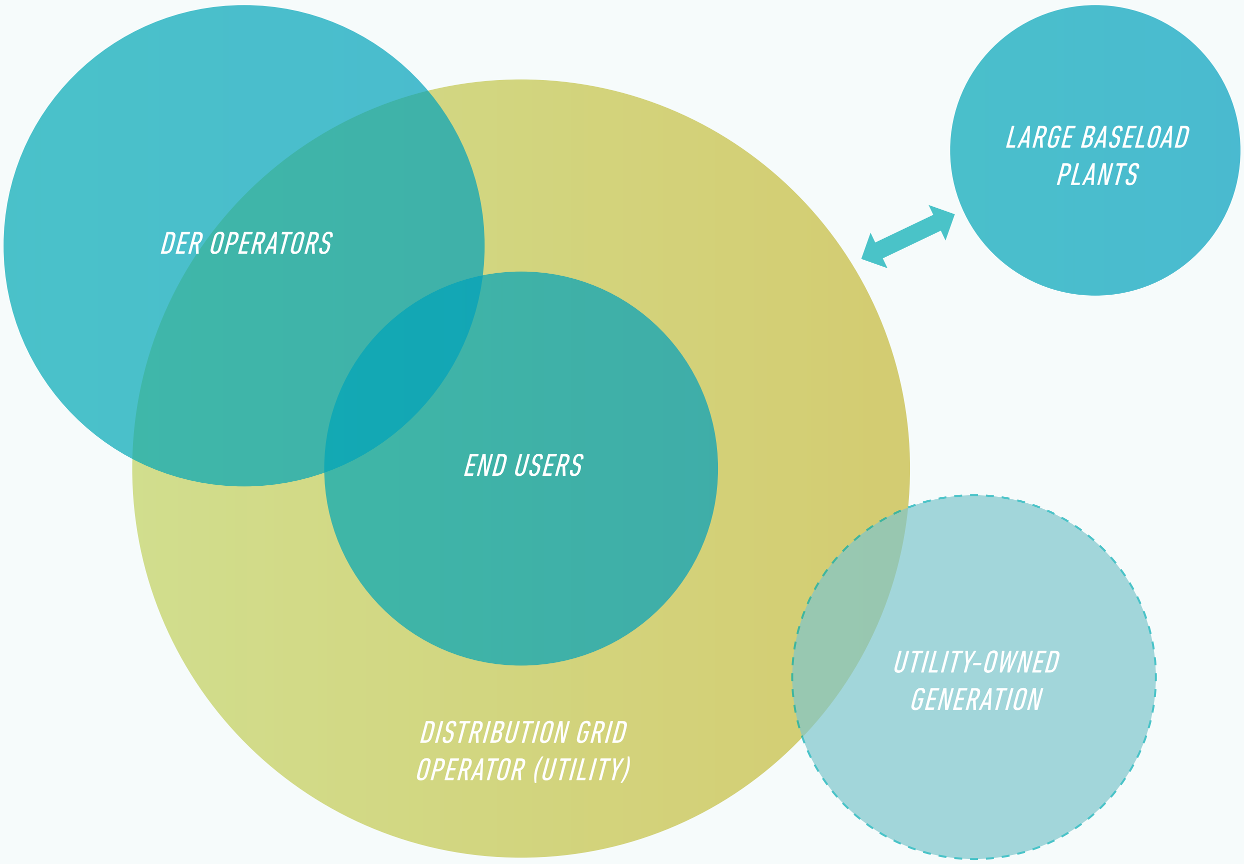
INTRODUCTION:

THE ENERGY NEIGHBORHOOD

An energy system is, in some ways, like a neighborhood. Energy neighbors affect each other, even when they don't always interact directly. The sharp rise in solar energy resources represents an opportunity for energy neighbors to learn to accommodate and adapt to each other, for considerable mutual benefit. Understanding your energy neighbors, and your energy neighborhood, can reduce any risks solar integration may pose while enhancing grid stability and reliability. All of this can be achieved while improving the bottom line of everyone involved.

Applying good neighborly values to the grid, as well as making sure the appropriate tools are deployed throughout the energy neighborhood, can help enable more effective energy choices and investments at many levels.

> *THE SHARP RISE IN SOLAR ENERGY RESOURCES REPRESENTS AN OPPORTUNITY FOR ENERGY NEIGHBORS TO LEARN TO ACCOMMODATE AND ADAPT TO EACH OTHER, FOR CONSIDERABLE MUTUAL BENEFIT.*



DISTRIBUTION GRID OPERATORS

- Reliably supplying electricity
- Maintaining grid balance
- Managing costs, maintaining or growing revenue
- Sustainability and environmental goals
- Accoun tability for spending ratepayer dollars
- Retaining customers
- Shareholder returns (if investor-owned)

END USERS *(INDUSTRIAL, COMMERCIAL, RESIDENTIAL)*

- Conducting core functions/business
- Managing costs (including utility bills)
- Ensuring resilience
- Minimizing negative environmental impacts

DER OPERATORS *(UTILITY-SCALE)*

- Profitable operation
- Meeting PPA commitments
- Maximizing output
- Minimizing curtailments

UTILITY-OWNED GENERATION
(BASELOAD, PEAKER/SPINNING, RENEWABLES)

- Controlling fuel costs
- Maximizing revenue
- Reducing greenhouse gas emissions

When all of these entities are empowered to accommodate each other — and, to some extent, collaborate effectively — then everyone in the energy neighborhood can realize a net gain from being a good energy neighbor, even while accepting some trade-offs.

For example: A large solar photovoltaic plant is built and interconnected at the edge of a utility distribution grid. The local utility, which is buying most of the plant's output, negotiates a power purchase agreement (PPA) that pays the solar developer more for energy delivered during peak periods. The PPA structure incentivizes the developer to orient the plant so that it generates more power late in the day. This choice yields less overall energy production, but more revenue under the terms of the PPA.

Furthermore, in order to speed the interconnection approval process, the solar developer agrees to install smart inverters at the plant. The utility requested this measure to help minimize voltage and frequency fluctuations on the grid, which is a common side effect of bidirectional power flow on older distribution grids that were built for one-way power flow. Smart inverters cost more, but faster time-to-market significantly reduces the developer's costs and risk.

Here's how everyone in the energy neighborhood benefits from these changes to the solar plant design:

- Solar developer. Faster, less costly and less risky project development and deployment, and overall increased revenues. More local support for the project from ratepayers, which helps to satisfy regulators and the utility.
- Utility. Less stress to the grid, improved service to customers near the solar farm (by smoothing voltage issues and ensuring power quality via the smart inverter), lower overall peak demand (which lowers overall operating cost), reduced backfeeding to the grid (which can reduce utility revenue) and progress toward carbon reduction targets.
- Customers. Increased power reliability and quality. Less risk of outages due to voltage fluctuations. More value delivered for their ratepayer dollars, including deferred costs for grid expansion and updates.

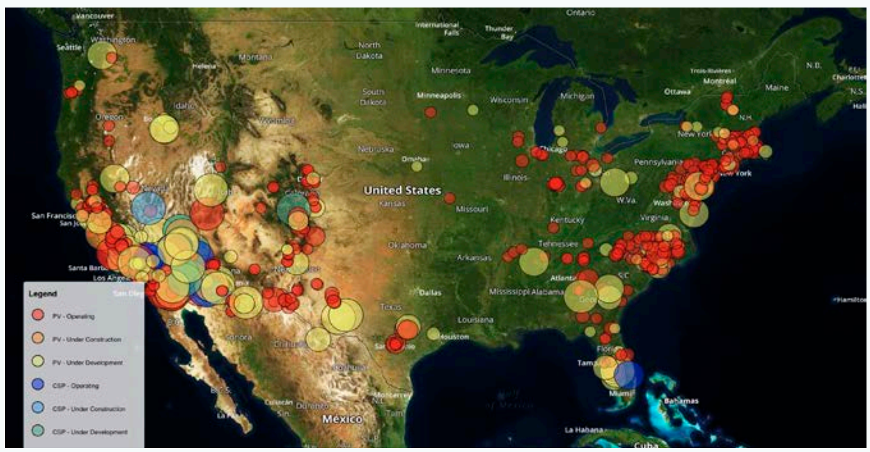
2 MORE EFFECTIVE SOLAR INTEGRATION

Utility-scale solar and other DERs are still small in terms of overall generation mix, but they can be a disproportionately disruptive influence on the grid. Disruptive does not mean "bad," but in this case, it usually means "challenging."

There are varying definitions of utility-scale solar. For the purposes of this paper, this refers to installations greater than 2 megawatts (MW), whether behind the meter or a standalone solar facility. Increasingly, large end users are signing their own PPAs — primarily as a long-term hedge against energy price volatility.

According to the Solar Energy Industries Association, there are currently nearly 2,900 MW of large solar PV plants in operation across the U.S. Growth is spiking: approximately 26,000 MW of U.S. utility-scale solar power projects are currently under development, enough to power more than 4.3 million households.

The Major Solar Projects List



The growth in U.S. renewables isn't necessarily competing with existing conventional generation. Rather, it's enabling the rightsizing of the overall energy system — especially considering that conventional generation (especially aging coal and nuclear plants) are under increasing pressure to retire for environmental and safety reasons.

Services provided by existing utility distribution grids are essential to solar growth. According to a 2013 issue brief by the Innovation Electricity Efficiency Institute (part of the Edison Electric Institute), The Value of the Grid to Distributed Generation Customers, the grid allows DERs to:

- Instantaneously and continuously balance supply and demand to maintain a stable frequency.
- Re-sell excess power produced via net energy metering or feed-in tariffs.
- Receive power from the grid when on-site generation cannot serve demand, either from low/no solar production or due to solar equipment maintenance or malfunction (backup supply).
- Control voltage and frequency, and maintain high AC waveform quality.

These grid services have associated costs that ideally are shared equitably by all energy neighbors, including by DERs. However, since many solar farms are not part of the rate base, per se, recouping the cost of their impact to the grid in an equitable way can be challenging. Some states are attempting to address this via regulatory enhancements.

Major equipment manufacturers are also stepping up to meet the challenge of easing big solar projects into energy neighborhoods. They are increasing the diversity of relevant product offerings, and introducing more competitive pricing. For instance, rather than purchase large centralized inverters, DER developers or grid operators may purchase a configuration of smart string inverters. Smart inverters provide more granular control over the solar plant's output, in response to hyperlocal conditions in weather and the grid. Ultimately, such flexibility helps to better regulate voltage and frequency. This improves conditions for customers in the area of the grid near the solar plant — as well as the utility's ability to interact with the solar plant to optimize important grid regulations services.

Thanks to technological improvements of the last few years, typical design-to-deployment time for solar facility development has shortened dramatically — now down to a mere 9-12 months. There's still a need to accelerate interconnection approval time, a factor that can hinder project economics. But overall, solar facilities are coming online faster than ever before.

As solar PV continues to improve in cost and performance, strong standards have vastly improved solar plant design and clarified equipment selection criteria. Today, there are far fewer problems with poor plant design; the industry has been learning from experience. This yields fewer problems with curtailments and disturbances in voltage or power quality. Taken together, these benefits make it easier for solar developers and investors to have confidence, paving the way for more large-scale solar projects to move forward swiftly.

However, pressure to accelerate deployment comes at a cost. Many solar project developers have become quite aggressive in pricing their PPAs, in a way that can be financially damaging to solar developers and utilities.

THANKS TO TECHNOLOGICAL IMPROVEMENTS OF THE LAST FEW YEARS, TYPICAL DESIGN-TO-DEPLOYMENT TIME FOR SOLAR FACILITY DEVELOPMENT HAS SHORTENED DRAMATICALLY — NOW DOWN TO A MERE 9-12 MONTHS.

Low PPA prices increase the pressure on solar project developers, and their equipment vendors, to cut corners on components. This helps solar developers negotiate more attractive financing for their projects. However, the performance of these facilities may not support the developer's business model, the health and stability of the power grid, or the interests of the solar farm's energy neighbors.

Solar farms typically are designed to operate for 20-25 years, so it helps to be able to pay up front for quality components from established vendors who won't cut corners on product or system design. Carefully writing project specifications, and checking bids to make sure these requirements are really met, can strike a balance between the up-front cost and ultimate performance of a solar facility. Services such as support, monitoring, operations and maintenance can also help ensure that a solar farm is capable of producing not just power, but reliable revenue. In this way, equipment vendors can provide vital support to the energy neighborhood.

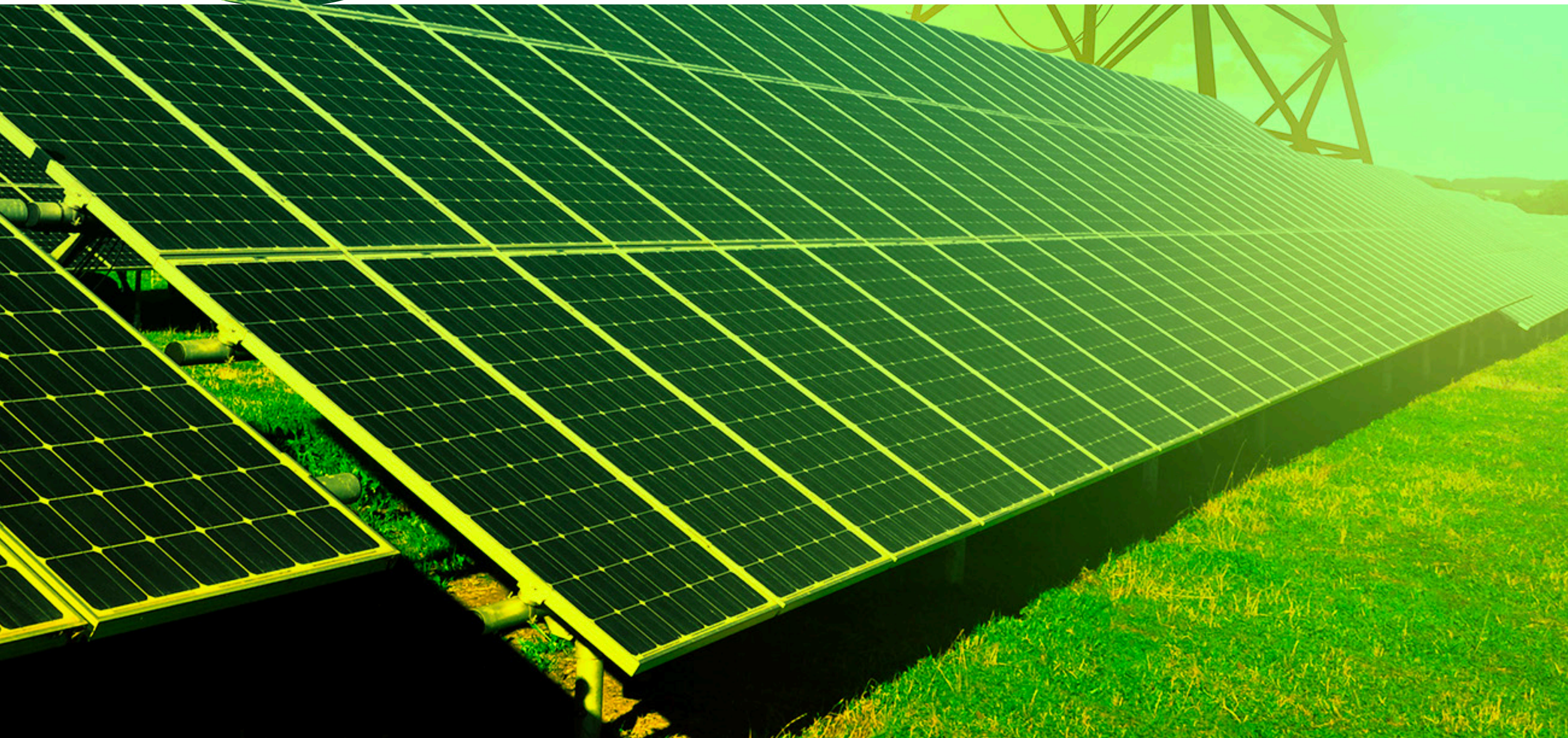
Battery energy storage, deployed both behind and in front of the meter, also can play a key role in helping distribution grids accommodate DER growth.

Deployed at commensurate scale, battery storage effectively expands the capacity of grids. It can store energy produced by intermittent renewable resources (or produced cheaply during off-peak hours) and release it instantaneously. This can compensate for seconds, minutes or hours when the sun is not shining or the wind is not blowing keeping the flow of power stable across the grid. Also, storage can be deployed at strategic locations on the grid to relieve grid congestion — effectively adding grid capacity without building new distribution lines and substations. (Commonly called "non-wires alternatives.")

Large customers who install behind-the-meter energy storage might contract with utilities to deploy this capacity to alleviate local stress on the grid, as part of a demand response program. In the future, battery storage units also might be operated as more-or-less standalone DERs, by utilities or energy service providers.

The cost of storage has been dropping fast – the DOE has modeled a 73 percent decline in battery costs over the last eight years – with product offerings becoming economical for almost anyone in the energy neighborhood. However, battery storage needs to become more standardized (as solar panel technology has) in order for its economics to continue to improve.

3 UTILITIES AND SOLAR INTEGRATION: KEY RISKS AND OPPORTUNITIES



Utilities are the hub of the energy neighborhood. Also, the traditional utility business model is being challenged like never before. Consequently, utilities are facing some of the largest direct risks from integrating large amounts of solar power onto their distribution grids. But, potentially, they also have much to gain.

POWER QUALITY ISSUES

Distribution grids generally were not designed for bidirectional power flows and fluctuating output. So when the output from a utility-scale solar facility exceeds the typical load on the distribution feeder where it interconnects, or if it exhibits large or frequent fluctuations, technical problems can arise.

Several of these technical issues were addressed in the Greentech Media white paper, *Distributed Energy Resources: Seizing Opportunities While Managing Distribution Grid Impacts*. In particular, voltage fluctuations (overvoltages or sags) can damage nearby equipment belonging to utilities and end users, or trigger brownouts or outages. These problems often co-occur with potentially damaging power quality problems, such as frequency variations — and utilities are tasked with maintaining proper frequency of the power supply.

Compensating technologies such as smart inverters, STATCOMs, battery energy storage and advanced communication and controls can address these problems to a significant extent, as well as yield additional benefits across the system. However, this is where conflicting interests — especially financial considerations — can stir trouble in the energy neighborhood.

Renewable facility owners generally pay to add equipment needed mainly to protect utility grids from the impact of renewable output. But they sometimes resist paying for all measures requested by the utility, since these costs can negatively impact their project economics. However, without robust protection for the grid, the likelihood of utility curtailments increases — which might impair a renewable energy project's return on investment even more significantly.

Utilities could install more of these protective devices themselves, but they may find it challenging to convince regulators to allow them to recoup these costs from the rate base. The time lag involved in attempting rate base relief would be a substantial obstacle for projects moving forward. Also, end users probably would not wish to see their electricity rates rise to cover these costs, unless this would yield direct improvements in service — not just avoided potential problems.

BACKFEEDING

Ideally, the output of a solar farm does not exceed the baseload capacity of the feeder where it's connected. Thus, solar energy serves local load, rather than traveling back up the grid. When power from DERs flows further up into the distribution network, this can stress grid assets and compromise grid stability, as well as trigger voltage and power quality problems.

Sometimes power output from DERs backfeeds all the way up to the transmission grid. This puts the solar farm owner's business interests in conflict with the utility's business interests. Usually, solar facilities have minimal capacity to store, on-site, any excess energy that they produce. Batteries and other energy storage technologies, deployed behind the meter, tend to substantially increase project cost. So usually DER operators have no choice but to feed all power to the grid as it's produced.

Usually, utilities lose kWh revenue when they must backfeed power to the transmission grid. However, utilities are generally obliged to accept the output of solar facilities through PURPA and state-level renewable energy targets, except when contractual conditions are met to enact a curtailment.

If the output of solar facilities was fairly predictable and steady, it would be easy for utilities and solar facilities to cooperate to minimize backfeeding, since the direct benefits to both neighbors would be more obvious. However, solar energy production tends to be highly variable. Thus, a large influx of solar power to the grid does not necessarily allow a utility to ramp down central generation, spinning reserve or wholesale power purchases to a level that would yield appreciable cost savings.

Like solar farms, utilities also typically do not own significant energy storage assets that would allow them to store excess energy and release it as needed onto the grid. Wider deployment of battery storage on both sides of the meter would provide this on-demand capacity, as well as power quality benefits to the entire grid. Thus, wider adoption of battery storage — along with support for increased standardization of this technology — might help ease some of the energy neighborhood conflicts over power backfeeding.

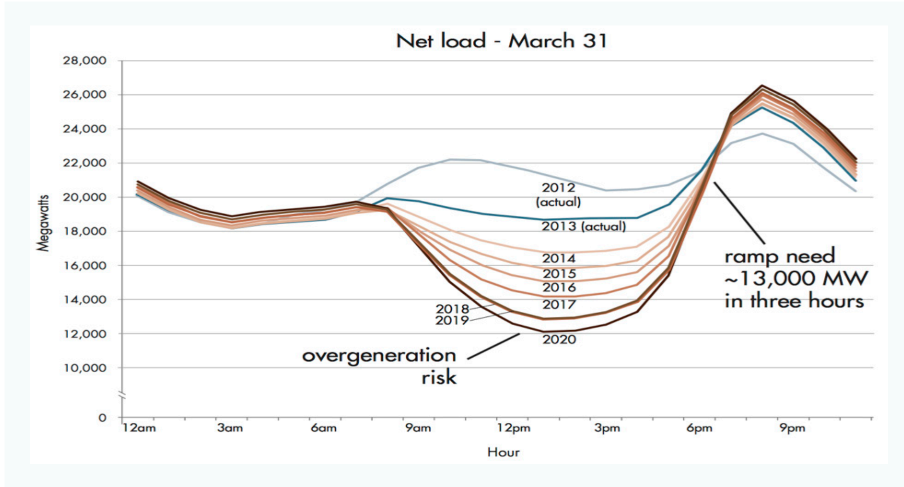
COORDINATING DERS AND CENTRALIZED GENERATION

This challenge is especially significant in deregulated markets, where utilities do not own or operate large central baseload plants. Nevertheless, utilities still must keep the grid balanced — despite juggling input from a variety of generation sources that they mostly don't control.

The operation of centralized plants can have a profound effect on everyone in the energy neighborhood. However, in deregulated markets, the interests of central plant owners and operators are mostly removed from the concerns of local energy neighborhoods. Thus, local energy neighbors must try to manage what they can. On the supply side, this can support adding advanced communication and control capability for DERs — including the ability for direct communication with, and perhaps some control by, the utility.

This could get easier as more U.S. utilities start to own DERs. U.S. utilities historically have mainly participated in the utility-scale renewables market as PPA offtakers. But urgency is building for them to own and operate these facilities — in part to not lose ground to international competition. Some European utilities have begun to aggressively pursue the U.S. utility-scale solar and wind markets, since this is an economical way for them to enter U.S. markets. For instance, Avangrid Renewables, part of the Iberdrola Group, owns wind and solar farms in many U.S. states. Duke Energy and Dominion are two major U.S. utilities that own, and are continuing to acquire, major U.S. renewable energy facilities.

The Duck Curve



The duck curve shows steep ramping needs and overgeneration risk due to significant amounts of wind and solar.

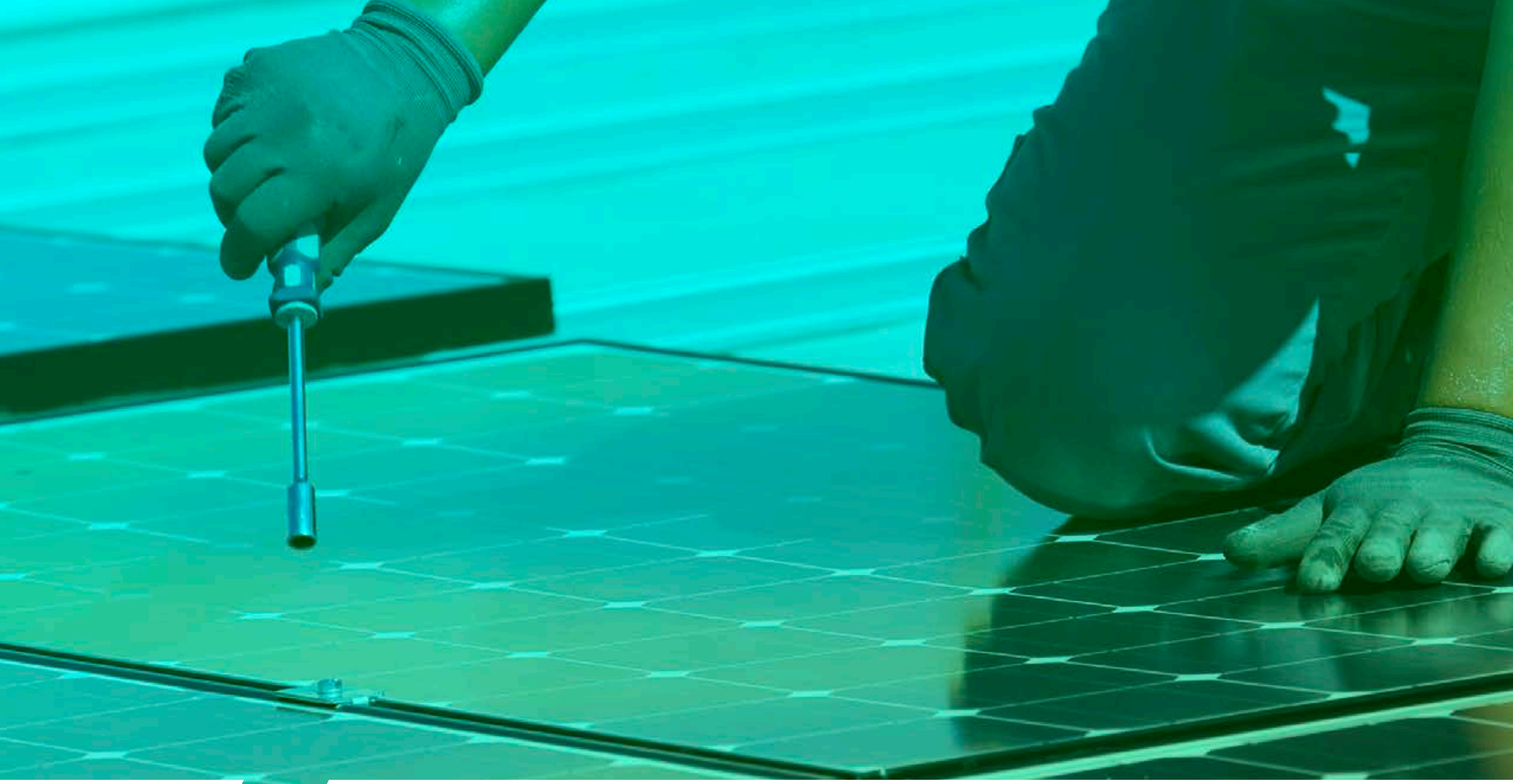
UPDATING INCENTIVES

In most cases, updating incentives will involve regulators. Perhaps the most dramatic attempt of regulators rethinking energy incentives is the State of New York's Reforming the Energy Vision (REV) initiative to overhaul the state's electricity markets at the distribution level. Transforming the state's investor-owned electric utilities into a distribution system platform would empower utilities to more effectively integrate solar power and other DERs into the grid. Another approach, suggested by SolarCity would be a regulatory model that separates the role of grid planning and sourcing from the role of grid asset owner. This would create a new type of energy neighbor: the independent distribution system operator.

Redesigning tariffs, especially net energy metering rates, can help align solar growth with grid evolution. Time-of-use rates and demand charges are powerful incentives for customers to increase energy efficiency and more actively manage when they use energy. In particular, demand charge reduction is a leading motivation to install DERs and energy storage.

This trend towards time-of-use rates increases opportunities for utility demand response (DR) programs, which can help defer considerable infrastructure investment. For instance, in New York, Con Edison is delaying a $1.2 billion investment in new substations with its Brooklyn-Queens Demand Management Project (BQDM). As part of BQDM, Con Edison is aggressively soliciting and utilizing demand management, so customers can expand the capacity of the existing grid.

In the solar plant development process, incentives can create projects that offer more benefits and fewer problems to all energy neighbors. For instance, when negotiating power purchase agreements, utilities could compensate solar plants depending on their location or the time of day.



4 TECHNOLOGY IMPROVEMENTS FOR THE ENERGY NEIGHBORHOOD

Energy neighbors can cooperate better with the right tools. Fortunately, energy technology has been improving in ways that can support well-functioning energy neighborhoods.

BATTERY ENERGY STORAGE

Battery energy storage is one of the most obvious beneficial technologies — and prices are dropping as capacity increases. Tesla's new Gigafactory near Sparks, NV is expected to produce 35 GWh of battery capacity by 2018, including for storage solutions such as the residential Powerwall battery, and scalable Powerpack units for commercial and utility-scale storage solutions.

SMART INVERTERS

Smart inverters have been improving in ways that increase the flexibility and effectiveness of components central to solar integration. The technology implements grid-balancing tasks at the point where direct current from solar panels is converted to alternating current. Smart inverters can compensate for the limitations of traditional capacitor banks, which cannot always effectively manage bidirectional power flows. They also enhance voltage optimization control.

Smart inverters are becoming more intelligent through the addition of real-time data communication with the grid, as well as the option to allow utilities some level of remote control over their operation. Utility distribution management systems can remotely control the set points of smart inverters. This helps the utility manage reactive power flow, which in turn helps control voltage on the distribution feeder. Smart inverters can enhance overall solar facility economics, while ensuring grid reliability.

Hawaii, California and Arizona are beginning to introduce smart inverters. Most notably, California's interconnection standard, Rule 21, updated requirements for how solar PV projects communicate and are controlled. This rule recommends that several key inverter set points and functions should automatically respond to utility signals. Implementation of Rule 21 has been slow so far, but the potential impact of smart inverters will become more evident in coming years.

DER MANAGEMENT SYSTEM (DERMS)

As more DERs move into local energy neighborhoods, there is a growing need to be able to manage them coherently as a system. As DERs grow substantially on the system, it becomes more complicated for the utility to balance energy supply and demand in real time. Solving this problem requires DERMS software that can aggregate and manage a variety of DERs across a grid — generation, storage and demand response capacity.

DERMS can play a key role in meeting need for grid balancing and other ancillary services. For instance, a Greentech Media report on DERMS noted that this technology could help the largest grid operator in the U.S., PJM Interconnection, meet its needs for grid services through increased local and on-site generation. Ultimately, this might pave the way for more energy storage and electric vehicles in PJM territory. More broadly, DERMS could be deployed by utilities or third parties to aggregate controllable DERs and loads into a reliable virtual power plant.

In 2016, PG&E identified three key benefits of DERMS deployment in California energy systems. These could ultimately serve the interests of all energy neighbors, which could help drive the market for DERMS:

- Safety. Ensuring that DER dispatch driven by the ISO market does not violate distribution system thermal and voltage limits.
- Affordability. Potentially growing grid capacity to better accommodate distributed generation at a far lower cost than traditional distribution network upgrades (often called "non-wires alternatives.")
- Reliability. DER coordination could enhance operational flexibility, and also enable microgrid islanding.

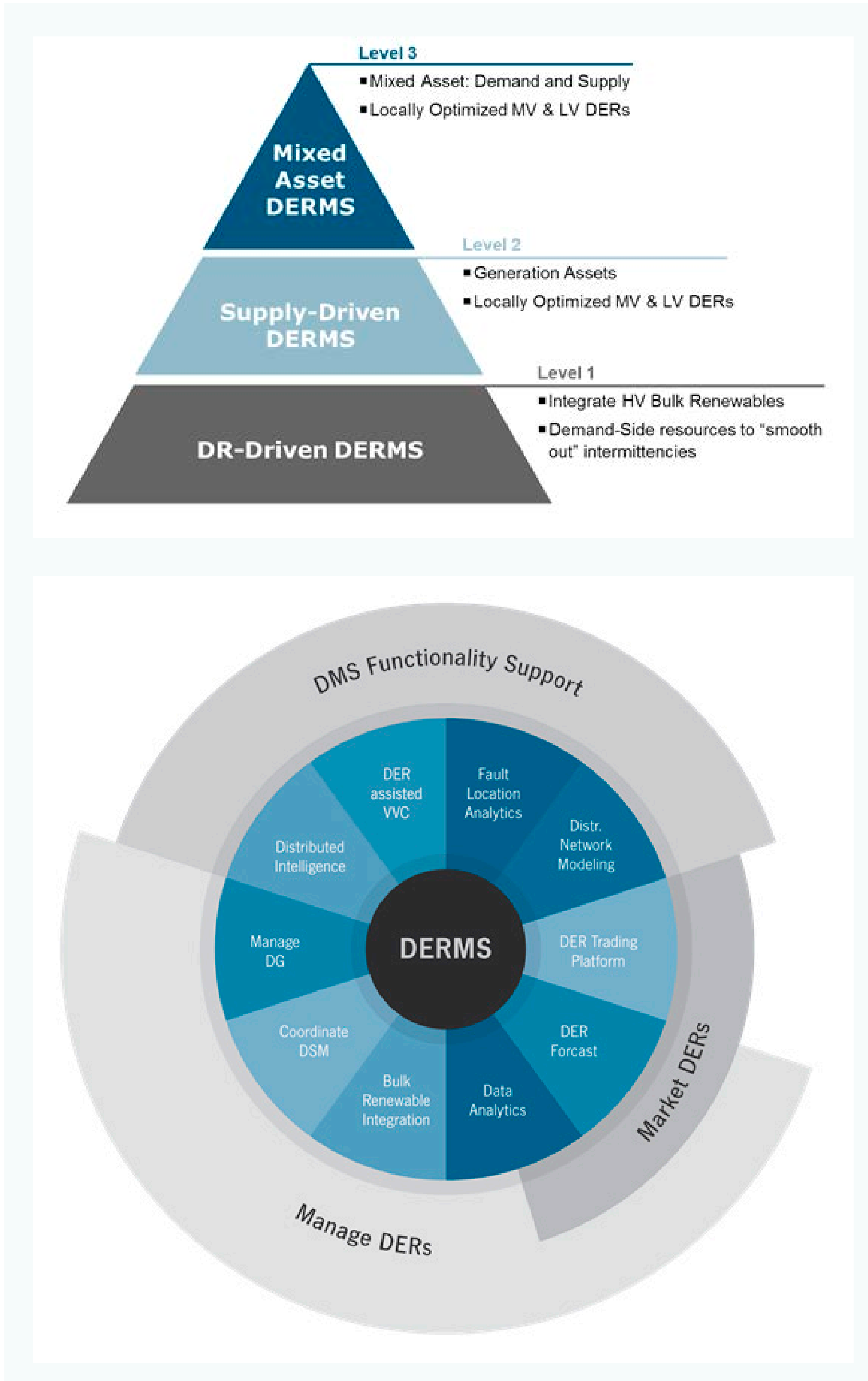
Several vendors are beginning to introduce DERMS offerings. For instance, ABB's DERMS supports portfolio management, forecasting, monitoring, control and analysis of individual and aggregated DERs. When used with ABB's DER scheduling software, the DERMS can optimize DER schedules while maintaining safe grid operations within the operating range of the network.

However, DERMS technology is still maturing. No two energy neighborhoods are alike, so a DERMS must be highly customizable to be effective.

For now, utilities that are not yet prepared to deploy a DERMS can at least start monitoring real and reactive power levels produced by DERs. DER data can be integrated with asset management data on the operation and performance of central and peaker generation. Then, when a DERMS is deployed, this existing data can be integrated further into utility operations and planning.

NO TWO ENERGY NEIGHBORHOODS ARE ALIKE, SO A DERMS MUST BE HIGHLY CUSTOMIZABLE TO BE EFFECTIVE.

DER Management System



Source: DER Management Systems 2014: Technology, Deployments and Market Size

5 CONCLUSION

Adopting the energy neighborhood perspective can help bridge historic silos in the energy market, which have been hindering the evolution of more flexible, efficient, sustainable, and environmentally friendly energy systems. By working together more, or at least consulting each other more regularly and proactively, utilities, DER operators and customers can make mutually beneficial decisions about assets, business operations and resources.

In particular, the strong growth of utility-scale solar at the grid edge represents a unique opportunity to develop a shared sense of the energy neighborhood. These projects can become a focus to bring energy neighbors together.

Reworking incentives around these projects, which may require updating how utilities are regulated, can help make this process more collaborative and less divisive. In many regions, regulatory innovation may not require a wholesale change of the utility's role, as is happening in New York, but rather rethinking elements of rate design. Many states are considering changes to rate design beyond retail net metering that could encourage DERs to be compensated, in part, by the services they can provide to the local energy neighborhood.

Greater cooperation between energy neighbors can help remove obstacles and help justify the investment of advanced technologies such as smart inverters, battery storage and DERMS. Deploying cutting-edge technology, whether energy storage or smart inverters, also can increase the opportunities, and rewards, associated with greater customer participation in utility programs, such as demand response.

Understanding interdependence, and leveraging it effectively, is essential to building capacity in any system. The ever-increasing pace of change to energy systems can become a rising tide that lifts all boats — as long as everyone in the boat keeps rowing together.

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