Smart Electric Power Alliance

2018 Utility Energy Storage Market Snapshot

AUGUST 2018

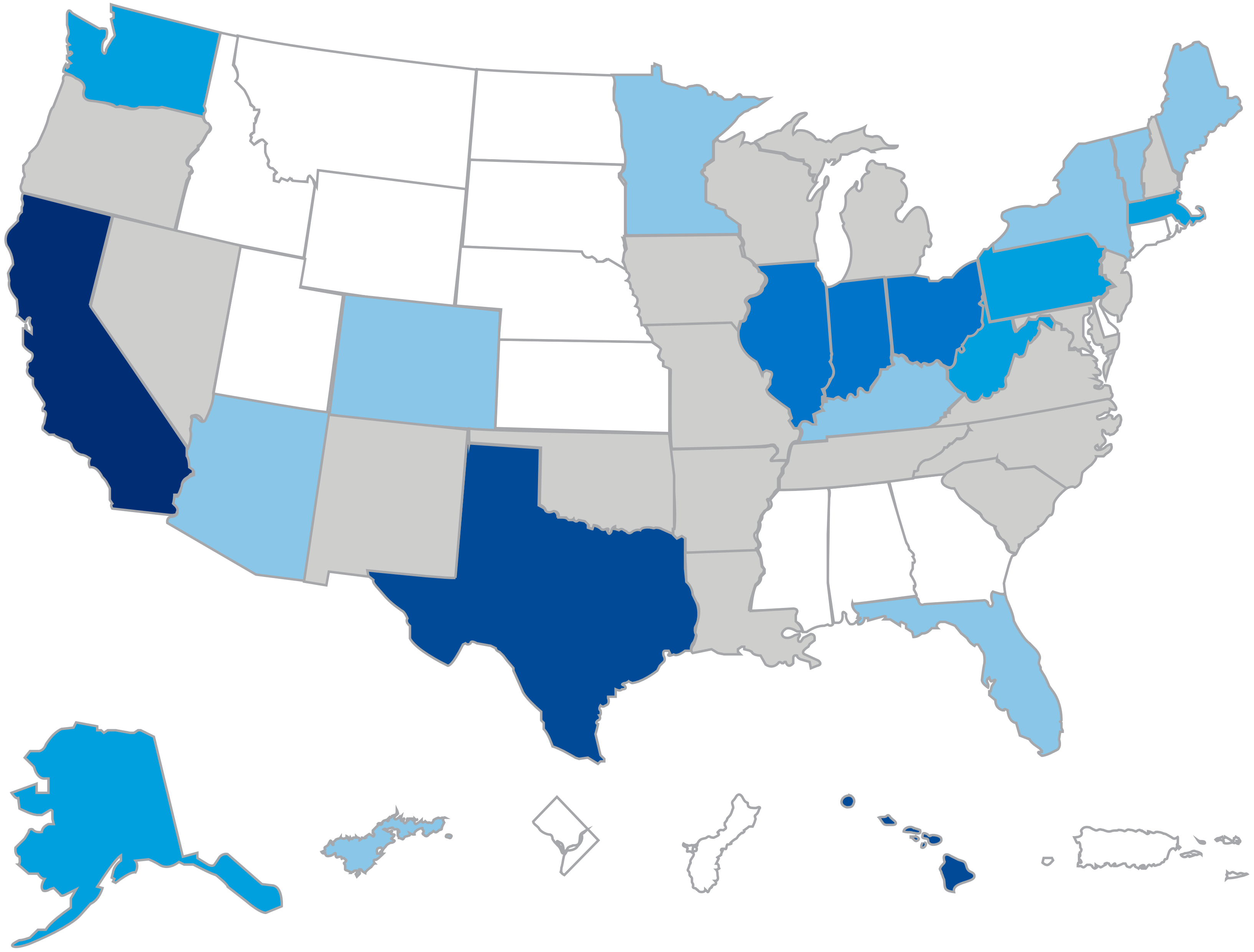

TABLE OF CONTENTS

Smart Electric Power Alliance

LIST OF TABLES

Smart Electric Power Alliance

LIST OF FIGURES

Smart Electric Power Alliance

ACKNOWLEDGMENTS

SEPA would like to recognize the following individuals for their support during SEPA's outreach process for the 2018 Utility Survey: Brad Rockwell with Kauai Island Utility Cooperative, Richard Benedict, Ted Ko with Stem, Nicholas Jewell with Louisville Gas and Electric & Kentucky Utilities, Jan Ahlen with National Rural Electric Cooperative Association, Ian Hoag with Pacificorp, Craig Ferreira and Josh Castonguay with Green Mountain Power, Alexandre Metz with Navigant, and John Lemire and Lisa Crawley with North Carolina Electric Membership Corporation.

We would like to acknowledge The Brattle Group, especially Ryan Hledik, Principal, Roger Lueken, Associate, and Cathy Wang, Research Analyst, for their contribution to the Wholesale Markets section (pg. 20-22) of this snapshot. The Brattle Group provides consulting services and expert testimony on economic, financial, regulatory, and strategic issues to corporations, law firms, and public agencies worldwide. Brattle's energy practice consists of approximately 90 consultants with expertise in a wide range of electric power issues across dozens of jurisdictions, including issues related to energy storage.

We would also like to thank the following SEPA staff for their assistance and review: Brenda Chew, Medha Surampudy, Erika Myers, K Kaufmann, Jared Leader, Tanuj Deora as well as Research Assistants David Golembeski and William Tedrick.

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ABOUT SEPA

SEPA facilitates collaboration across the electric power industry to enable the smart deployment and integration of clean energy resources. Our focus centers on solar, storage, demand response, electric vehicles, grid management, and other enabling technologies.

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About the Report

The Smart Electric Power Alliance (SEPA) began surveying electric utilities in 2007 to track the amount of solar power interconnected to the grid each year. Now in its 11th year, the survey, which was expanded two years ago, has collected two years of energy storage and demand response deployment data.

This 2018 Utility Energy Storage Market Snapshot summarizes 2017 energy storage deployment based on the data collected, supplemented with SEPA's updated trend analysis and insights that include market developments in the first half of 2018. The participating utilities represent slightly more than 82 million customer accounts, or approximately 56% of all customer accounts throughout the U.S.[1]

SURVEY METHODOLOGY AND SURVEY COVERAGE

SEPA conducted its annual Utility Survey between January and March 2018, using an online survey platform. 137 participating utilities[2] throughout the United States and its territories provided cumulative and 2017 deployment data on grid interconnected energy storage installations interconnected in their service territories prior to December 31, 2017. Only utilities with at least 500 customer accounts were considered for the watts-per-customer rankings.

SEPA encouraged participation through direct outreach to key energy storage contacts at utilities, and through partner organizations' listservs and newsletters. Utilities with service territories in multiple states reported data from each state separately. SEPA verified the accuracy of survey information through contacts at utilities, previous data submissions, and external sources.

For the purpose of this snapshot, energy storage installations include batteries, flow batteries, and kinetic energy storage (such as flywheels), supercapacitors, and compressed air energy storage. Our 2017 survey did not include pumped hydropower, thermal energy storage, and electric vehicles. SEPA has aggregated or supplemented survey data with additional information, including energy storage project data from S&P Global Market Intelligence, project data acquired through online research and through interviews with energy storage project developers and stakeholders.

Please note that recommissioned batteries are not counted as additional capacity. In addition energy storage systems deployed as uninterruptible power supply (UPS) are not counted as in SEPA's energy storage deployment figures. SEPA estimated each residential battery storage system as having 5 kilowatts (kW) and 10 kilowatt-hours (kWh) in instances utilities were unable to provide specific capacity and generation data for residential batteries.

For more information or questions, contact SEPA at research@sepapower.org.

1 U.S. Territories: Electric utility data from the U.S. territories Puerto Rico and Virgin Islands was not available to SEPA due to the territories' focus on infrastructure recovery as a result of the 2017 hurricane season.

2 See Appendix E for a full list of participants.

Executive Summary

NATIONAL MARKET OVERVIEW

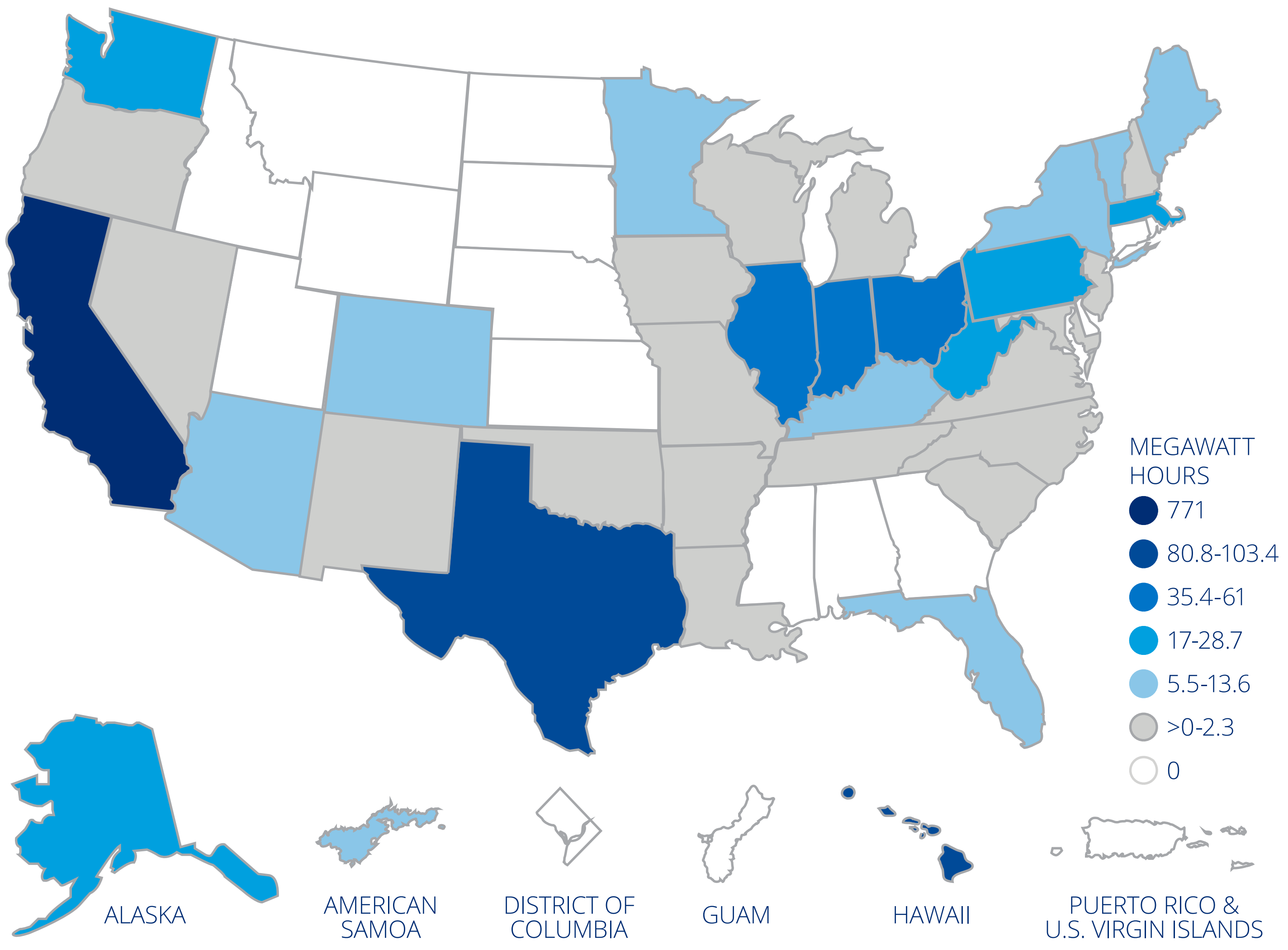
Energy storage has become simultaneously a disruptive force in the U.S. electric utility industry, and an exciting, nascent market as the many capabilities of this technology are piloted, and new incentives, programs and regulations are rolled out. The key driver here is the ability of energy storage to charge and discharge electricity —a first for the industry—providing benefits for customers and the grid (see page 11). 2017 saw prices falling and momentum building across all sectors:

- U.S. utilities interconnected 216.7 megawatts (MW), 523.9 MWh of energy storage to the grid across a total of 2,588 systems. By the end of the year, cumulative deployed energy storage nationwide had reached 922.8 MW, 1,293.6 MWh across 5,167 systems (see page 12).
- In 2017, residential accounted for 13.3 MW, 29.3 MWh; while non-residential added 59 MW, 139.7 MWh; and utility supply reported 144.4 MW, 354.9 MWh. In most instances, these figures represent significant year-over-year increases.

2016 TO 2017 ENERGY STORAGE GROWTH RATES BY SECTOR

	MW	MWH
RESIDENTIAL	202%	317%
NON-RESIDENTIAL	9%	105%
UTILITY-SUPPLY	-3%	89%
TOTAL	5%	104%

CUMULATIVE ENERGY STORAGE DEPLOYMENT (MWH)



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FERC ORDER 841

Earlier this year, the Federal Energy Regulatory Commission (FERC) issued Order 841, requiring grid operators across the country to establish market rules to allow energy storage to participate in wholesale markets (see page 20-22).

- The order provides opportunities for storage to sell capacity, energy, and ancillary services into wholesale markets.
- It also sets standards for dispatchability, project size—a minimum of 100 kilowatts (kW)—and pricing for wholesale energy used to charge a battery and then sold back into the grid.

STATE MANDATES, INCENTIVES AND INTEGRATED RESOURCE PLANNING

- In 2017, New Jersey was the only state to pass a new energy storage mandate—600 MW in three years and 2 gigawatts (GW) by 2030. Meanwhile, New York directed its public utility commission to set a target by the end of 2018, while Nevada regulators will first study the impacts of a storage mandate before deciding if they should set one (see page 16).
- Nevada has also ordered its public utility commission to establish energy storage incentives. A total of $5 million in incentives is planned (see page 16).
- Three states—Michigan, New Mexico and Washington—have issued specific regulatory guidance for utilities to consider energy storage in their integrated resource planning. About half of the utilities responding to SEPA's Utility Survey are now studying how to better integrate storage into their planning activities (see page 17).
- The Advancing Commonwealth Energy Storage (ACES) initiative in Massachusetts has provided $20 million in funding for 26 storage pilot projects (see pages 18-19).

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ENERGY STORAGE APPLICATIONS—MARKET TRENDS

Energy storage—in particular, electrochemical batteries, such as lithium-ion—are both fast and accurate when coupled with control systems, which means they can provide just about any service needed on the grid. Technical issues must be resolved, but a broad range of storage applications are now being tested:

- **Residential Storage:** SEPA found overwhelming interest in residential solar offerings and incentives among the utilities responding to its annual survey. For example, Green Mountain Power in Vermont has both an on-bill storage leasing program and a Bring Your Own Battery program that provides monthly bill credits to customers installing their own storage systems (see page 26).
- **Non-Residential Storage:** Storage used by commercial and industrial (C&I) customers to shave peak demand, and demand charges could be a huge market opportunity. This market encompasses not only new projects, but adding storage to existing solar or other renewable projects (see pages 27 - 28).
- **Stand-Alone Batteries:** Utilities have begun to install stand-alone battery storage as a grid asset, used, for example, for frequency response (Indianapolis Power & Light), peak shaving (San Diego Gas & Electric), or black start (Imperial Irrigation District, see pages 29 - 30).
- **Non-Wires Alternatives:** As utilities increasingly look to DERs for deferral of transmission and distribution upgrades. For example, a 2 MW, 8 MWh battery is allowing Arizona Public Service to avoid rebuilding 20 miles of distribution lines (see page 31).
- **Solar + Storage:** Solar plus storage projects are rapidly emerging across the U.S. as the costs decline and utilities leverage the capabilities these systems can offer. The Salt River Project is testing a solar plus storage project for smoothing out intermittent renewable generation, while the Kauai Island Utility Cooperative now has a solar plus storage system that provides fully dispatchable solar power (see pages 32-34).
- **Generation-Agnostic Storage**: Storage can also be combined with natural gas generation (Southern California Edison), hydro (AEP), and wind (NextEra and E.ON, see page 35).
- **Microgrids:** Storage is increasingly seen as a key component of microgrids being developed for on- or off-grid resilience. The devastation of Puerto Rico's electricity system in September 2017 has resulted in a number of microgrids being deployed to power critical community services, such as fire stations and health centers (see pages 36 - 37).
- **Aggregated Mobile Storage—EVs:** For utilities, EVs represent new load that could grow to 100 terawatt hours (TWh) by 2030. Managed charging and vehicle to grid (V2G) and vehicle to home (V2H) technologies could allow customers and utilities to leverage EV batteries to save money and provide grid services. Maui Electric's JUMPSmart pilot has successfully tested off-peak charging and V2H discharging (see pages 38-39).

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SEPA's Top 10 Utility Energy Storage Rankings

Each year, SEPA recognizes the U.S. utilities that interconnected the most new energy storage capacity in their service territories with two categories of top 10 awards: most energy storage megawatts and watts per customer. SEPA tracks four types of deployment metrics for energy storage—MW, MWh, watts per customer (W/C), and watt-hours per customer (Wh/C)—which are listed in Appendix B for both 2017 and cumulative.

TABLE 1: TOP 10 UTILITIES BY ANNUAL ENERGY STORAGE CAPACITY (MW)

1	SOUTHERN CALIFORNIA EDISON	California	56.2
2	SAN DIEGO GAS & ELECTRIC	California	45.3
3	TUCSON ELECTRIC POWER COMPANY	Arizona	21
4	PACIFIC GAS & ELECTRIC	California	16.4
5	KAUAI ISLAND UTILITY COOPERATIVE	Hawaii	13.7
6	NATIONAL GRID	Massachusetts	7
7	ARIZONA PUBLIC SERVICE	Arizona	4.2
8	GREEN MOUNTAIN POWER	Vermont	2.8
9	MAUI ELECTRIC	Hawaii	2.6
10	HAWAIIAN ELECTRIC	Hawaii	2.2

Source: Smart Electric Power Alliance, 2018.

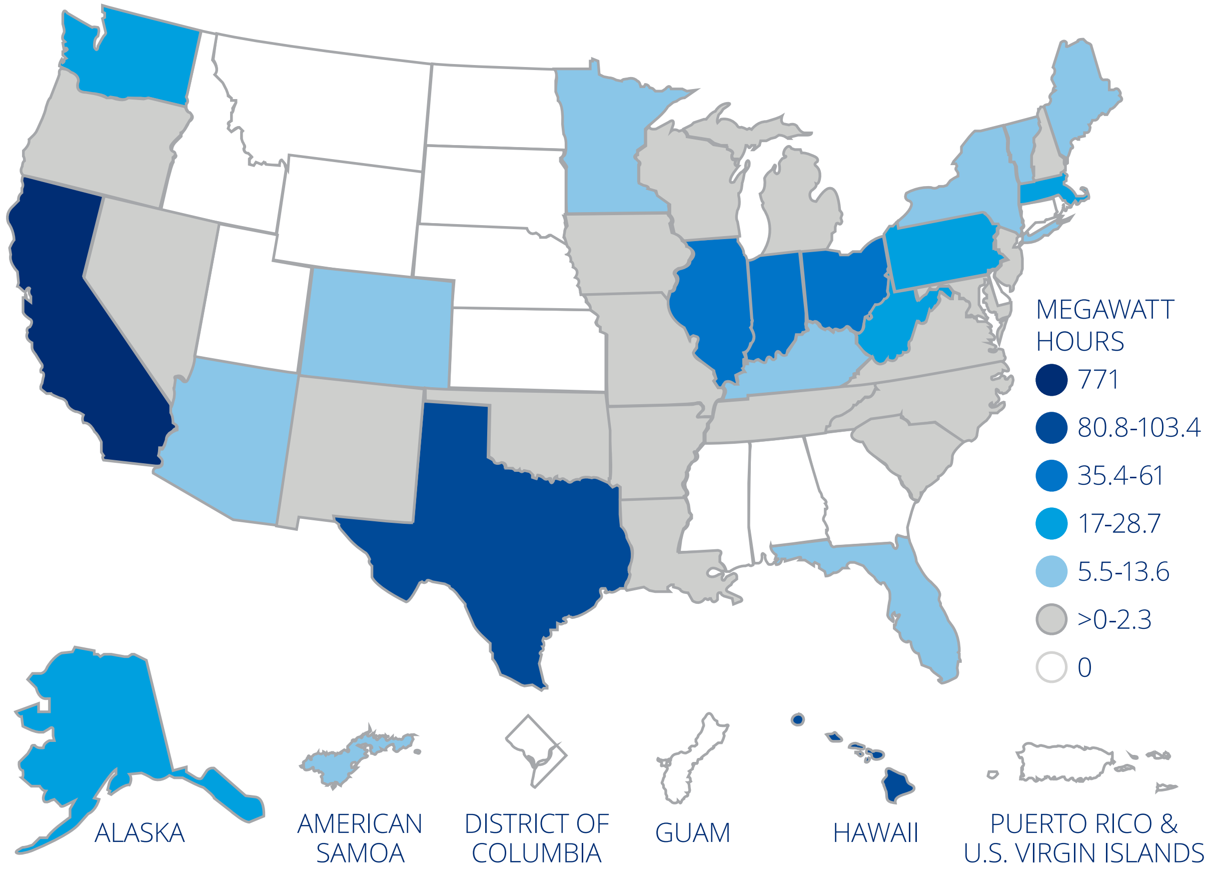
TABLE 2: TOP 10 UTILITIES BY ANNUAL ENERGY STORAGE WATTS PER CUSTOMER (W/C)

1	KAUAI ISLAND UTILITY COOPERATIVE	Hawaii	415.3
2	TUCSON ELECTRIC POWER COMPANY	Arizona	50
3	MAUI ELECTRIC	Hawaii	36.5
4	SAN DIEGO GAS & ELECTRIC	California	31.7
5	GLENDALE WATER & POWER	California	22.9
6	AMERICAN SAMOA POWER AUTHORITY	American Samoa	20.4
7	HAWAII ELECTRIC LIGHT COMPANY	Hawaii	16.4
8	SOUTHERN CALIFORNIA EDISON	California	11.1
9	GREEN MOUNTAIN POWER	Vermont	10.6
10	CITY UTILITIES OF SPRINGFIELD, MO	Missouri	8.8

Source: Smart Electric Power Alliance, 2018.

Market Overview

FIGURE 1: CUMULATIVE ENERGY STORAGE DEPLOYMENT (MWH)



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STATE OF THE INDUSTRY

Energy storage is becoming a disruptive technology as it can both consume and inject electricity to the grid—a first for the electric industry—providing benefits to customers and the grid. At a nascent stage today with just 922.8 MW/1,293.6 MWh installed across 5,167 systems, the grid-interconnected energy storage market holds great promise.

Energy storage technologies, particularly battery storage, offer a great deal of capabilities that allow this asset class to provide grid support, enhance currently existing generation, and provide resilience. Growth of this market is inevitable as the costs of technologies fall due to manufacturing economies of scale. Lithium-ion battery storage is the first storage technology to achieve economically competitive deployment in scaled applications, largely due to cost declines achieved from a ramp up of lithium-ion battery manufacturing to match the demand for electric vehicles.

Nationwide deployment of grid-connected energy storage is small, but localized markets are emerging. Their jump-start can be attributed to state-level policies such as procurement mandates, incentive programs, and in some cases, changes to net metering. Outside of these markets, storage is emerging in specific scenarios where conditions make it economically advantageous, for example, in Iowa where two commercial solar and storage projects were deployed.

The economic viability of battery energy storage is expanding to new use cases as costs continue their downward trajectory. On the grid, battery storage has been deployed as a stand-alone resource for grid support and capacity, paired with solar to make solar a fully dispatchable resource, deployed in a microgrid and integrated with generators to form hybrid power plants.

In short, the capabilities of energy storage are beginning to be tested in a wide range of applications and they are repeatedly providing value to the grid and customers.

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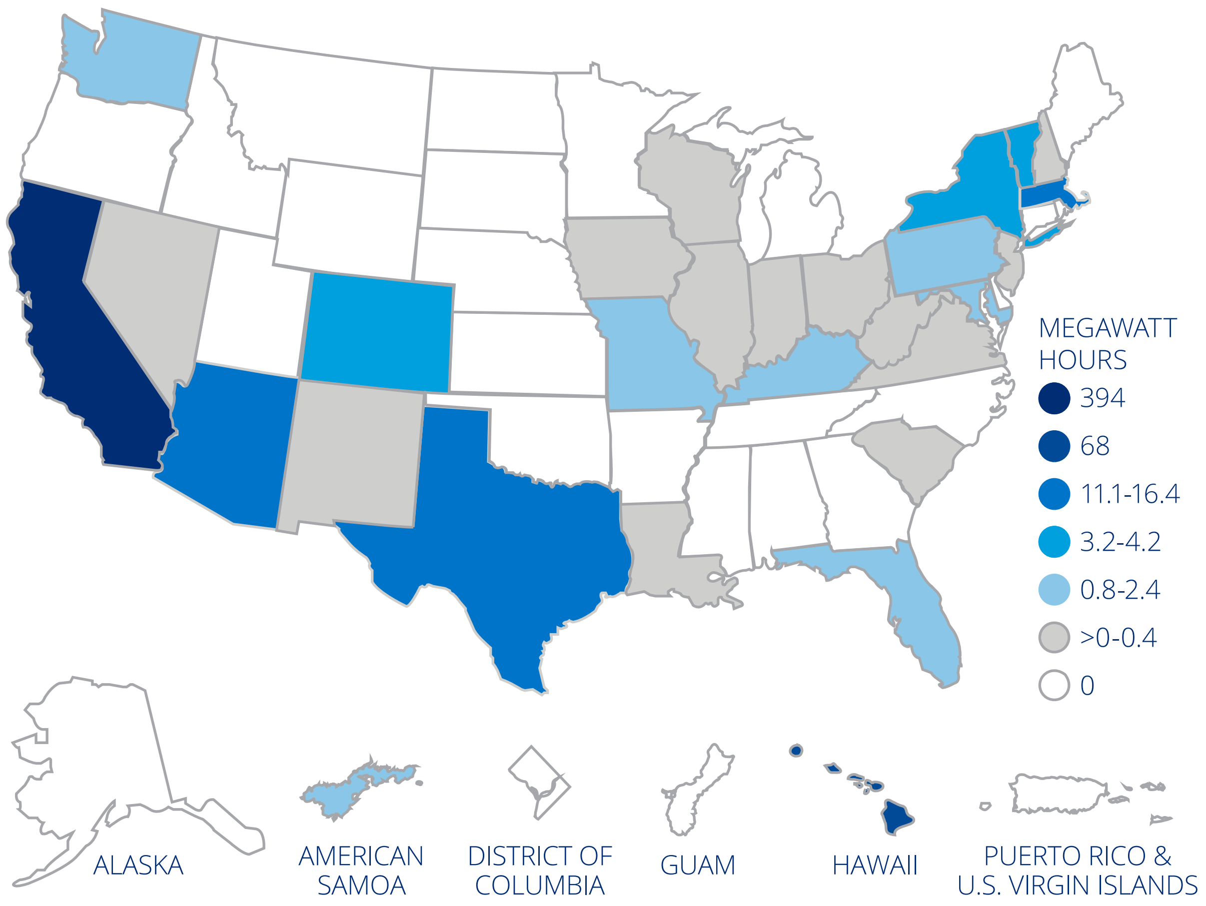
National Energy Storage Market

FIGURE 2: 2017 ENERGY STORAGE DEPLOYMENT (MWH)



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2017 DEPLOYMENT

- Utilities interconnected 216.7 MW, 523.9 MWh of energy storage to the grid, across a total of 2,588 systems. Total installed energy storage nationwide was 922.8 MW, 1,293.6 MWh across 5,167 systems.
- Residential deployment grew by more than 200% in terms of MW and more than 300% in terms of MWh. Non-residential deployment grew by more than 9% in terms of MW and 100% in terms of MWh. Finally, utility-supply deployed capacity dropped 3% in terms of MW but increased by almost 90% in terms of MWh.
- In 2017 residential deployments accounted for 13.3 MW, 29.3 MWh; non-residential accounted for 59 MW, 139.7 MWh; and utility-supply accounted for 144.4 MW, 354.9 MWh.

TABLE 3: 2016 TO 2017 ENERGY STORAGE GROWTH RATES BY SECTOR

	MW	MWH
RESIDENTIAL	202%	317%
NON-RESIDENTIAL	9%	105%
UTILITY-SUPPLY	-3%	89%
TOTAL	5%	104%

- States interconnecting the most energy storage in 2017 were California (120.2 MW, 393.6 MWh), Texas (32.1 MW, 16.4 MWh), and Arizona (25.5 MW, 11.1 MWh).
- Of the 137 utilities responding to our survey, 51 had at least one energy storage installation in their service territory as of the end of 2017. Nearly one quarter of those (10 utilities, 22%) deployed their first energy storage project in 2017.

RESIDENTIAL ENERGY STORAGE MARKET

FIGURE 3: RESIDENTIAL BATTERY CAPACITY BY STATE—2017 (MWH)

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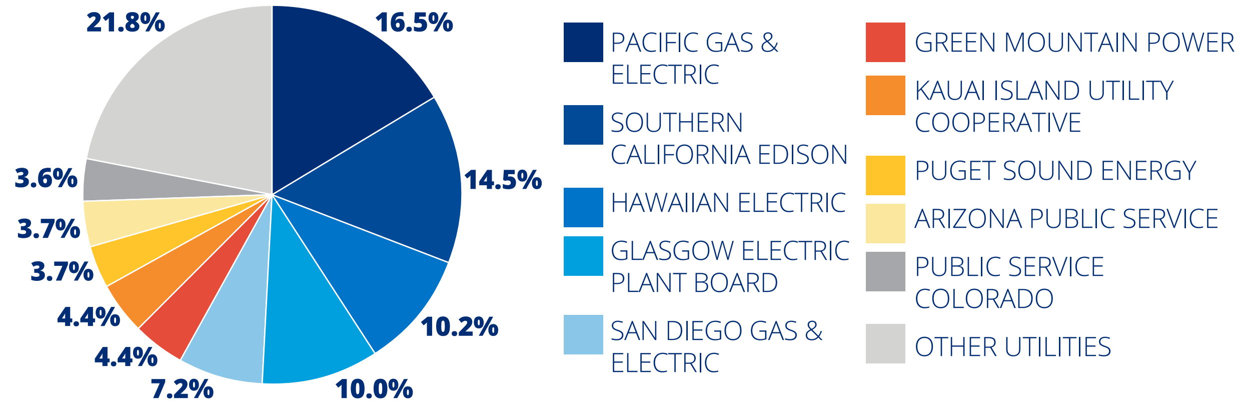
FIGURE 4: TOP UTILITIES BY CUMULATIVE PERCENTAGE OF RESIDENTIAL (MWH)



Source: Smart Electric Power Alliance, 2018.

TABLE 4: RESIDENTIAL BATTERY DEPLOYMENT BY UTILITY TYPE

	2017			CUMULATIVE		
	CAPACITY (MW)	ENERGY (MWH)	NO. OF SYSTEMS	CAPACITY (MW)	ENERGY (MWH)	NO. OF SYSTEMS
COOPERATIVE	0.9	2	206	1.3	3.1	290
INVESTOR OWNED	11.8	25.8	1,984	19.4	42.7	3,523
PUBLIC POWER	0.6	1.5	131	3	8.1	429
TOTAL	13.3	29.3	2,321	23.7	53.9	4,242

Source: Smart Electric Power Alliance, 2018.

- **Hawaii** saw significant growth in deployment of residential storage capacity from just under 0.3 MW in 2016 to 3.9 MW in 2017—a nearly 1,200% increase year over year. The increase in installations can be attributed to net metering changes that offered a self-consumption option, that drove deployment.
- **California** continues to lead the way when it comes to energy storage deployment. The number of residential systems interconnected in the state grew from 182 in 2016 to 1,211 in 2017, a 565.3% increase year over year. The capacity of those projects grew from 3.1 MWh in 2016 to 13.7 MWh in 2017, a 341.9% increase. This growth is the result of the state's Self-Generation Incentive Program (SGIP), which is further covered in Appendix C.

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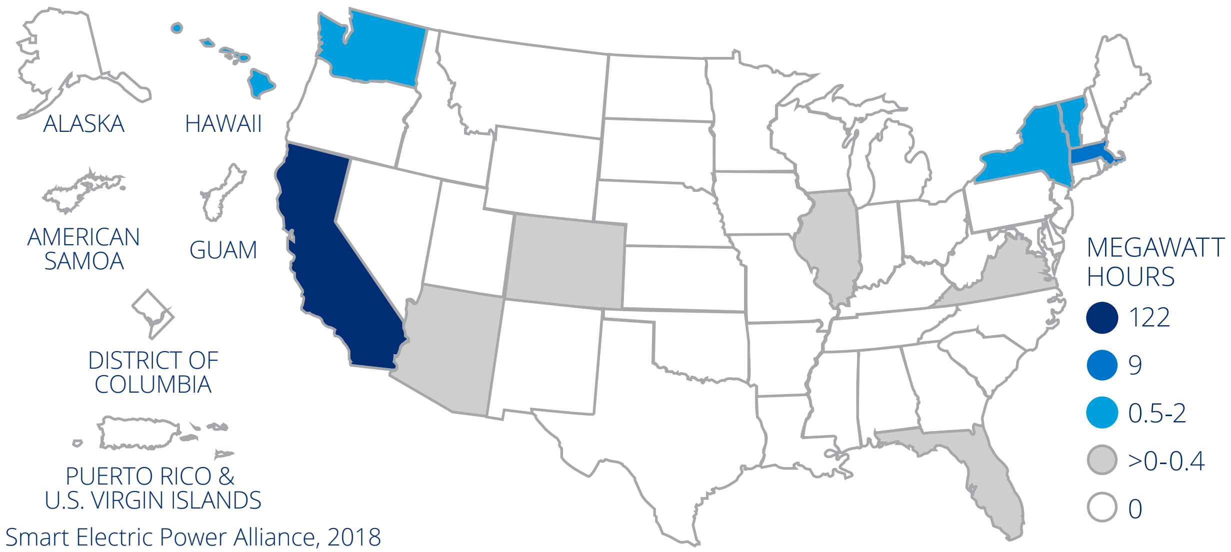
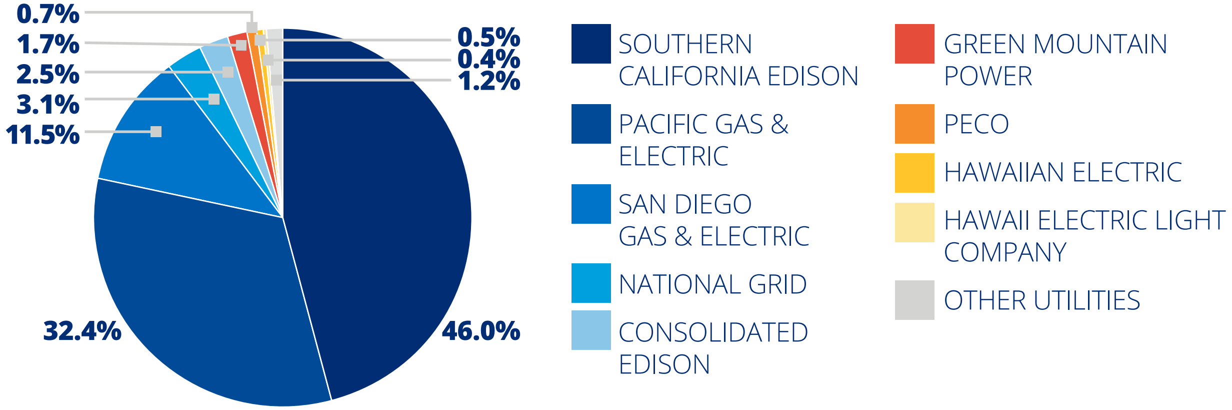
NON-RESIDENTIAL ENERGY STORAGE MARKET

FIGURE 5: NON-RESIDENTIAL BATTERY CAPACITY BY STATE—2017 (MWH)



Smart Electric Power Alliance, 2018

FIGURE 6: TOP UTILITIES BY CUMULATIVE PERCENTAGE OF NON-RESIDENTIAL (MWH)



Source: Smart Electric Power Alliance, 2018.

TABLE 5: NON-RESIDENTIAL BATTERY DEPLOYMENT BY UTILITY TYPE

	2017			CUMULATIVE		
	CAPACITY (MW)	ENERGY (MWH)	NO. OF SYSTEMS	CAPACITY (MW)	ENERGY (MWH)	NO. OF SYSTEMS
COOPERATIVE	0.01	0.01	1	0.04	0.04	2
INVESTOR OWNED	58.4	137.6	227	143.1	318.6	773
PUBLIC POWER	0.6	2.1	3	0.3	0.4	7
TOTAL	59.0	139.7	231	143.4	319.0	782

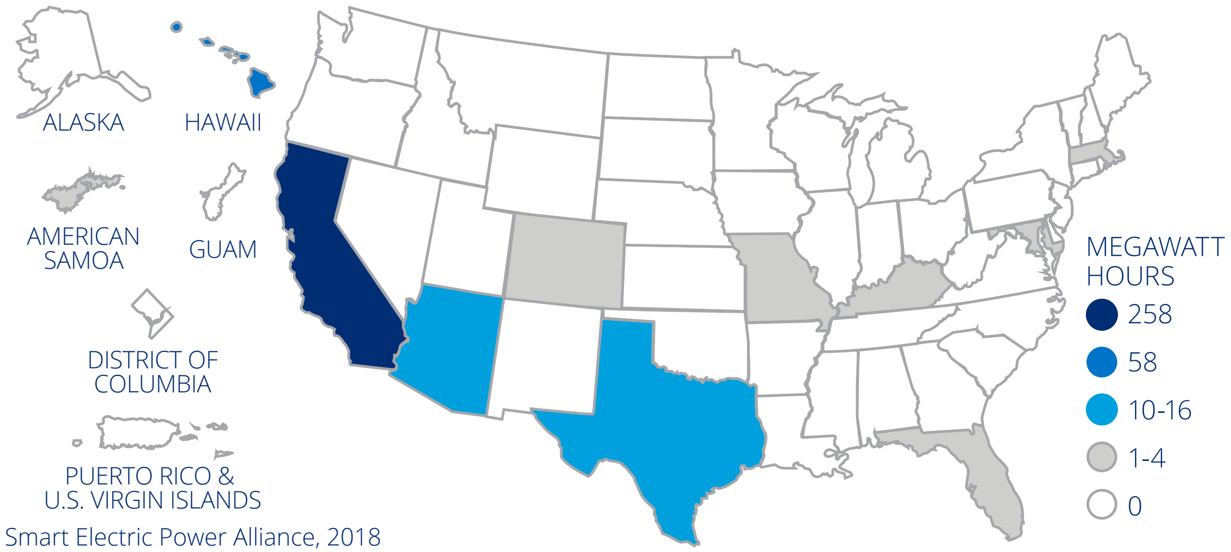
Source: Smart Electric Power Alliance, 2018.

Regions with the most growth in non-residential capacity:

- **California's** utilities interconnected 47.2 MW of non-residential storage last year, a 10% increase over 2016. The state continues to account for the vast majority of non-residential deployment, driven by favorable incentives within the Self-Generation Incentive Program (SGIP) and the storage mandate for the state's three IOU's.
- **Massachusetts** experienced the second highest increase in non-residential capacity between 2016 and 2017. Utilities deployed 9 MWh of non-residential storage in 2017, an increase of 1.1 MWh or 13.9% over 2016.
- **Vermont** and **Hawaii** rounded out the states with the most growth in non-residential capacity. Vermont deployed 1 MW in 2017 while Hawaii deployed 0.7 MW in 2017.

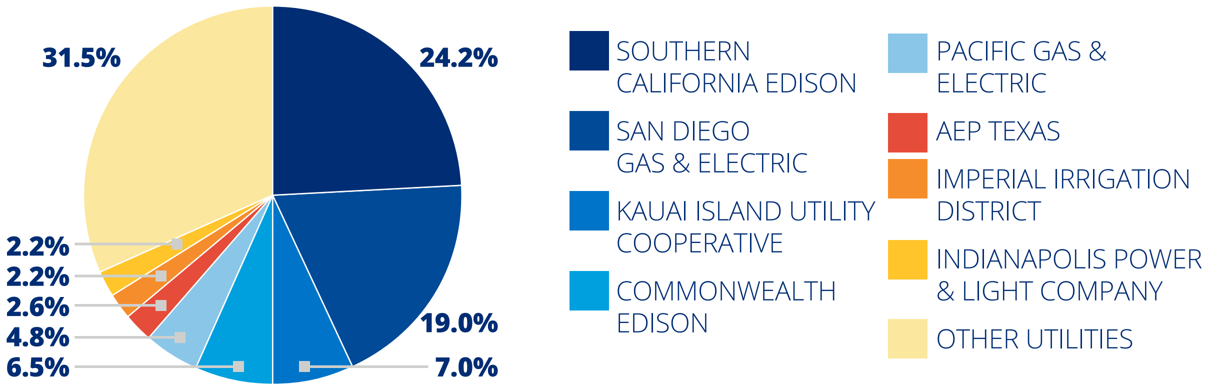
UTILITY-SUPPLY ENERGY STORAGE

FIGURE 7: UTILITY-SUPPLY CAPACITY DEPLOYED BY STATE—2017 (MWH)



Smart Electric Power Alliance, 2018

FIGURE 8: TOP UTILITIES BY CUMULATIVE PERCENTAGE OF UTILITY-SUPPLY (MWH)



Source: Smart Electric Power Alliance, 2018.

TABLE 6: UTILITY-SUPPLY ENERGY STORAGE DEPLOYMENT BY UTILITY TYPE

	2017			CUMULATIVE		
	CAPACITY (MW)	ENERGY (MWH)	NO. OF SYSTEMS	CAPACITY (MW)	ENERGY (MWH)	NO. OF SYSTEMS
COOPERATIVE	13.0	57.1	1	58.1	73.6	10
INVESTOR OWNED	126.0	292.6	27	601.2	779.0	111
PUBLIC POWER	5.4	5.2	8	71.5	53.9	21
TRANSMISSION	0	0	0	25	14.2	1
TOTAL	144.4	354.9	36	755.8	920.7	143

Source: Smart Electric Power Alliance, 2018.

- The majority of deployments of utility-supply energy storage in 2017 were interconnected in **California**, driven by the Aliso Canyon procurements and the California IOUs' specific targets for energy storage procurement.
- A single 2 MW, 8 MWh vanadium redox flow battery was commissioned in California by San Diego Gas & Electric as a four-year demonstration project to determine if flow battery technology can adequately provide voltage frequency, power support, and shift energy demand.[3]
- Batteries are being retroactively co-located with wind farms in **Texas**. These batteries, listed on page 35, accounted for 32 MW of battery storage capacity—22.2% of all utility-supply capacity deployed in 2017.

TABLE 7: 2017 UTILITY SUPPLY BY STATE (MW AND MWH)

STATE	TOTAL MW	TOTAL MWH
CALIFORNIA	66.1	258.2
TEXAS	32	16
ARIZONA	25	10
HAWAII	15	57.5

3 "SDG&E Spurs Energy Storage Innovation with Flow Battery Technology." San Diego Gas & Electric, 2017. https://www.prnewswire.com/news-releases/sdge-spurs-energy-storage-innovation-with-flow-battery-technology-300425175.html

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Energy Storage Policy Update

The energy storage market remains policy dependent, just as the solar energy market was a decade ago. A few states have implemented energy storage mandates and incentive programs through legislation. Below is a map, which indicates the states that have such policies. Policy updates that have occured since the publication of SEPA's last Energy Storage snapshot are detailed. Please see Appendix D for a complete table of state energy storage mandates and incentives.

FIGURE 9: ENERGY STORAGE COMMITMENTS AND INCENTIVES BY STATE

NEVADA

SB 204: In 2017, Nevada state legislators directed state regulators to study the cost effectiveness of an energy storage mandate for the state's utilities by Oct. 1, 2018. If a study proves that energy storage is a cost-effective improvement, the Nevada Public Utilities Commission will begin the process of implementing a biennial energy storage procurement target.

SB 145: Signed into law in 2017, mandates Nevada's Public Utilities Commission (PUC) to establish energy storage incentives under the Solar Energy Systems Incentives Program. The state's total energy storage incentives paid out by utilities is broken into two sub-categories each totaling $5 million. One category targets residential and small commercial customers while the other identifies systems between 100 kW and 1 MW. The Nevada PUC is currently working with stakeholders and is expected to implement the new incentive program later this year.

Source: Smart Electric Power Alliance, 2018.

NEW YORK

AB 6571: At the end of 2017, AB 6571 was signed into law. It directs the state PSC to investigate and set an energy storage target for 2030. The PSC is expected to implement the target by the end of 2018. Once set, New York State Energy Research and Development Authority (NYSERDA) and Long Island Power Authority (LIPA) will spearhead a deployment program that focuses on both customer-sited and front-of-the-meter storage.

NEW JERSEY

A3723: Signed into law on May 23 2018, bill A3723 calls for 600 MW of energy storage capacity in the state within three years and 2 GW of capacity by 2030. Additionally, the bill requires that the New Jersey Public Utilities Board analyze the potential costs and benefits of further energy storage investment, focusing on storage to provide backup power, offset peak load, and promote the use of electric vehicles in the state.

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ENERGY STORAGE IN INTEGRATED RESOURCE PLANNING (IRP)

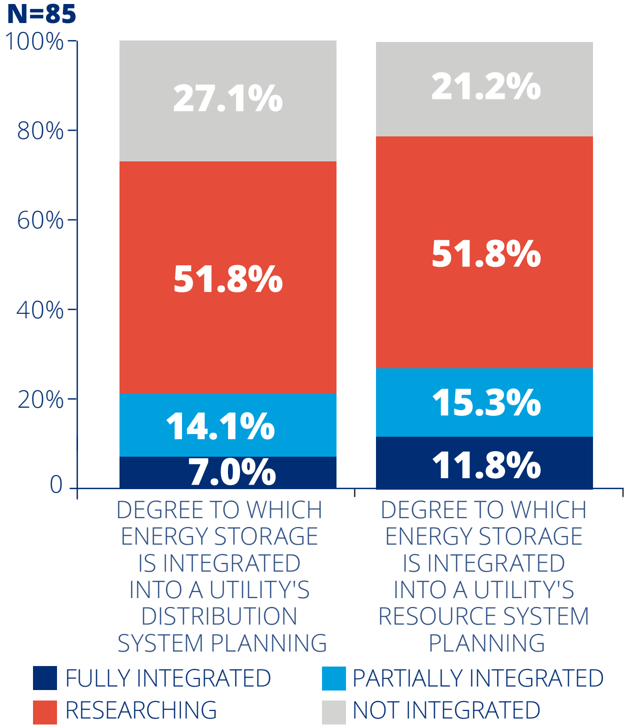
The role of energy storage, particularly battery storage, is increasingly considered in integrated resource planning. Individual utilities have altered the technologies considered in their planning to include energy storage while states have also issued specific regulatory guidance for utilities to consider energy storage in their IRPs.

UTILITY ACTIVITY

Hawaiian Electric Company: In August 2017, Hawaiian Electric Companies (HECO) released an updated grid modernization plan, projecting 89 MWh of customer sited storage by 2021 and 1,057 MWh by 2045. 104 MWh of demand response energy storage is expected to be integrated by 2021.[4]

Tucson Electric Power: In their 2017 IRP, TEP declared their aim to have renewable resources play an increasingly prominent role in their resource portfolio. TEP views energy storage as an increasingly cost-effective method to balance the grid, providing frequency response, regulation, and voltage support. By 2031, TEP expects to have 100 MWs of energy storage capacity online.[5]

FIGURE 10: UTILITY INTEREST IN ENERGY STORAGE FOR DISTRIBUTION AND RESOURCE SYSTEM PLANNING



Source: Smart Electric Power Alliance, 2018.

TABLE 8: INTEGRATED RESOURCE PLANNING CHANGES BY STATE

WASHINGTON	In late 2017, Washington State Utilities and Transportation Commission issued a policy statement to provide regulatory guidance on integrating energy storage into the IRP process. It directs the Washington IOUs to improve their planning models by adopting sub-hourly planning and integrating competitive bidding processes for storage acquisitions.[6]
NEW MEXICO	In 2017, the New Mexico Public Regulation Commission amended the state's 2017 IRP rules to include energy storage. In addition to creating a distinct section for energy storage separating it from demand response, the amendment directs New Mexico IOUs to evaluate all feasible supply-side and demand-side resources on a comparable and consistent basis.[7]
MICHIGAN	A law that mandates the state's IOUs to submit IRPs went into effect in April, 2017. Parameters set forth ensure that utilities will take into account distributed resources such as batteries and EV's when modeling for load curves and future demands.[8]
ARIZONA	Earlier this year the Arizona Corporation Commission (ACC) rejected Arizona IOU IRPs, placed a moratorium on natural gas plants larger than 150 MWs through years-end 2018[9] and encouraged greater consideration of renewables and storage in the place of a heavy reliance on natural gas.[10]

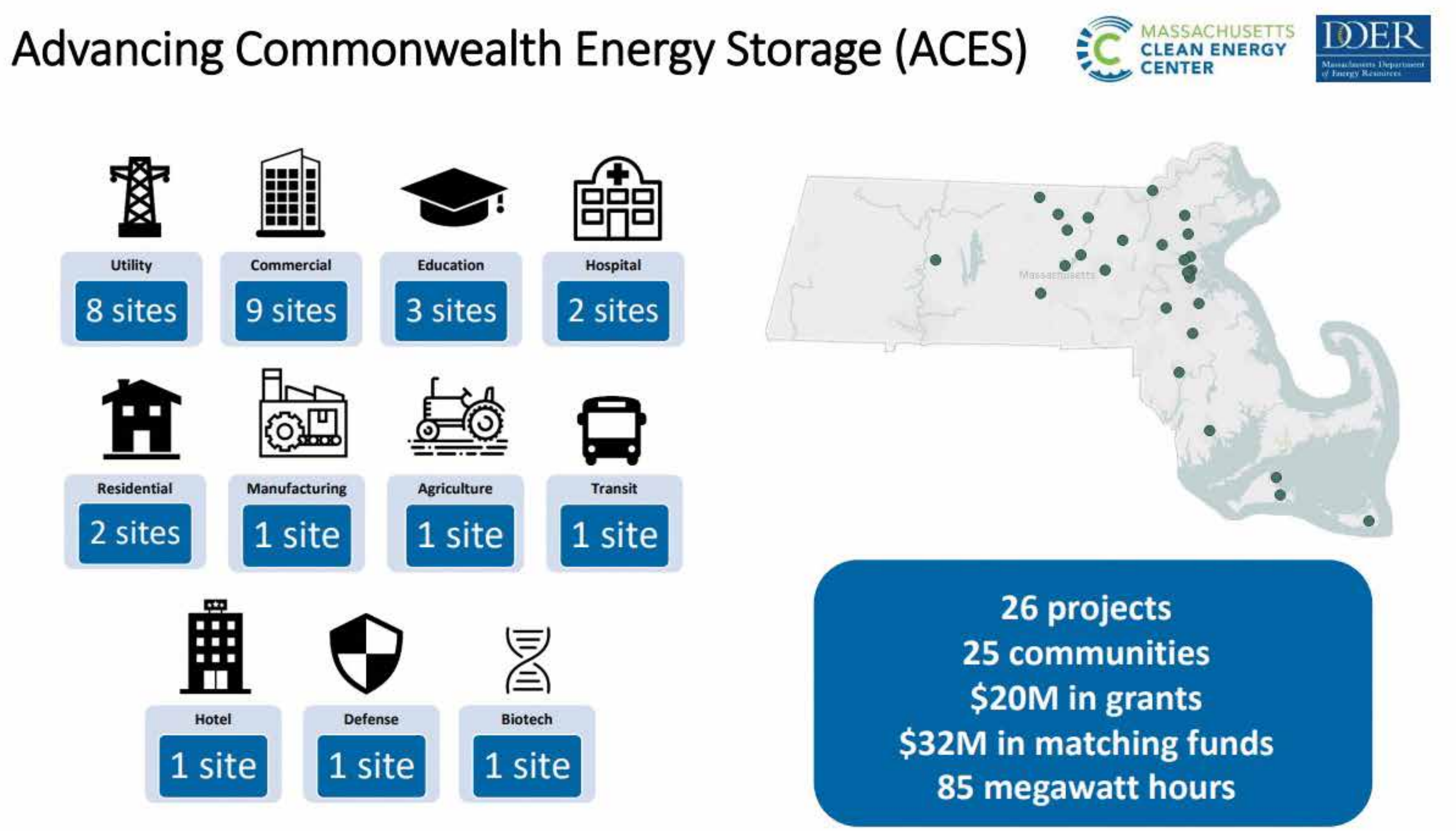
4 "Modernizing Hawaii's Grid For Our Customers." Hawaiian Electric Company, 2017 https://www.hawaiianelectric.com/Documents/about_us/investing_in_the_future/final_august_2017_grid_modernization_strategy.pdf
5 "Integrated Resource Plan." Tucson Electric Power, 2017 https://www.tep.com/wp-content/uploads/2016/04/TEP-2017-Integrated-Resource-FINAL-Low-Resolution.pdf
6 "Washington utilities need to consider storage in resource planning, regulators say." Utility Dive, 2017 https://www.utilitydive.com/news/washington-utilities-need-to-consider-storage-in-resource-planning-regulat/507177/
7 "Commission Unanimously Approves Amending Rule to Include Energy Storage." New Mexico Public Regualtion Commission, 2017 http://www.nmprc.state.nm.us/rssfeedfiles/pressreleases/2017-8-8CommissionUnanimouslyApprovesAmendingRuleToIncludeEnergyStorage.pdf
8 "Michigan Integrated Resource Planning Parameters" Michigan https://www.michigan.gov/documents/mpsc/11-21-2017_MIRPP_Final_606706_7.pdf
9 Docket No. E-00000V-15-0094. Arizona Corporation Commission, 2018 http://images.edocket.azcc.gov/docketpdf/0000186484.pdf
10 "Arizona regulators move to place gas plant moratorium on utilities." Utility Dive, 2018 https://www.utilitydive.com/news/arizona-regulators-move-to-place-gas-plant-moratorium-on-utilities/519176/

POLICY IN ACTION—MASSACHUSETTS—ADVANCING COMMONWEALTH ENERGY STORAGE

The Massachusetts Energy Storage Initiative was launched by the governor in May 2015 with the goal of establishing a local energy storage industry. Advancing Commonwealth Energy Storage (ACES)[11] is a collaborative demonstration program between the Massachusetts Department of Energy and Resources and the Massachusetts Clean Energy Center. The program has offered grants to projects that are testing a wide variety of energy storage applications and business models. In total, the ACES program has issued $20 million in cost-share grant funding for a diverse array of 26 demonstration projects,[12] accounting for 32 MW, 81 MWh. These projects were determined to have the best opportunity to increase commercialization and deployment of energy storage technologies.

The novel concepts being tested are an investment in the energy storage industry and worth paying attention to as their potential success may be replicable across the country. A few categories of project models being explored are listed with brief descriptions of projects that have received funding.

FIGURE 11: ADVANCING COMMONWEALTH ENERGY STORAGE (ACES) PROGRAM



Source: Massachusetts Clean Energy Center, 2018.

11 "Advancing Commonwealth Energy Storage (ACES)." Massachusetts Clean Energy Center http://www.masscec.com/advancing-commonwealth-energy-storage-aces

12 A PDF with a list and description of all 26 projects: http://files.masscec.com/Simplified%20Projects%20Summary_3.pdf

POLICY IN ACTION—MASSACHUSETTS—ADVANCING COMMONWEALTH ENERGY STORAGE, CONTINUED

NEW BUSINESS MODELS

- A solar plus storage system on a big box retailer, where an active demand management system will reduce peak load and provide seasonal dispatchable peak demand management.
- A battery co-located with existing solar PV is testing a "between-the-meter" PPA which could be a viable model for combining a community solar subscription with personal ownership of a behind-the-meter battery storage system.

BEHIND THE METER: RESIDENTIAL—DISPATCHABLE

- An aggregated system of 500 Powerwalls in Nantucket residences will be collectively called upon during peak times to assist in the deferral of a third undersea cable. These systems will also provide cost reductions and backup power to residents.
- 200 aggregated battery storage systems are being paired with solar in National Grid's service territory. The projects will demonstrate net metering time of use, be dispatched to respond to local grid needs, and provide backup power to the residents.

RESILIENCE

- 16 flywheels will be co-located with a solar PV facility in West Boylston Municipal Light and Power territory. The flywheels will be providing peak load reduction, energy arbitrage, and will enable the municipal utility to maintain minimal power services for a nearby prison during a power outage.

NEW CONSTRUCTION

- Ice storage co-located with a solar PV system at General Electric's new headquarters near Fort Point. The system being drawn into the design for the building will require a much smaller HVAC system than if the storage system was retrofitted.
- Tesla will deploy a ~1 MW, 4.2 MWh battery with a solar PV system at the Wynn Boston Harbor resort, which is under construction. The system will be integrated into the construction plans and may serve as a model for those planning large-footprint developments.

ALLEVIATING SOLAR SATURATION

- A solar plus storage system in Martha's Vineyard, which would not be able to interconnect without the storage system, will provide solar smoothing to reduce voltage flicker on its saturated feeder.
- A municipal utility will deploy a 2MW, 4 MWh battery to enable solar to interconnect to the system, which is oversaturated and no longer accepting interconnections. In addition to opening behind-the-meter solar interconnections again, 200 kW of wind will also be interconnected.

Wholesale Markets

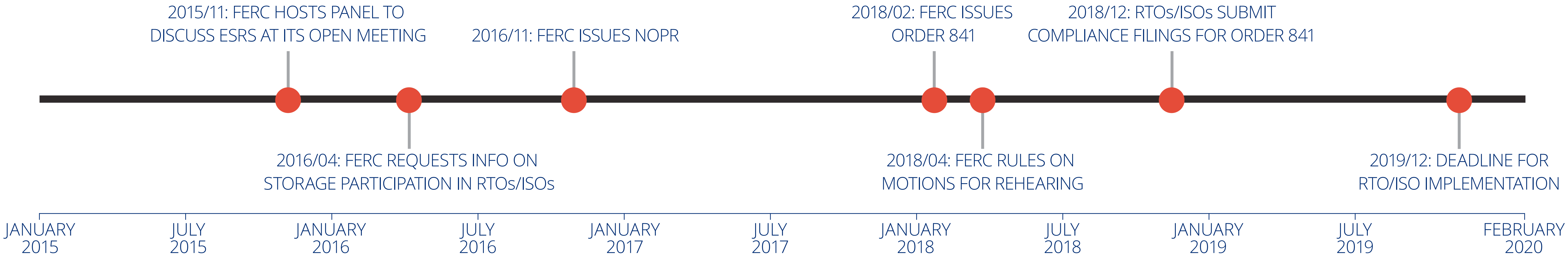
OVERVIEW OF FERC ORDER 841

PURPOSE AND SUMMARY OF REQUIREMENTS

FERC Order 841 directs RTOs/ISOs to establish a participation model consisting of market rules that, recognizing the physical and operational characteristics of electric storage resources (ESRs), facilitates their participation in the regional transmission organization (RTO) and independent system operator (ISO) markets.

The participation model must:

- Ensure that a resource using the participation model is eligible to provide **all capacity, energy, and ancillary services** that the resource is technically capable of providing in the RTOs/ISOs
- Ensure that a resource using the participation model can be **dispatched** and can set the **wholesale market clearing price**
- Account for the **physical and operational characteristics** of electric storage resources through bidding parameters or other means
- Establish a **minimum size requirement** for participation in the RTO/ISO markets that does not exceed 100 kW
- Each RTO/ISO must specify that the sale of electric energy from the RTO/ISO markets to an electric storage resource that the resource then resells back to those markets must be at the wholesale **locational marginal price**



Sources and Notes: FERC Docket Nos. RM16-23-000; AD16-20-000. NOPR refers to the Notice of Public Rulemaking

RESPONSES TO THE ORDER

A wide range of stakeholders filed comments in March 2018 pursuant to the publication of FERC Order 841. While many respondents were supportive of lowering participation barriers for Electric Storage Resources (ESRs), others identified areas for clarification or rehearing of the order.

IN SUPPORT

- **Improved market access.** Facilitates participation in RTO markets by requiring RTOs to improve market access, e.g. by clarifying existing rules, allowing storage resources to de-rate capacity to meet minimum run-time requirements.
- **Maximizing competition from all resources.** Including full participation of ESRs increases competition and supports just and reasonable rates.
- **Improved system flexibility.** Expanding participation of energy storage in wholesale markets allows consumers to capitalize on its inherent flexibility, both in operations and siting, creating value both on wholesale and retail markets.
- **Improved access for distributed energy resources (DERs) in wholesale markets.** Improves market access for small resources through 100-kW minimum size requirement.

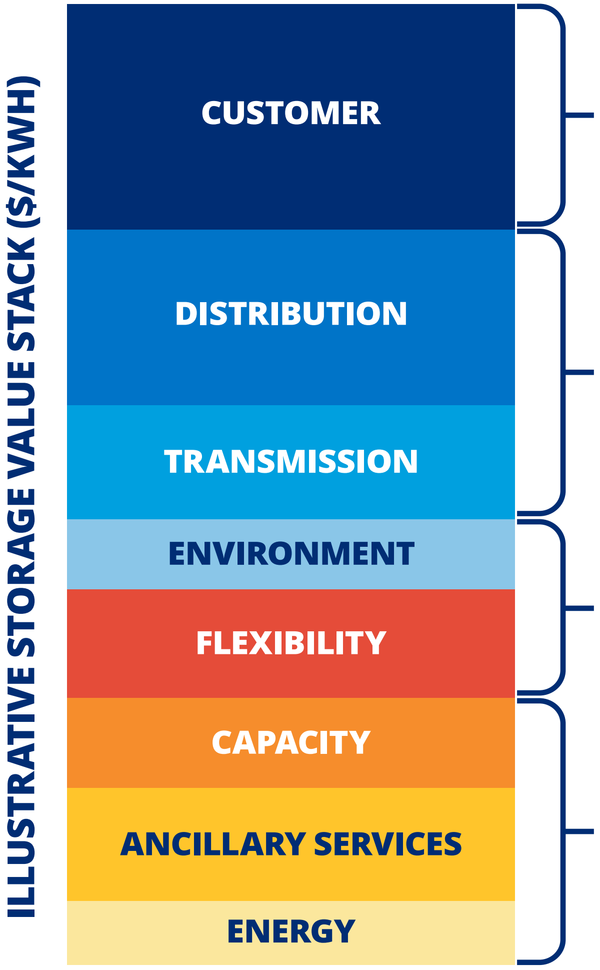
CONCERNS/REQUESTS FOR REHEARING

- **Federal and state jurisdictional authority.** Concerns that the order's requirements for distributed-connected storage should not conflict with state jurisdictional authority over distribution systems.
- **Opt-out provision.** FERC did not adopt an opt-out provision that would allow state and local regulators to bar ESRs in their jurisdiction from participating in wholesale markets.
- **100-kW minimum size threshold.** Concerns that a 100-kW minimum size threshold requirement could add administrative, reliability, and cost issues.
- **Accommodation of DERs.** Concerns that the order's implementation deadline does not accommodate DER issues that are still ongoing at the FERC.
- **Participation in both wholesale and retail markets.** Concerns that ESRs will resell retail energy purchases into the wholesale markets.
- **Metering requirements for behind-the-meter storage.** Concerns that dual participation in wholesale and retail markets may create metering challenges.

Sources and Notes: FERC Docket Nos. RM16-23-000; AD16-20-000

ORDER 841 AND THE STORAGE VALUE STACK

FIGURE 12: STORAGE VALUE STACK IMPACTED BY FERC ORDER 841



Source: The Brattle Group, 2018.

Maximizing the potential of energy storage requires capturing multiple value streams across the customer supply chain. Order 841 affects a subset of those value streams that are transacted on wholesale markets.

END-USE CUSTOMER VALUE (NOT AFFECTED BY ORDER 841)

- Increased customer reliability by reducing exposure to outages on the distribution system
- Increased customer engagement in their energy procurement decisions
- Retail bill savings through reduced demand charges and arbitrage of time of use rates[13]

UTILITY INFRASTRUCTURE VALUE (NOT AFFECTED BY ORDER 841)

- Deferred or avoided investments in distribution and transmission infrastructure by targeted storage siting

EMERGING WHOLESALE MARKET VALUES (AFFECTED BY ORDER 841)

- Participation in new, innovative wholesale market products to increase system flexibility
- Storage may be able to capitalize on emerging clean-energy products

TRADITIONAL WHOLESALE MARKET VALUE (AFFECTED BY ORDER 841)

- RTOs required to allow storage to participate in all market products they are technically capable of providing
- Storage well-suited to provide some products, e.g. high-quality ancillary services
- RTOs required to compensate storage fairly for providing all services, e.g., by derating capacity on capacity markets

13 These are potentially duplicative with other wholesale values.

Energy Storage Market Trends

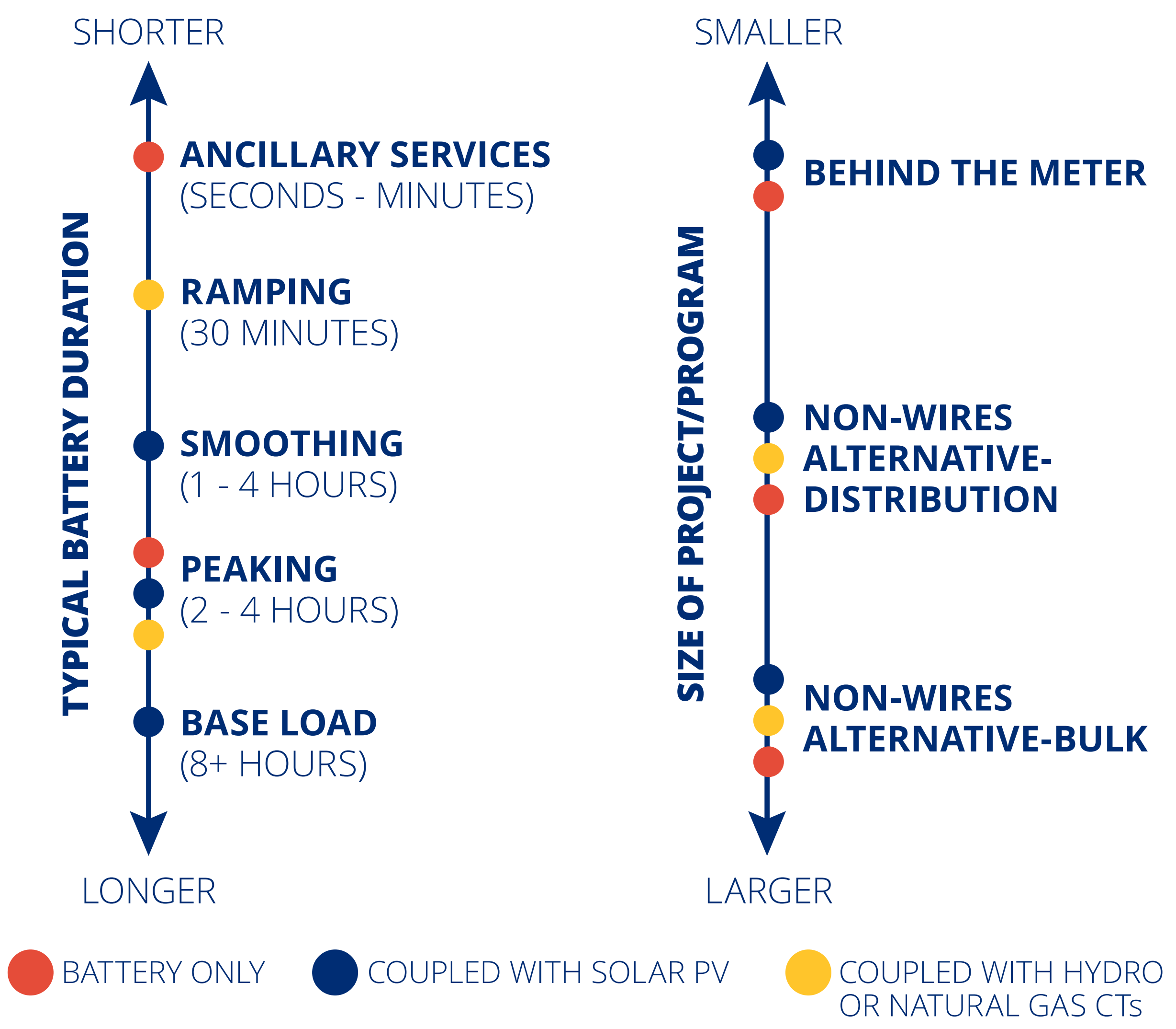
APPLICABILITY OF ENERGY STORAGE CAPABILITIES

The energy storage market is a rapidly evolving segment of the electricity sector. Storage technologies are being deployed in demonstration projects across a wide range of applications. Early stage markets are being animated by local incentives. A few projects in specific circumstances are being deployed that require no incentives to be financially viable.

Battery storage in particular has been equated to a "Swiss Army knife"[14] due to its broad set of capabilities. While these capabilities have been demonstrated, the energy storage industry is still in its early days: deployment is less than 1 GW as of 2017 and price declines due to economies of scale remain around the corner for the majority of storage technologies.

Despite being a newly emerging market, energy storage is set to play a rapidly expanding role in the electricity sector. As the price of battery storage technologies continues to decline, more of the capabilities of energy storage—as shown in Figure 13—become economically viable.

FIGURE 13: TYPICAL APPLICATIONS OF ENERGY STORAGE



Source: Smart Electric Power Alliance, 2018

14 "Electric Storage Participation in Markets Operated by RTOs and ISOs." FERC, 2018 https://www.ferc.gov/media/statements-speeches/lafleur/2018/02-15-18-lafleur-E-1.asp#.W1dl0dJKiUI

Smart Electric Power Alliance

DECLINING ENERGY STORAGE PRICES

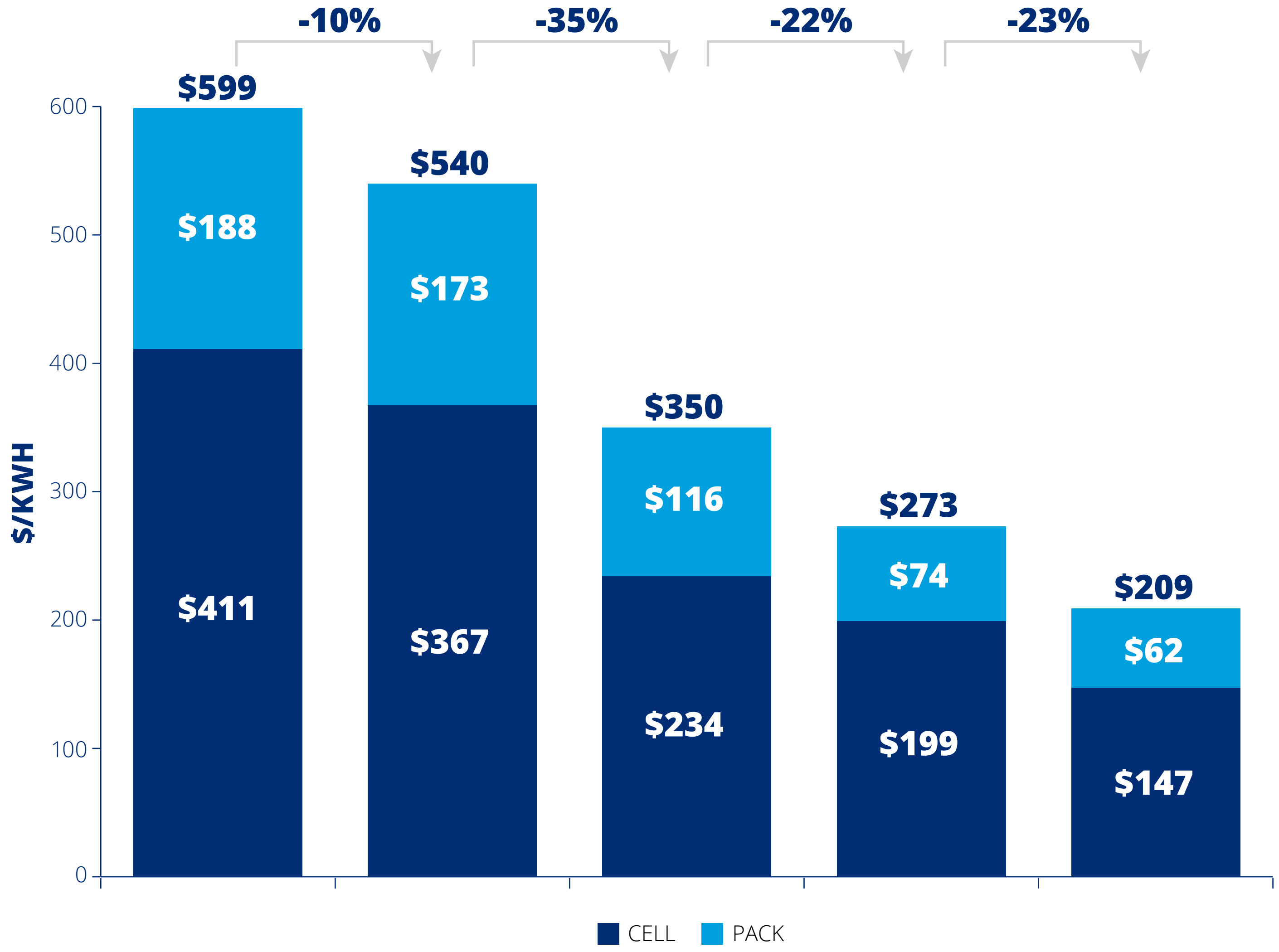
Lithium-ion battery prices, as shown in Figure 14, have declined by more than 20% annually over the past three years. The data collected from this survey aggregates battery prices within electric vehicles, e-buses, and stationary energy storage systems.[15]

With applications in telephones, computers, and electric vehicles, lithium-ion batteries have seen a drop in costs as a result of expanded research and funding.

The cost of these battery packs will continue to decline as lithium-ion battery production scales up to match the demand for electric vehicles. As a result, this storage technology is the first to achieve economies of scale, which is why lithium-ion accounts for the vast majority of stationary energy storage projects deployed globally.

There are a number of other energy storage technologies with capabilities that align with the needs of the electric grid and demand for stationary storage will continue to evolve.

FIGURE 14: LITHIUM-ION BATTERY PRICES



Source: Bloomberg New Energy Finance, 2018

15 It is important to note that automakers tend to order GWh of batteries and therefore receive more favorable pricing compared to energy storage providers, who are often placing orders for volumes that are an order of magnitude smaller.

CAPABILITY TESTING: TEST SITES IN KENTUCKY AND FLORIDA

The diversity of energy storage applications is due to the capabilities of the asset class, as shown in the figure below. Electrochemical battery systems, in particular, are both fast and accurate when coupled with control systems, which means they can provide just about any service needed on the grid. Despite the promise of the technology, many issues have yet to be resolved, which is why ongoing research is essential at this stage.

FIGURE 15: SOLAR AND ENERGY STORAGE CAPABILITIES MATRIX

TECHNOLOGIES	ENERGY	GENERATING CAPACITY	DISTRIBUTION CAPACITY	VOLTAGE REGULATION	FREQUENCY REGULATION	LOAD FOLLOWING	BALANCING	SPINNING RESERVES	NON-SPINNING RESERVES	BLACK START
DISTRIBUTED SOLAR	Energy Generator	◐	◐	○	○	○	○	No	No	No
DISTRIBUTED SOLAR + ADVANCED INVERTER FUNCTIONALITY	Energy Generator	◐	◐	●	●	◐	○	No	No	No
BATTERY STORAGE	Energy Storage	●	●	●	●	●	●	Yes	Yes	Yes
SOLAR + BATTERY STORAGE	Dispatchable Generation	●	●	●	●	●	●	Yes	Yes	Yes

○ Unsuitable for reliably performing the specified service.
◐ May be able to perform a service, but is not well suited or can provide partial support.
◑ Able to perform a service, but may be limited by factors such as availability or customer behavior.
● Well suited to perform a service; may exceed legacy technologies for providing the service.

Source: SEPA, Beyond the Meter, Distributed Energy Resources: Capabilities Guide, 2016

Located near Harrodsburg, Kentucky, the E.W. Brown Energy Storage Research and Demonstration Site is a test bed for evaluating utility-scale energy storage technologies and their subsystems.[16] The facility, operated by Louisville Gas and Electric (LG&E) and Kentucky Utilities (KU) in collaboration with Electric Power Research Institute (EPRI), is developing new control functions and implementation methods for stacking or prioritizing storage operations in real time. The facility has been designed to be a modular plug-and-play system that is technology-agnostic and able to test three individual 1-MW energy storage systems along with the associated power conditioning and controls systems simultaneously. The first technology being tested is a 1 MW, 2 MWh lithium-ion battery storage system.

- Energy storage systems can interact with the grid directly and provide grid services, or be isolated from the grid to test islanded or microgrid functionality. Integration with nearby generation (solar, hydro, and natural gas) allows for testing functions such as smoothing, ramp rate control, and blackstart. The on-site programmable load bank also provides dynamic load profile testing, which allows novel controls and equipment to be tested and evaluated under a variety of situations.
- Without a central power authority to signal when a system should charge or discharge during a given cycle, LG&E and KU have been able to generate that signal on their own, essentially creating a smart system independent of a command and control unit.

In conjunction with EPRI's Energy Storage Integration Council (ESIC), information from the demonstration projects is being made available to the public. Resources include one-second battery performance data, implementation guides, technical specification templates, test manuals, commissioning guides, and cost templates and tools.[17]

16 Kentucky power plant becomes energy storage testing ground" LG&E and KU, 2017, https://lge-ku.com/newsroom/press-releases/2017/02/28/kentucky-power-plant-becomes-energy-storage-testing-ground.

17 "EPRI Energy Storage Integration Council (ESIC)." EPRI, n.d. https://www.epri.com/#/pages/sa/epri_energy_storage_integration_council_(esic)?lang=en

Smart Electric Power Alliance

RESIDENTIAL STORAGE OFFERINGS

Utilities participating in SEPA's Annual Utility Survey expressed an overwhelming interest in customer-sited energy storage. A few utilities are piloting energy storage offerings for their customers, while others are offering incentives for customers deploying their own battery storage.

RESIDENTIAL PROGRAMS

Green Mountain Power (GMP)—Tesla Powerwall Grid Transformation Innovative Pilot

GMP's pilot offers customers the ability to lease a discounted battery system owned and operated by the utility. Customers pay $15 a month during the 10-year program, or pay a one-time payment of $1,500. The pilot aims to deploy 2,000 residential Powerwalls with the goal of reducing peak load by 10 MW. At the end of July 2018, GMP had deployed just under 300 Powerwalls, with an additional 450 scheduled for installation. The utility anticipates more than $2 million in savings over the life of the program.

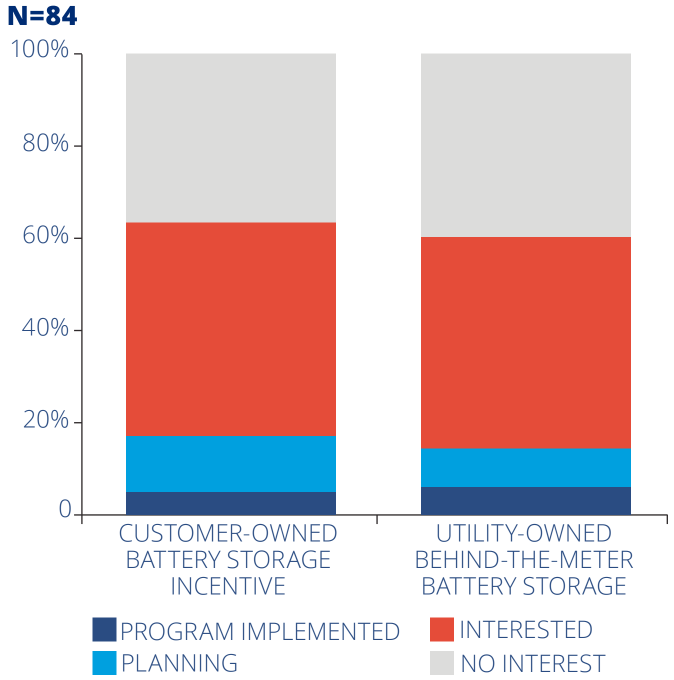
GMP—Bring Your Own Battery Program

Begun in March 2018, this 18-month pilot will allow customers to install up to a total of 2 MW, 6 MWh of new battery storage systems. Participating customers receive a monthly credit for agreeing to let GMP have shared access to their battery storage systems. This credit varies between $14.50 and $36 a month depending on the projected value for each kW of storage capacity. Batteries can be used as backup power at customer premises, but they must be available to charge and discharge in accordance with GMP's instructions and maintain a Wi-Fi connection for system communications purposes. GMP's peak events typically occur five to eight times a month for three to six hours at a time, and customers are notified at least four hours in advance.

In April 2018, **Jacksonville Electric Authority** launched a battery storage incentive program, giving residential customers with solar a 30% rebate on the purchase and installation of storage, up to $2,000 per customer.[18]

Salt River Project has rolled out a storage incentive of up $1,800 ($150 per kWh DC) for residential customers purchasing their own battery storage systems. This incentive is available to the first 4,500 customers installing storage between May 2018 and May 2021.

FIGURE 16: UTILITY INTEREST IN BATTERY STORAGE PROGRAMS FOR RESIDENTIAL CUSTOMERS



Source: Smart Electric Power Alliance, 2018.

POTENTIAL MARKET CATALYST—SOFTWARE UPDATES

In May 2018, Tesla released an update to the Powerwall 2 customer app. The update allows customers to optimize battery use to take advantage of time-varying rates—charging when rates are low, discharging when rates are high—thereby reducing the payback period.[19]

18 "Florida's JEA to offer battery storage incentive to customers." American Public Power Association, 2017 https://www.publicpower.org/periodical/article/floridas-jea-offer-battery-storage-incentive-customers

19 "Tesla software update allows Powerwall 2 owners to optimize for time-varying rates." Utility Dive, 2018 https://www.utilitydive.com/news/tesla-software-update-allows-powerwall-2-owners-to-optimize-for-time-varyin/523588/

Smart Electric Power Alliance

NON-RESIDENTIAL STORAGE OFFERINGS

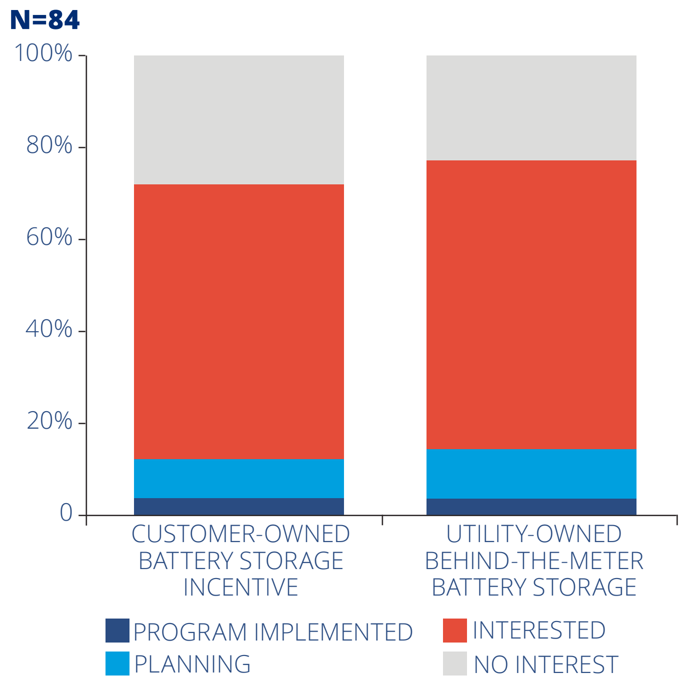
In SEPA's annual Utility Survey, utilities' interest in providing energy storage options to non-residential customers was even greater than their interest in providing similar options for residential customers. The reason—non-residential customers accounted for 65% of electricity sold by volume in 2016.[20] However, the number of kWh delivered is not the main cost driver here, but the times at which the customer demand spikes occur. Consequently, non-residential rate schedules typically include demand charges[21] aimed at incentivizing customers to avoid peaks in consumption. A high demand charge can result in higher electricity prices, either for a single billing cycle or the entire year.

Non-residential battery deployments represent a significant market opportunity.

A study from NREL[22] has estimated that about 5 million non-residential customers currently play demand charges of more than $15 to $20 a kW—a level that will make storage an attractive economic alternative. California and New York are the two states identified as having the largest markets. Another study conducted by LBNL[23] found that solar and storage together are more effective at managing demand charges, but that demand charge savings are highly customer specific. Thus, the design of the demand charge rate a specific customer pays will impact the economics of solar plus storage.

The combined findings of the studies by the national labs and the emergence of early projects in the Midwest make the non-residential solar plus storage market one to watch. Similarly, retrofitting existing non-residential solar PV systems with batteries is another prospective and growing market to track. In 2017, non-residential solar grew 48% over deployments in 2016, the highest growth rate for any sector. By the end of 2017, a cumulative total of more than 68,000 solar systems had been installed behind non-residential customer meters.

FIGURE 17: UTILITY INTEREST IN BATTERY STORAGE PROGRAMS FOR NON-RESIDENTIAL CUSTOMERS



Source: Smart Electric Power Alliance, 2018.

20 "Sales_Ult_Cust_2016" EIA Form 861 2016 data file https://www.eia.gov/electricity/data/eia861/

21 "Demand Charges." Stem http://www.stem.com/resources/demandcharges/

22 "Identifying Potential Markets for Behind-the-Meter Battery Energy Storage: A Survey of U.S. Demand Charges." NREL, 2017 https://www.nrel.gov/docs/fy17osti/68963.pdf

23 "Solar + Storage Synergies for Managing Commercial-Customer Demand Charges." Berkeley Lab and NREL, 2017 http://eta-publications.lbl.gov/sites/default/files/solarstorage_synergies_report.pdf

NON-RESIDENTIAL STORAGE OFFERINGS, CONTINUED

Behind-the-meter batteries have the opportunity to compete with other resources and have the same capabilities that batteries in front of the meter do.

The California Public Utilities Commission created Local Capacity Requirements (LCRs) to identify the minimum local resource capacity required to reliably meet the needs of a specific area. In 2013, Southern California Edison (SCE) issued a LCR request for offer (RFO) for incremental capacity within its service territory, prioritizing the integration of energy storage, energy efficiency, demand response and other preferred resources.[24] In response to this RFO, Stem, Inc., deployed 85 MW of aggregated behind-the-meter storage at multiple non-residential sites in 2016. Stem became the first energy storage provider to meet SCE's reliability and performance requirements. The systems were also notable for being the first energy storage systems to interact with SCE's DR programs.

DEPLOYMENT IN AREAS WITH HIGH DEMAND CHARGES IS UNDERWAY

In **Iowa**, Ideal Energy has deployed two solar plus storage systems to help non-residential customers manage demand charges. The first, a demonstration project, came online in December 2016. The 216-kW solar farm and 30-kW battery[25] enable the commercial customer to shave consumption peaks and manage demand charges. The second project began operating in May 2018. This 1.1-MW solar array with a 1.05-MW, 1-MWh battery was deployed at a university in Iowa.

24 "Energy Action Plan II: Implementation Roadmap for Energy Policies." State of California, 2005 http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF

25 The future starts here: Iowa's first commercial solar-plus-storage project." Ideal Energy, 2016 https://www.idealenergysolar.com/iowas-first-commercial-solar-plus-storage-project/

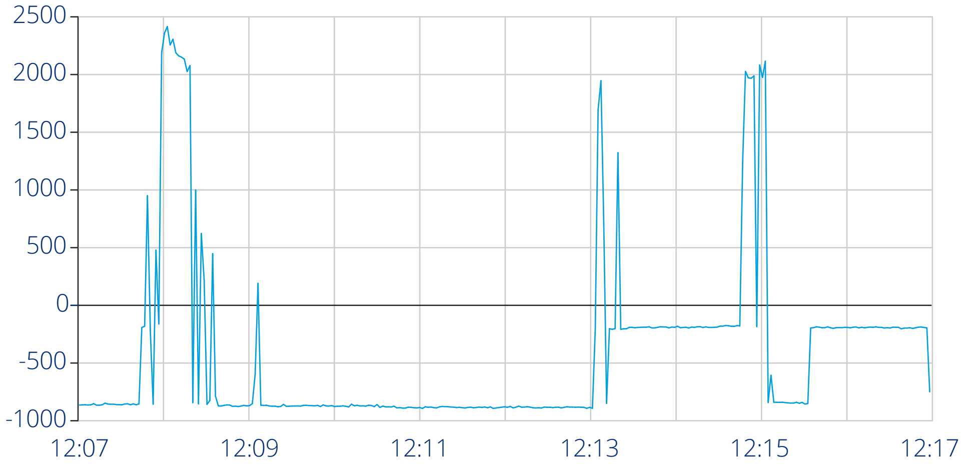
STAND-ALONE BATTERY STORAGE—DEPLOYMENT EXAMPLES

As a stand-alone, utility-scale grid asset, battery energy storage has unique capabilities. With domestic deployment set to expand, a review of existing deployments is useful. On this page, a few prime deployments are summarized, as well as the recommissioning of two battery storage projects.

PRIMARY FREQUENCY RESPONSE FROM A BATTERY

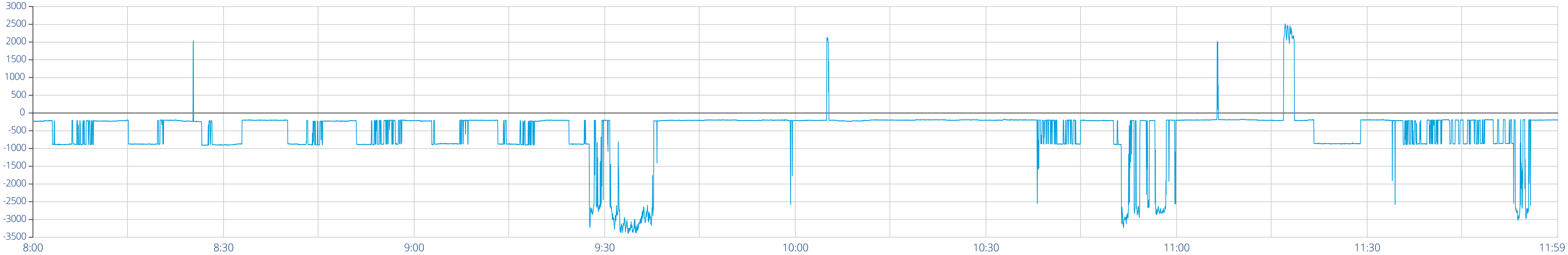
In 2016, Indianapolis Power & Light Company (IPL) deployed the first battery storage project in the Midcontinent Independent System Operator (MISO) service territory —a 20-MW, 20-MWh AES battery which provides primary frequency response. The lithium-ion battery is currently being used to provide primary frequency control, actively monitoring grid frequency and then autonomously charging or discharging to correct the frequency back to 60Hz. Figure 18 shows 10 minutes of two-second-interval operation data for the project, demonstrating the system's speed and accuracy. Figure 19 displays a four-hour window of two-second operating data, which shows the battery had been set to charge and maintain a near-50% state of charge while also performing primary frequency control.

FIGURE 18: TEN MINUTES OF TWO-SECOND INTERVAL OPERATION DATA FOR 20 MW, 20 MWH LITHIUM-ION BATTERY



Source: Indianapolis Power & Light Company, 2018

FIGURE 19: FOUR-HOURS OF TWO-SECOND INTERVAL DATA FOR 20 MW, 20 MWH LITHIUM-ION BATTERY



Source: Indianapolis Power & Light Company, 2018

STAND-ALONE BATTERY STORAGE—DEPLOYMENT EXAMPLES, CONTINUED

Battery for shaving peak and helping with the duck curve—San Diego Gas & Electric deployed one of the the world's largest lithium-ion battery storage facility in early 2017 as part of the procurements resulting from the loss of resources from Aliso Canyon. The 30-MW, 120-MWh storage facility charges when energy is plentiful and discharges that power when resources are in high demand, which helps mitigate the impact of the California duck curve.[26] The project has been bid into the California Independent System Operator (CAISO) day-ahead and real-time markets.

Battery for black start—Imperial Irrigation District (IID) is the owner of the only battery storage system in the country that can black start a generator.[27] The 30-MW, 20-MWh battery has the ability to black start the El Centro station, the main generator in IID's fleet. A unique characteristic of the IID battery storage is that once it has successfully black started the generator, it can immediately begin charging to act as load.

RE-COMMISSIONING BATTERY STORAGE

The re-commissioning of battery storage projects has occurred in two cases this past year.[28] In each case, older, lead-acid technology was replaced by lithium-ion technology.

- Formerly lead-acid, the Notrees 36-MW battery storage system, co-located with the 153-MW Notrees wind farm in west Texas, has been repowered with lithium-ion technology by Younicos. The repowered battery continues to participate in Texas's Fast Responding Regulation Service (FRRS) market. The replacement of battery technologies was done in two phases, each replacing 50% of the battery, which required hybrid control software to avoid performance interruption.[29]
- Kodiak Island in Alaska deployed two, 1.5 MW lead-acid batteries to provide frequency response and spinning reserve as the island achieved its 95% renewables goal by shifting its generation pool to a heavy reliance on wind. In late 2017, the two batteries were upgraded to lithium-ion technology to further enhance the grid's performance and flexibility.[30]

26 CAISO, https://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf

27 "IID demonstrates battery's emergency black start capability." Imperial Irrigation District, 2017 https://www.iid.com/Home/Components/News/News/557/30?backlist=%2F

28 Note: Recommissioned batteries are not counted as added capacity in SEPA's deployment figures.

29 "Younicos Recommissions Notrees 36 MW Battery Plant." Younicos, 2017 https://www.younicos.com/younicos-recommissions-duke-energys-36-mw-bees /

30 "Younicos Commissions Upgraded 3 MW System on Kodiak Island." Younicos, 2017 https://www.younicos.com/younicos-commissions-upgraded-3-mw-system-kodiak-island/

T&D DEFERRAL: ENERGY STORAGE AND NON-WIRES ALTERNATIVES

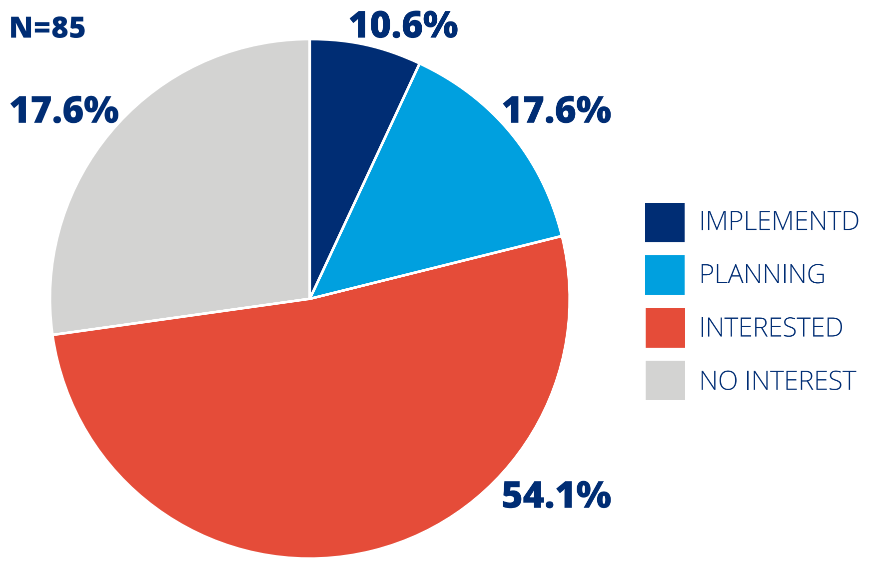
Across the country, utilities are increasingly opting to screen for locational DER opportunities prior to upgrading transmission and distribution (T&D) infrastructure.

As a result, non-wires alternative (NWA)[31] projects are cropping up in new regions. Battery energy storage and its capabilities have been deployed in a handful of current NWA projects. The use of storage solutions to replace or complement traditional infrastructure build-outs is set to expand widely as energy storage is considered in planning activities, and grid operators become more comfortable with the technology.

Arizona Public Service (APS) deployed a 2 MW, 8 MWh battery in early 2018 as an alternative to rebuilding 20 miles of distribution lines that serve Punkin Center, a small town of 600 people.[32] The battery storage system cost 50% less than rebuilding the line, minimized environmental disruption, and is more flexible to the changing needs of the grid over the long term. The battery system will be discharged when the town's peak demand exceeds the capacity of the power lines; it will also help manage power quality through frequency regulation.

Southern California Edison's Distribution Energy Storage Integration (DESI) 1 pilot project is SCE's first distribution-connected battery energy storage system. This lithium-ion battery is a compact system squeezing 2.4 MW and 3.9 MWh into a 1,600 square-foot easement. It is designed to defer distribution system upgrades through circuit load management. Rather than add capacity to the circuit, the DESI 1 project helps monitor the 12-kV phase current on the distribution circuit, and then discharges as needed to help prevent the current from exceeding the circuit's planned loading limit during peak conditions.

FIGURE 20: UTILITY INTEREST IN PROCURING ENERGY STORAGE TO DEFER AND/OR AVOID CAPITAL EXPENDITURES IN THE DISTRIBUTION OR TRANSMISSION GRID



Source: Smart Electric Power Alliance, 2018.

National Grid is in the process of deploying a 6-MW, 48-MWh battery on Nantucket Island. The island currently has two submarine lines and is experiencing demand growth that would require a third cable in about 12 years. The battery will provide backup power and help stabilize the grid, but most importantly it will defer the need for that additional line by another 15 to 20 years by reducing the island's peak demand.[33]

31 Non-wires alternative (NWA), also known as non-wires solutions (NWS) was defined in SEPA's 2017 Utility Demand Response Market Snapshot report as "An electricity grid investment or project that uses non-traditional transmission and distribution (T&D) solutions, such as distributed generation (DG), energy storage, energy efficiency (EE), demand response (DR), and grid software and controls, to defer or replace the need for specific equipment upgrades, such as T&D lines or transformers, by reducing load at a substation or circuit level." (Navigant, Non Wires Alternatives 2017).

32 "APS Brings Battery Storage to Rural Arizona." Arizona Public Service, 2017 https://www.aps.com/en/ourcompany/news/latestnews/Pages/aps-brings-battery-storage-to-rural-arizona.aspx

33 "National Grid Develops Innovative Solution for an Island Community's Unique Energy Challenges." National Grid, 2017 https://news.nationalgridus.com/2017/11/national-grid-develops-innovative-solution-island-communitys-unique-energy-challenges/

SOLAR + STORAGE

No longer limited to remote communities or island grids, solar plus storage projects have begun to rapidly emerge across the U.S. mainland. All signs indicate the trend continuing, and growing, as the cost of solar and battery storage declines and utilities increasingly leverage the capabilities these combined systems can offer. A number of models for solar plus storage deployment are being rolled out, accompanied by a wave of announcements in the summer of 2018. More projects are to be expected as rules are defined for storage participation in RTO and ISO wholesale markets, and the solar investment tax credit remains in place. Solar plus storage projects are proving to be ideal resources as they address the solar's primary challenge—its intermittency. A few solar plus storage projects address this variability by smoothing and increasing the dispatchability of solar energy.

A Solar + Storage Peaking Plant—APS And First Solar

APS has signed a PPA with First Solar for 65 MW of solar, with a 50-MW, 135-MWh battery. Control of the battery will be available to APS from 3 p.m. to 8 p.m. These times coincide with APS's evening peak, which is much longer than most utilities' due to Arizona' desert-driven air conditioning load in the summer months. Outside of those hours, First Solar can sell power and services from the project on the market.[34,35] In June of 2018, APS issued a request for proposals (RFP) for 106 MW of storage capacity to be added to its existing solar projects.[36]

Smoothing Solar Intermittency—Salt River Project

Salt River Project (SRP) signed a solar plus storage PPA for a 20-MW solar array with a 10-MW, 40-MWh battery storage system.[37] SRP will use the project to study the economic feasibility and effectiveness of storage in smoothing out the intermittency of renewable generation. The project will help SRP meet its goal of 20% retail electricity from renewable energy by 2020.

Making Solar An Increasingly Dispatchable Resource—Florida Power & Light

Florida Power & Light Co. (FPL) is deploying batteries at two 74.5-MW solar farms. One will be a 4-MW, 16-MWh battery located at a solar farm in DeSoto County that will charge with solar normally clipped during peak generation periods.[38] The other battery will be 10 MW, 40 MWh and used to mitigate peaks in network demand.[39] In short, both of these batteries will make FPL's solar more dispatchable.

Solar + Storage For PPA Clipping Capture In Texas

To account for over-generation from a 180-MW solar PPA, Vistra Energy is developing a 10-MW, 42-MWh storage project to capture and discharge energy at peak times that would otherwise be clipped.[40] The battery will also enable load shifting by charging from the grid at night when prices are lower and discharging during the mornings when the prices are higher, creating more predictable ramp-up and ramp-down periods throughout the day as well.

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34 "First Solar Made Good on Its Promise to Beat Out Gas Peakers With Solar and Batteries." Greentech Media, 2018 https://www.greentechmedia.com/articles/read/50-megawatt-battery-will-give-arizona-peak-power-from-the-sun#gs.95xUIak

35 "APS to install 50 MW, 135 MWh solar-shifting battery." Utility Dive, 2018 https://www.utilitydive.com/news/aps-to-install-50-mw-135-mwh-solar-shifting-battery/516850/

36 "APS seeks partners to bring customers more clean energy using batteries." Arizona Public Service, 2018 https://www.aps.com/en/ourcompany/news/latestnews/Pages/aps-seeks-partners-to-bring-customers-more-clean-energy-using-batteries.aspx

37 "Arizona's largest solar plus storage plant starring Tesla, First Solar and NEXTracker." PV Magazine, 2018 https://pv-magazine-usa.com/2018/05/29/tesla-first-solar-and-nextracker-grace-the-arizona-desert/

38 "FPL deploys the US' first DC-coupled grid-scale battery at Florida solar farm." Energy Storage News, 2018 https://www.energy-storage.news/news/fpl-deploys-the-us-first-dc-coupled-grid-scale-battery-at-florida-solar-far

39 "'USA's largest': Florida Power & Light announces 74.5MW / 40MWh solar-plus-storage project." Energy Storage News, 2018 https://www.energy-storage.news/news/usas-largest-florida-power-light-announces-40mwh-solar-plus-storage-project

40 "Texas to get its largest battery, coupled with its largest solar power plant." PV Magazine, 2018 https://pv-magazine-usa.com/2018/06/18/texas-getting-its-largest-battery-10-mw-42-mwh-coupled-with-its-largest-solar-power-plant

UTILITY HIGHLIGHT: KAUAI ISLAND UTILITY COOPERATIVE: DISPATCHABLE SOLAR

For the Kauai Island Utility Cooperative (KIUC) in Hawaii—No. 1 on SEPA's 2018 Top 10 list for storage watts per customer—battery storage is no longer an add-on; it is a necessity.

KIUC serves 33,000 customer accounts with a peak demand of 75 MW, which occurs about an hour after sunset. As of the end of 2017, KIUC had 85.8 MW of solar and 24.5 MW, 67.1 MWh of energy storage deployed. Three of KIUC's solar farms on the island each comprise 20% of midday island demand. These solar farms can go from maximum output to 20% of nominal output as a cloud passes over the system, and then return to 100% output within the span of a minute or two.

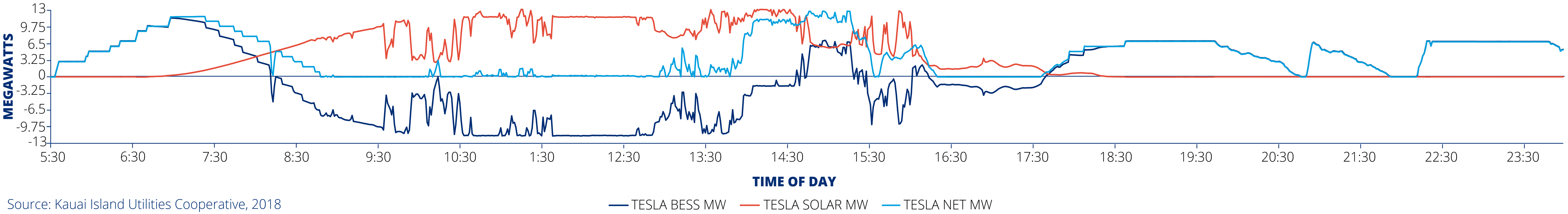
Even with ever-improving cloud forecasting, a grid with a significant penetration of variable generation requires dispatchable generation to maintain power quality. Fortunately, battery energy storage and control systems can be paired with solar to both address this variability and make the solar power a dispatchable form of generation.

In 2017, KIUC deployed its first solar plus storage system: a 13-MW, fixed-tilt solar system coupled with a 13-MW, 52-MWh Tesla battery energy storage system. As can be seen in Figure 21, this solar plus storage system is set to a net-zero point where the battery mirrors real-time solar generation. This enables the system to be a fully dispatchable grid resource.

The system is being dispatched in a couple of ways:

- The battery can be dispatched as an on-demand source of generation when needed by adjusting the net-zero setting of the system. Examples can be seen during the morning peak, from 2-3:30 p.m. and after the sun sets. These dispatches help KIUC deal with solar variability, delaying when they have to start traditional generators, and/or enabling units to go offline earlier.
- The system includes a control scheme developed by KIUC to autonomously discharge the battery to maintain system frequency for the entire island grid, which allows KIUC to forego using traditional generators for the service and instead run them at steady and more efficient output levels.

FIGURE 21: KAUAI ISLAND UTILITY COOPERATIVE 13 MW-AC SOLAR + 13 MW, 52 MWH BATTERY



Source: Kauai Island Utilities Cooperative, 2018

MORE SOLAR, LONGER-DURATION BATTERIES

KIUC plans to deploy additional solar and storage projects over the next two years. A 20-MW, single-axis tracking solar farm coupled with a 20-MW, 100-MWh storage system developed by AES will be operational in late 2018. The co-op has also signed another PPA with AES for an additional 14-MW, single-axis tracking solar farm with a 14-MW, 70-MWh battery to be located at the U.S. Navy's Pacific Missile Range Facility (PMRF).[41]

The duration of these batteries is five hours, one hour greater than the Tesla project, due to the increased amount of generation from single-axis tracking. Both solar plus storage systems will be used primarily to shift low-cost solar generation to the island's evening and morning peaks, while providing frequency response if needed. The PMRF system will also be able to island the base and support mission-critical activities in the event of a short-term or extended grid outage.

In 2016, the KIUC Board of Directors set a goal for the co-op to operate on 70% renewable energy by 2030, but the current and planned solar and storage projects could help it reach that goal much sooner. In 2017, solar energy accounted for 27% of the electricity generated on KIUC's system. The AES system to be deployed in 2018 will push that figure up to around 38%, while the PMRF project, set to be operational in 2019, will bring the island to 45%. Including other renewable resources on island, such as hydro and biomass, KIUC will reach 65% renewables by 2020.

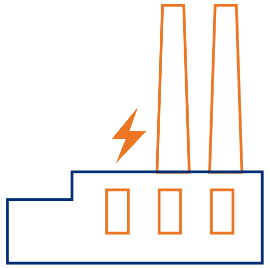
AERIAL VIEW OF KAUAI ISLAND UTILITY COOPERATIVE'S 13 MW-AC SOLAR + 13 MW, 52 MWH BATTERY

Source: Kauai Island Utility Cooperative, 2018

41 "KIUC and PMRF to Partner on Solar PV Plus Storage Project." Kaua'i Island Utility Cooperative, 2017 http://kiuc.coopwebbuilder2.com/sites/kiuc/files/PDF/pr/pr2017-1221-PMRFpvbattery.pdf

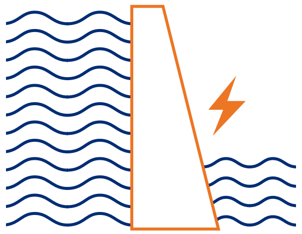
GENERATION-AGNOSTIC STORAGE

Solar is not the only generating source battery storage has been combined with; natural gas, hydro, and wind have been combined with battery storage to enhance the capabilities that stand-alone generators offer.



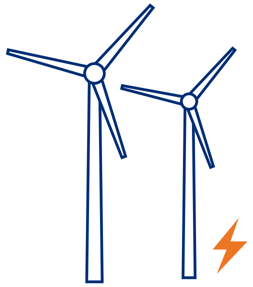
NATURAL GAS

Southern California Edison has coupled two, 50-MW natural gas combustion turbines each with a 10-MW, 4.3-MWh battery—the first hybrid gas power plants. By combining the quick response of a battery with the generation of a natural gas plant, this project demonstrates the resource and economic efficiencies that a hybrid gas-battery system can achieve. The battery is designed to react to a signal and discharge to the grid for the 10 minutes it takes the combustion turbine to ramp up to the power output called for. In effect, the battery storage system acts as spinning reserve without the gas plant running in stand-by mode, allowing the hybrid system to bid into the market as spinning reserve while saving both fuel and water resources.



HYDRO

Greensmith and AEP have integrated a 4-MW, 4-MWh battery interconnected with two hydro plants (20 MW and 10 MW) enabling the combined assets to participate in both the Reg D and Reg A frequency signals in PJM.[42] The speed of the battery and the energy capacity of the hydro allows for the participation in the fast frequency response signal of Reg D in PJM and the longer duration signal of Reg A. On their own, these resources would not be able to respond to these signals effectively and economically. The batteries' duration is not ideal, but the asset is fast and accurate. The hydro plants have a wealth of generating capacity, but are slower to ramp and less accurate than a battery.



WIND

In Texas a significant amount of battery storage has been deployed co-locating the assets with existing wind farms. These batteries are participating in ERCOT's Fast Response Regulating Service (FRRS[43]) but are not directly integrated with wind.

- Nextera—30-MW battery is co-located with the Blue Summit wind farm.
- E.ON—two 10-MW projects each became operational in January 2018. The projects are co-located with the existing E.ON Pyron and Inadale wind farms in west Texas.

In New York, National Grid is deploying a 5-MW, 40-MWh battery to be connected to first offshore wind farm in New York to serve as a receiving station for the proposed 90-MW installation.[44]

42 "Greensmith and AEP launch hybrid hydro energy storage project in USA" Greensmith Energy, 2017 http://www.greensmithenergy.com/greensmith-and-aep-launch-hybrid-hydro-energy-storage-project-usa

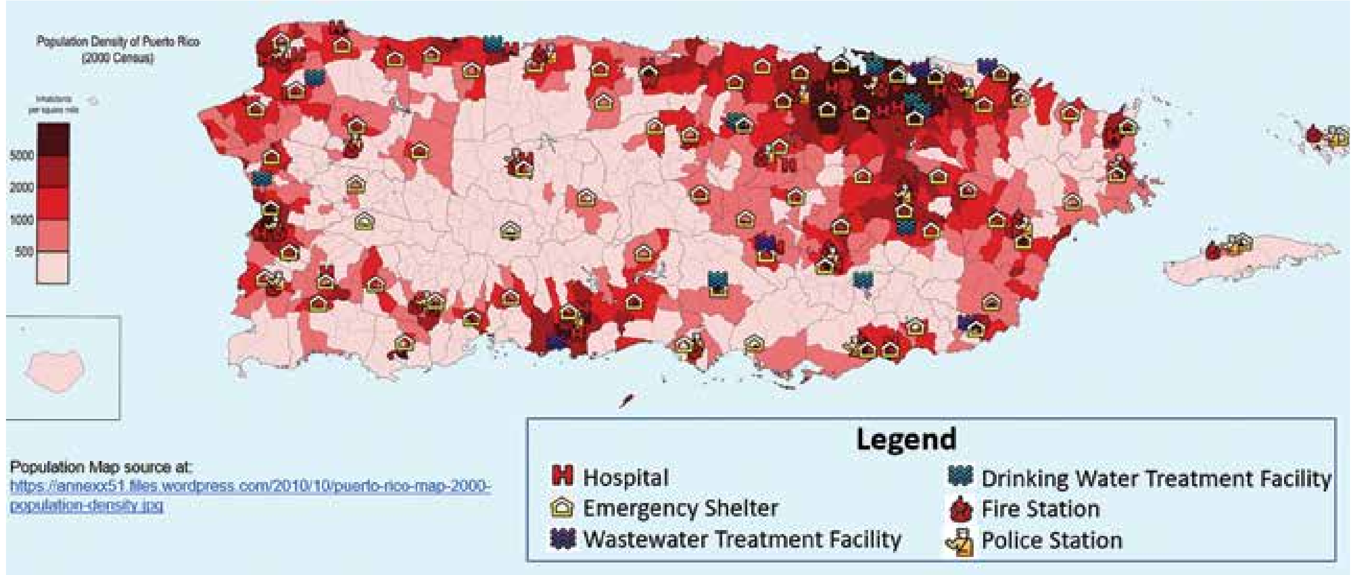
43 "Fast Responding Regulation Service—Completed." Electric Reliability Council of Texas, 2017 http://www.ercot.com/mktrules/pilots/frrs

44 "National Grid files to build 40 MWh storage project on Long Island." Utility Dive, 2017 https://www.utilitydive.com/news/national-grid-files-to-build-40-mwh-storage-project-on-long-island/441016/

MICROGRIDS—BATTERY STORAGE

Battery storage is an ideal asset to be integrated into a microgrid.[45] Microgrids are reliant on a dispatchable form of generation, which is typically a diesel generator, that can ramp to manage power quality and align supply with demand. As has been discussed on previous pages, battery storage is more than capable of competing with diesel for that role. As the cost of energy storage continues to fall, the applicability of energy storage in microgrids will grow as more applications become economical.

FIGURE 22: HYPOTHETICAL ISLANDING OF PUERTO RICO CRITICAL INFRASTRUCTURE



Source: Smart Electric Power Alliance, 2017[46]

PUERTO RICO—PLANNING MICROGRIDS FOR RESILIENCE

In September 2017, Puerto Rico's power grid was devastated by hurricanes Irma and Maria. Approximately 70% of the generation on the island is located in the south, while 70% of the island's electricity consumption is located in the north. In December 2017, SEPA helped develop "Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico" along with Puerto Rico Governor Ricardo Rossello and New York Governor Andrew Cuomo. With the aim of building a better, more resilient grid,[46] SEPA developed a hypothetical deployment strategy and economic modeling of 159 critical infrastructure microgrids (fire stations, police stations, hospitals, emergency shelters, water/wastewater treatment facilities seen in Figure 22) and three remote community microgrids.

MICROGRIDS IN ACTION DURING BLACKOUT

In April 2018, a blackout on the Puerto Rico grid occured due to a powerline being struck by a bulldozer. During this blackout microgrids deployed on the island were able to keep the power on:

- Three microgrids at fire stations were deployed by SunRun. During the blackout, critical infrastructure was energized.
- Sonnen has deployed more than 10 community microgrids in PR with it's partner Pura Energia—a couple of which were at health centers.

45 Microgrids are defined as a group of interconnected loads and distributed energy resources (DER) within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid, and that can connect and disconnect from the grid to enable it to operate in both grid-connected and 'island' mode. "Microgrids—Expanding Applications, Implementations, and Business Structures," SEPA and EPRI, 2016 https://sepapower.org/resource/microgrids-expanding-applications-implementations-and-business-structures/

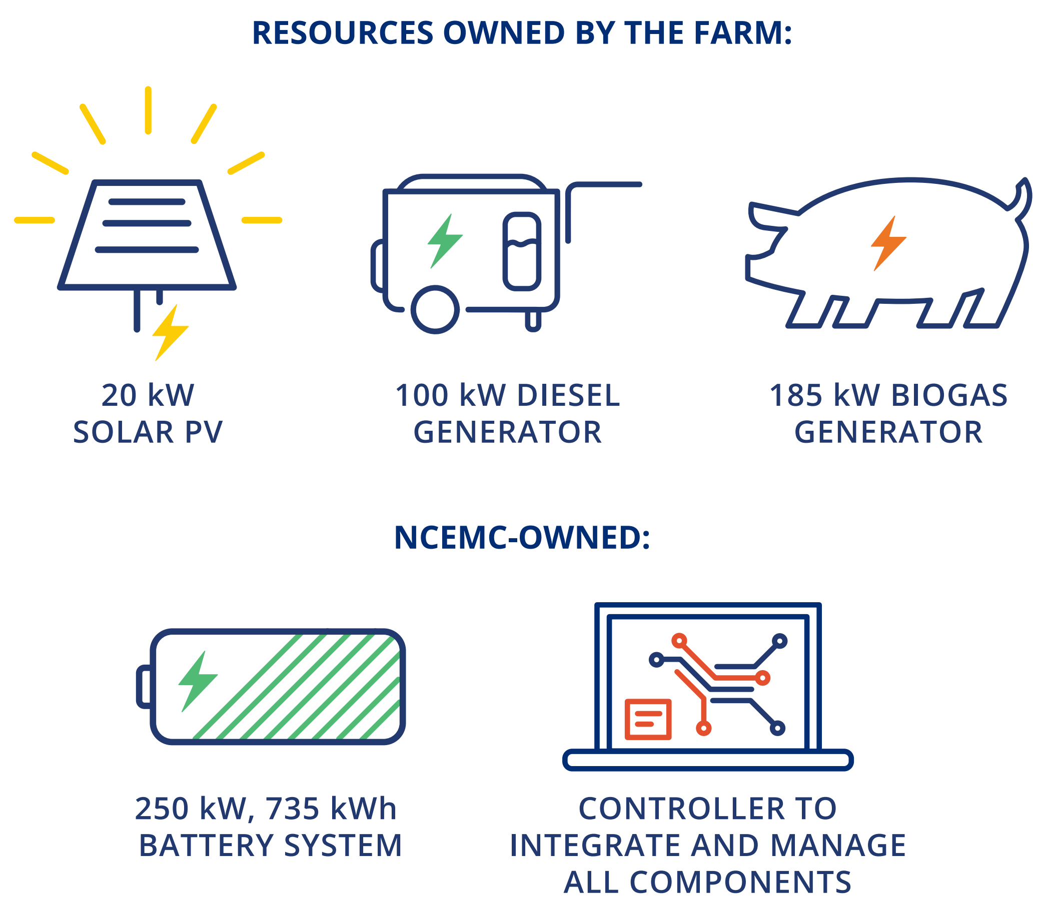
46 "Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico." SEPA et al., 2017 https://www.governor.ny.gov/sites/governor.ny.gov/files/atoms/files/PRERWG_Report_PR_Grid_Resiliency_Report.pdf

BUTLER FARMS MICROGRID IN NORTH CAROLINA—THE BATTERY AT THE "HEART" OF THE MICROGRID

The Butler Farms Microgrid, which is located in South River Electric Membership Corporation's (South River EMC) service territory, is made up of a few components: a 20-kW solar farm, 100-kW diesel generator, and a 185-kW biogas generator, which are all owned by the farm. The other component is a 250-kW, 735-kWh battery system. This project is an R&D project in partnership with the Butler Quality Pork & Renewable Energy Farm, South River Electric Membership Corporation, and North Carolina Electric Membership Corporation (NCEMC).

- **Phase one—"Grid-Tie" and "Farm Island" Mode**
  - In the current and first phase of the project, the battery acts as a demand response resource in Grid-Tie mode, dispatching when the costs of electricity are high and charging during off-peak times. While in Grid-Tie mode, the system can autonomously sense when the grid has gone down and switch into an islanded system. When in Farm Island mode, the battery is directed by the microgrid controller to maintain frequency and match the demand for electricity. In this phase of the project, the only generator charging the battery is the farm's solar system. The system can also perform a seamless transition from Grid-Tie to Farm Island mode for maintenance activities.
- **Phase two—"Feeder Island" Mode**
  - In phase two of the project, the microgrid will be expanded to include 28 residences that are located on the same feeder.
- **Phase three—[unnamed]**
  - In the third phase of the project, both the biogas and diesel generators, which are owned by the customer, will become dispatchable when in Farm Island and Feeder Island mode to support the electricity needs of the farm and neighboring homes. After sufficient testing, the plan is to expand he Feeder Island boundary to incorporate additional homes.

FIGURE 23: BUTLER FARM MICROGRID COMPONENTS



Source: North Carolina Electric Membership Corporation, 2018

Aggregated Mobile Storage

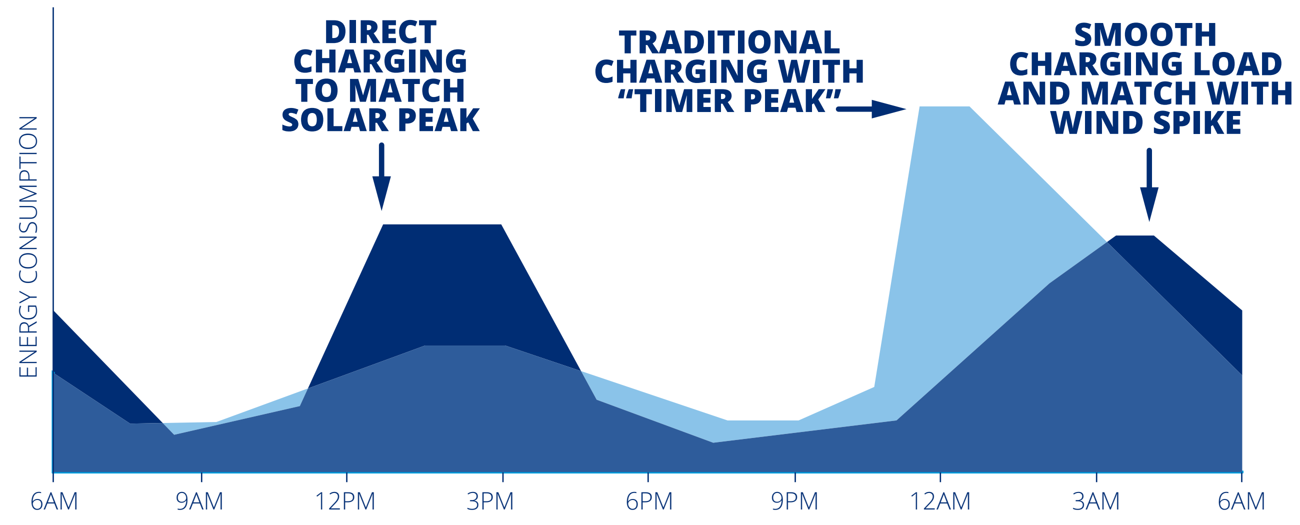
Bloomberg New Energy Finance (BNEF) forecasts EV consumption will increase from a few terawatt-hours (TWh) today to over 100 TWh by 2030.[47] This new load, while potentially a liability to the grid, is also seen as an opportunity that is capable of providing grid services and smoothing load spikes through aggregation with behind-the-meter batteries. Two potential methods include:

- Managed charging (or V1G) and
- Vehicle-to-grid (V2G) and vehicle-to-home (V2H)

MANAGED CHARGING (V1G)

Managed charging is seen as a near-term opportunity to leverage EVs similar to other demand response resources.[48] By providing residential customers with a financial incentive for integrating into a network of DERs, utilities or third-party providers can use that aggregate capacity to smooth out spikes that might result from EV charging. This is achieved by deciding when to turn charging activities, on, off, up, or down. Additionally, managed charging enables utilities or third-party providers to potentially "soak up" excess renewable energy generation into the EV battery, potentially displacing the need for stationary storage.[49] Figure 24 demonstrates just how managed charging can smooth loads while also introducing the concept of timer peaks that can result from customers charging EVs the moment off-peak pricing begins in a time-of-use (TOU) rate plan. Managed charging offers utilities an opportunity to further smooth timer peaks by staggering EV fleet charges.

FIGURE 24: OPPORTUNITIES FOR EV MANAGED CHARGING TO MEET GRID NEEDS (ILLUSTRATIVE)



Source: BMW of North America, 2016[50] with edits by Smart Electric Power Alliance, 2017

Within Massachusetts' ACES program, two proposed projects seek to support the electrification of transportation systems. One project integrates a 500-kW, 1,400-kWh storage system paired with solar PV to minimize or eliminate demand charges incurred from charging during peak hours. The other project proposes the installation of smart DC fast chargers paired with load management software and price signals to integrate renewables, reduce demand charges, and defer T&D upgrades.

47 BNEF, Electric Vehicle Outlook 2018, https://about.bnef.com/electric-vehicle-outlook/#toc-download

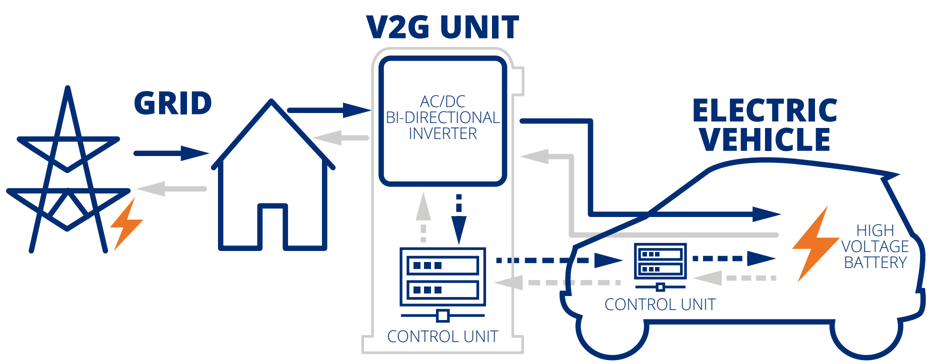
48 See SEPA, 2017, "Utilities and Electric Vehicles: The Case for Managed Charging."

49 Clean vehicles as an enabler for a clean electricity grid." Lawrence Berkeley National Laboratory, 2018 http://iopscience.iop.org/article/10.1088/1748-9326/aabe97/pdf

50 Adam Langton of BMW of North America LLC, "BMW Electric Vehicles and the Grid," April 2016, https://www.dropbox.com/sh/zmkca2v9cdiu9os/AAB4BMGmFKBzhrOHDqEWKOyGa/The%20OEM%20Perspective?dl=0&preview=Langton_June2016_v2.pdf

VEHICLE-TO-GRID AND VEHICLE-TO-HOME

FIGURE 25: ILLUSTRATIVE CONCEPT OF VEHICLE-TO-GRID



Source: FleetCarma, 2017

V2G dispatch uses a plugged-in EV with available charged battery capacity to feed power back to the grid. V2G can potentially provide services to the grid in exchange for financial compensation to the vehicle owner. While in the early stages, V2G may have the potential to provide significant value for utilities and balancing authorities if technical barriers can be overcome. At this moment, V2G is still more conceptual than commercial. While V2G technology is likely to develop over time, it will require additional elements for widespread adoption.[51]

- **Second-Life Batteries:** EVgo has worked to make V2G more practical by launching a project that integrates recycled BMW i3 car batteries into fast charging stations.[52] By reusing batteries that also offer demand charge management capabilities for back-up charging, the lifespan of EVs is extended and the impact of EV charging on the grid is reduced. These recycled batteries offer an opportunity to manage EV charging as grid assets rather than grid liabilities by ensuring that the battery is charged and discharged most efficiently for the grid—reducing the stress on the grid and keeping charging affordable.
- **V2H Cropping Up In California:** In 2015, the state's three major IOUs were ordered to develop transportation electrification programs. As a result PG&E conducted a V2H pilot program that included an EV with export capabilities, a 5-kW solar PV system, and a 5-kW, 8.6-kWh residential-sited stationary storage device.[53] The pilot found that while V2H is technically feasible, there are market barriers in place preventing its adoption. These barriers include high upfront costs, requisite DR mechanisms and processes, and DER competition within the same solution space. Partnerships among automakers, energy aggregators, and utilities could help to expedite the commercial feasibility of V2G.
- **JUMPSmart Maui—Vehicle-To-Home Pilot:** Maui's V2H pilot was split into two phases. The first phase involved the recruitment of over 200 Nissan Leaf owners/lessees and the installation of 13 fast-charging stations across the island.[54] From the data collected in this phase, Maui Electric sought to evaluate how EVs could act as grid assets with the integration of more renewables. Phase two involved the distribution of 80 EV—power conditioning systems (EV-PCS) that allowed EVs to charge during off-peak periods and discharge power to the volunteers' homes under a pilot rate of 1 kWh. The project was deemed a success as it helped Maui Electric understand how best to integrate smart grid technologies with renewable energy and electric vehicles.

51 See SEPA, 2018, "Utilities and Electric Vehicles: Evolving to Unlock Grid Value." https://sepapower.org/resource/utilities-electric-vehicles-evolving-unlock-grid-value/
52 "EVgo Announces Grid-Tied Public Fast Charging System With Second-Life Batteries." EVgo, 2018 https://www.prnewswire.com/news-releases/evgo-announces-nations-first-grid-tied-public-fast-charging-system-with-second-life-batteries-300678315.html
53 "Electric Program Investment Charge: Test Smart Inverter Enhanced Capabilities." PG&E, 2018 https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/electric-program-investment-charge/PGE-EPIC-Project-2.03.pdf
54 "Japan - U.S. Collaborative Smart Grid Demonstration Project in Maui Island of Hawaii State: A case study." NEDO, 2017 http://www.nedo.go.jp/content/100864936.pdf

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Appendix A: 2017 and Cumulative Energy Storage Capacity, Energy, and Installations by State and U.S. Territory

TABLE 9: ENERGY STORAGE CAPACITY, ENERGY, AND INSTALLATIONS BY STATE AND TERRITORIES

	2017 TOTAL			CUMULATIVE TOTAL		
STATE	MW	MWH	NO. OF SYSTEMS	MW	MWH	NO. OF SYSTEMS
ALABAMA	0	0	0	0	0	0
ALASKA	0	0	0	60.8	24.5	9
AMERICAN SAMOA	0.3	1	1	1.1	7.1	3
ARIZONA	25.5	11.1	106	26.4	13.3	254
ARKANSAS	0	0	0	0.01	0.02	2
CALIFORNIA	120.2	393.6	1,424	296.6	770.6	2,506
COLORADO	1.3	3.2	24	2.6	5.5	214
CONNECTICUT	0	0	0	0	0	0
DELAWARE	0	0	0	0	0	0
FLORIDA	1.1	1.3	16	4.4	7.4	60
GEORGIA	0	0	0	0	0	0
HAWAII	19.9	68.3	649	35.6	80.8	957

Source: Smart Electric Power Alliance, 2018

TABLE 9: ENERGY STORAGE CAPACITY, ENERGY, AND INSTALLATIONS BY STATE AND TERRITORIES

	2017 TOTAL			CUMULATIVE TOTAL		
STATE	MW	MWH	NO. OF SYSTEMS	MW	MWH	NO. OF SYSTEMS
IDAHO	0	0	0	0	0	0
ILLINOIS	0.3	0.3	1	121	61	10
INDIANA	0.01	0.03	2	24.1	35.4	15
IOWA	0.01	0.02	1	0.1	0.1	4
KANSAS	0	0	0	0	0	0
KENTUCKY	1	2	1	2.8	7.4	167
LOUISIANA	0.01	0.01	1	0.6	0.8	23
MAINE	0	0	0	16.7	11.1	3
MARYLAND	2	1	3	12.6	1.9	16
MASSACHUSETTS	7	12.1	9	10	17	12
MICHIGAN	0	0	0	0.03	0.1	5
MINNESOTA	0	0	0	1	7.2	3

Source: Smart Electric Power Alliance, 2018

Smart Electric Power Alliance

TABLE 9: ENERGY STORAGE CAPACITY, ENERGY, AND INSTALLATIONS BY STATE AND TERRITORIES	2017 TOTAL			CUMULATIVE TOTAL		
STATE	MW	MWH	NO. OF SYSTEMS	MW	MWH	NO. OF SYSTEMS
MISSISSIPPI	0	0	0	0	0	0
MISSOURI	1	2	1	1	2	1
MONTANA	0	0	0	0	0	0
NEBRASKA	0	0	0	0	0	0
NEVADA	0.0001	0.002	15	0.0001	0.002	25
NEW HAMPSHIRE	0.002	0.02	1	0.002	0.02	1
NEW JERSEY	0.2	0.4	18	0.7	0.6	20
NEW MEXICO	0.04	0.1	6	0.7	2.3	102
NEW YORK	0.9	3.2	20	22.2	13.6	33
NORTH CAROLINA	0	0	0	1	1.6	10
NORTH DAKOTA	0	0	0	0	0	0
OHIO	0.04	0.1	8	53.2	35.6	55
OKLAHOMA	0	0	0	0.07	0.2	12
OREGON	0	0	0	5	1.3	1

Source: Smart Electric Power Alliance, 2018

TABLE 9: ENERGY STORAGE CAPACITY, ENERGY, AND INSTALLATIONS BY STATE AND TERRITORIES	2017 TOTAL			CUMULATIVE TOTAL		
STATE	MW	MWH	NO. OF SYSTEMS	MW	MWH	NO. OF SYSTEMS
PENNSYLVANIA	0.3	0.8	49	54.6	24.9	67
RHODE ISLAND	0	0	0	0	0	0
SOUTH CAROLINA	0.02	0.1	4	0.04	0.1	5
SOUTH DAKOTA	0	0	0	0	0	0
TENNESSEE	0	0	0	0.03	0.07	7
TEXAS	32.1	16.4	29	88.7	103.4	71
UTAH	0	0	0	0	0	0
VERMONT	2.8	4.2	155	4.9	7.8	190
VIRGINIA	0.1	0.2	12	0.5	1	71
WASHINGTON	0.6	2.4	29	8.1	19.2	212
WEST VIRGINIA	0.01	0.03	2	65.6	28.7	15
WISCONSIN	0.004	0.01	1	0.1	0.1	6
WYOMING	0	0	0	0	0	0
GRAND TOTAL	216.7	523.9	2,588	922.8	1,293.6	5,167

Source: Smart Electric Power Alliance, 2018

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Appendix B: SEPA's Top 10 Utility Energy Storage Rankings

ENERGY STORAGE CAPACITY (MW)

TABLE 10: TOP 10 UTILITIES BY ANNUAL ENERGY STORAGE CAPACITY (MW)			
1	SOUTHERN CALIFORNIA EDISON	California	56.2
2	SAN DIEGO GAS & ELECTRIC	California	45.3
3	TUCSON ELECTRIC POWER COMPANY	Arizona	21
4	PACIFIC GAS & ELECTRIC	California	16.4
5	KAUAI ISLAND UTILITY COOPERATIVE	Hawaii	13.7
6	NATIONAL GRID	Massachusetts	7
7	ARIZONA PUBLIC SERVICE	Arizona	4.2
8	GREEN MOUNTAIN POWER	Vermont	2.8
9	MAUI ELECTRIC	Hawaii	2.6
10	HAWAIIAN ELECTRIC	Hawaii	2.2

Source: Smart Electric Power Alliance, 2018

TABLE 11: TOP 10 UTILITIES BY CUMULATIVE ENERGY STORAGE CAPACITY (MW)			
1	SOUTHERN CALIFORNIA EDISON	California	142.5
2	COMMONWEALTH EDISON	Illinois	121
3	SAN DIEGO GAS & ELECTRIC	California	68.4
4	MONONGAHELA POWER COMPANY	West Virginia	63.5
5	PACIFIC GAS & ELECTRIC	California	53.1
6	IMPERIAL IRRIGATION DISTRICT	California	30
7	PENNSYLVANIA ELECTRIC COMPANY	Pennsylvania	28.4
8	KAUAI ISLAND UTILITY COOPERATIVE	Hawaii	24.5
9	DAYTON POWER AND LIGHT	Ohio	24
10	TUCSON ELECTRIC POWER COMPANY	Arizona	21

Source: Smart Electric Power Alliance, 2018

ENERGY STORAGE (MWH)

TABLE 12: TOP 10 UTILITIES BY ANNUAL ENERGY STORAGE (MWH)			
1	SOUTHERN CALIFORNIA EDISON	California	185
2	SAN DIEGO GAS & ELECTRIC	California	166.8
3	KAUAI ISLAND UTILITY COOPERATIVE	Hawaii	58.6
4	PACIFIC GAS & ELECTRIC	California	40.2
5	NATIONAL GRID	Massachusetts	12.1
6	TUCSON ELECTRIC POWER COMPANY	Arizona	6
7	HAWAIIAN ELECTRIC	Hawaii	4.7
8	ARIZONA PUBLIC SERVICE	Arizona	4.4
9	GREEN MOUNTAIN POWER	Vermont	4.2
10	PUBLIC SERVICE COLORADO	Colorado	3.2

Source: Smart Electric Power Alliance, 2018

TABLE 13: TOP 10 UTILITIES BY CUMULATIVE ENERGY STORAGE (MWH)			
1	SOUTHERN CALIFORNIA EDISON	California	376.6
2	SAN DIEGO GAS & ELECTRIC	California	215.4
3	PACIFIC GAS & ELECTRIC	California	156.3
4	KAUAI ISLAND UTILITY COOPERATIVE	Hawaii	67.1
5	COMMONWEALTH EDISON	Illinois	61
6	AEP TEXAS	Texas	24.2
7	INDIANAPOLIS POWER & LIGHT COMPANY	Indiana	20
7	IMPERIAL IRRIGATION DISTRICT	California	20
9	AEP OHIO	Ohio	14.9
10	APPALACHIAN POWER / WHEELING POWER	West Virginia	14.6

Source: Smart Electric Power Alliance, 2018

ENERGY STORAGE WATTS/CUSTOMER

TABLE 14: TOP 10 UTILITIES BY ANNUAL ENERGY STORAGE WATTS PER CUSTOMER (W/C)			
1	KAUAI ISLAND UTILITY COOPERATIVE	Hawaii	415.3
2	TUCSON ELECTRIC POWER COMPANY	Arizona	50
3	MAUI ELECTRIC	Hawaii	36.5
4	SAN DIEGO GAS & ELECTRIC	California	31.7
5	GLENDALE WATER & POWER	California	22.9
6	AMERICAN SAMOA POWER AUTHORITY	American Samoa	20.4
7	HAWAII ELECTRIC LIGHT COMPANY	Hawaii	16.4
8	SOUTHERN CALIFORNIA EDISON	California	11.1
9	GREEN MOUNTAIN POWER	Vermont	10.6
10	CITY UTILITIES OF SPRINGFIELD, MO	Missouri	8.8

Source: Smart Electric Power Alliance, 2018

TABLE 15: TOP 10 UTILITIES BY CUMULATIVE ENERGY STORAGE WATTS PER CUSTOMER (W/C)			
1	VILLAGE OF MINSTER	Ohio	4,676
2	KAUAI ISLAND UTILITY COOPERATIVE	Hawaii	742.6
3	STERLING MUNICIPAL LIGHT DEPT	Massachusetts	522.2
4	GLASGOW ELECTRIC PLANT BOARD	Kentucky	244.6
5	IMPERIAL IRRIGATION DISTRICT	California	200.8
6	MONONGAHELA POWER COMPANY	West Virginia	162.9
7	AMERICAN SAMOA POWER AUTHORITY	American Samoa	87.1
8	MAUI ELECTRIC	Hawaii	50.9
9	TUCSON ELECTRIC POWER COMPANY	Arizona	50
10	PENNSYLVANIA ELECTRIC COMPANY	Pennsylvania	48.4

Source: Smart Electric Power Alliance, 2018

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ENERGY STORAGE WATT-HOURS PER CUSTOMER

TABLE 16: TOP 10 UTILITIES BY ANNUAL ENERGY STORAGE WATT-HOURS PER CUSTOMER (WH/C)

1	**KAUAI ISLAND UTILITY COOPERATIVE**	Hawaii	1,778.4
2	**SAN DIEGO GAS & ELECTRIC**	California	116.6
3	**AMERICAN SAMOA POWER AUTHORITY**	American Samoa	81.4
4	**SOUTHERN CALIFORNIA EDISON**	California	36.6
5	**HAWAII ELECTRIC LIGHT COMPANY**	Hawaii	35.3
6	**MAUI ELECTRIC**	Hawaii	27.8
7	**CITY UTILITIES OF SPRINGFIELD, MO**	Missouri	17.5
8	**GREEN MOUNTAIN POWER**	Vermont	15.8
9	**HAWAIIAN ELECTRIC**	Hawaii	15.3
10	**TUCSON ELECTRIC POWER COMPANY**	Arizona	14.3

Source: Smart Electric Power Alliance, 2018

TABLE 17: TOP 10 UTILITIES BY CUMULATIVE ENERGY STORAGE WATT-HOURS PER CUSTOMER (WH/C)

1	**KAUAI ISLAND UTILITY COOPERATIVE**	Hawaii	2,036
2	**VILLAGE OF MINSTER**	Ohio	2,004
3	**STERLING MUNICIPAL LIGHT DEPT**	Massachusetts	1,018.3
4	**GLASGOW ELECTRIC PLANT BOARD**	Kentucky	733.9
5	**AMERICAN SAMOA POWER AUTHORITY**	American Samoa	577.9
6	**SAN DIEGO GAS & ELECTRIC**	California	150.6
7	**IMPERIAL IRRIGATION DISTRICT**	California	133.8
8	**SOUTHERN CALIFORNIA EDISON**	California	74.6
9	**MAUI ELECTRIC**	Hawaii	42.8
10	**INDIANAPOLIS POWER & LIGHT COMPANY**	Indiana	41.1

Source: Smart Electric Power Alliance, 2018

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Appendix C: States With Energy Storage Commitments

TABLE 18: ENERGY STORAGE COMMITMENTS BY STATE

STATE	BILL(S)	DESCRIPTION
CALIFORNIA	AB 2154 and AB 2868	California set the first and most aggressive energy storage procurement target in the US in 2013 as a result of AB 2154. The target is for the state's three IOUs to procure 1,325 MW of storage by 2020 with installations operational by 2024 (580 MW from SCE, 580 MW from PG&E, 165 MW from SDG&E). A second bill, AB 2868, was signed into law in 2016 allowing an additional 500 MW to be rate-based by those same three IOUs, and ordered that no more than 25 percent of the capacity of those should be behind-the-meter. In April 2017, the California PUC proposed refinements to AB 2868 that create a process for implementation and adopts rules regarding treatment of station power for energy storage devices.
MASSACHUSETTS	H.4568	H.4568 was signed into law in 2016, directing the Massachusetts Department of Energy Resources (DOER) to assess if energy storage goals are prudent and, if so, to implement a procurement target for 2020. As a result, the Massachusetts DOER set an aspirational target of deploying 200 MWh of storage by Jan. 1, 2020 from the state's three distribution companies. In December 2017, under Massachusetts' Energy Storage Initiative, $20 million in grants were awarded to 26 projects. These projects represent an additional 85 MWh of energy storage capacity to the grid, 45 MWh help meet the state target.
OREGON	HB 2193	At the end of 2016, the Oregon Public Utility Commission (OPUC) issued guidelines under HB 2193, which requires Portland General Electric and PacifiCorp to each propose a minimum of 5 MWh of energy storage to be procured by January 2020 pending approval from the OPUC. In March 2018, Portland General Electric forecasted they will surpass the OPUC requirement by procuring 39 MW of energy storage. PacifiCorp also plans to propose one or more projects to meet the standard. Final proposals were submitted on April 2, 2018.

Source: Smart Electric Power Alliance, 2018

APPENDIX C: STATES WITH ENERGY STORAGE COMMITMENTS, CONTINUED

TABLE 18: ENERGY STORAGE COMMITMENTS BY STATE

STATE	BILL(S)	DESCRIPTION
NEW YORK	AB 6571	At the end of 2017, AB 6571 was signed into law. It directs the state PSC to investigate and set an energy storage target for 2030. The PSC is expected to implement the target by the end of 2018. Once set, New York State Energy Research and Development Authority (NYSERDA) and Long Island Power Authority (LIPA) will spearhead a deployment program that focuses on both customer-sited and front-of-the-meter storage.
NEW JERSEY	A3723	Signed into law on May 23 2018, bill A3723 calls for 600 MW of energy storage capacity in the state within three years and 2 GW of capacity by 2030. Additionally, the bill requires that the New Jersey Public Utilities Board analyze the potential costs and benefits of further energy storage investment, focusing on storage to provide backup power, offset peak load, and promote the use of electric vehicles in the state.
NEVADA	SB 204	In 2017, Nevada state legislators directed state regulators to produce a study of the cost effectiveness of an energy storage mandate for the state's utilities by Oct. 1, 2018. If a study proves that energy storage is a cost-effective improvement, the Nevada Public Utilities Commission will begin the process of implementing a biennial energy storage procurement target. The study is expected to be complete in August 2018 and will cover such topics as quantifying how much storage can be cost-effectively deployed on the NV Energy system over the next six years, and how storage can help meet the state's existing electric systems needs.

Source: Smart Electric Power Alliance, 2018

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Appendix D: State and Federal Energy Storage Incentives

TABLE 19: ENERGY STORAGE INCENTIVES BY FEDERAL AND STATE GOVERNMENTS

FEDERAL	The Solar Investment Tax Credit (ITC), established by the Energy Policy Act of 2005, was updated in 2015 to clarify energy storage eligibility. Residential energy storage systems are only eligible for the 30% credit if they are charged by an on-site solar system. Owners of commercial energy storage systems can claim a percentage of the tax credit based on how much of the the storage system's discharged electricity is charged by an interconnected renewable generator. Anything less than a 75% charge from a renewable energy system receives no credit while charges greater than 75% receive a credit proportional to the rate at which they are charged up to 100% multiplied by the 30% credit.[5]
NEVADA	SB 145[56] of 2017 mandates Nevada's Public Utilities Commission (PUC) to establish energy storage incentives under the Solar Energy Systems Incentives Program. The state's total energy storage incentives paid out by utilities is broken into two sub-categories each totaling $5 million. One category targets residential and small commercial customers, while the other identifies systems between 100 kW and 1 MW. Additionally, the law defines storage devices as within the same category as solar, wind, and geothermal on the basis that they all deliver energy.The Nevada PUC is currently working with stakeholders and is expected to implement the new incentive program later this year.
MARYLAND	Maryland is offering a 30% tax credit for energy storage systems. The credit is capped at $5,000 for residential and $75,000 for commercial projects. There is an aggregate cap of $750,000 on tax credits issued to taxpayers in a taxable year and credits will be issued on a first-come, first-serve basis. The tax credit can be applied to systems installed between Jan. 1, 2018, and Dec. 31, 2022. In February 2018, the Maryland Energy Administration began accepting applications for the tax credit program. As of June 19, 2018, there was $170,382.40 available for residential tax credits and $525,000 available for commercial tax credits.[57]
CALIFORNIA	Self-Generation Incentive Program (SGIP), California's statewide incentive program, provides rebates to support distributed energy resources interconnected behind the customer's meter. Energy storage qualifies under two categories of resources: Small Residential (<10 kW) and Large Scale Storage (>10 kW, up to 5 MW). In 2017, the California Public Utilities Commission approved a budget increase to more than $48 million in rebates for small residential storage systems and more than $300 million for large-scale storage systems. The state also allocated $70 million for energy storage rebates in low-income communities. The program has an annual budget of $166 million through 2020 for storage and other technologies. The program will continue until the full subscription amount is reached or end by January 1st, 2021.[58]

Source: Smart Electric Power Alliance, 2018.

55 Docket No. 201809003, IRS, March 2, 2018. https://www.irs.gov/pub/irs-wd/201809003.pdf

56 Senate Bill 145. Nevada General Assembly, 2017 https://www.leg.state.nv.us/App/NELIS/REL/79th2017/Bill/4981/Text

57 "Energy Storage Tax Credit Program - Tax Year 2018." Maryland Energy Administration, 2018 http://energy.maryland.gov/business/Pages/EnergyStorage.aspx

58 "Self-Generation Incentive Program" California Public Utilities Commission http://www.cpuc.ca.gov/sgip/

Appendix E: Survey Participants

AEP Ohio
AEP Texas
Alger Delta Cooperative Electric Association
Algoma Utilities
Alliant Energy—IA
Alliant Energy—WI
American Samoa Power Authority
Appalachian Power
Appalachian Power / Wheeling Power
Arizona Public Service
Austin Energy
Avista Utilities
Baltimore Gas & Electric
Baraga Electric Utility
Black Hills Energy—Colorado Electric
Black River Falls Municipal Utilities
Boscobel Utilities
Brodhead Water & Light
Brunswick Electric Membership Corp.
Cedarburg Light & Water Utility
City of Anaheim, Public Utilities Department
City of Palo Alto Utilities
City of Rock Hill
City of Tallahassee
City Utilities of Richland Center
City Utilities of Springfield, MO
Clark Public Utilities
Columbus Water & Light
Commonwealth Edison
Consolidated Edison
CPS Energy
Crystal Falls Electric Department
Cuba City Light & Water
Cumberland Valley Electric
Dayton Power and Light
Denton County Electric Cooperative, Inc., d/b/a CoServ Electric
Dominion Energy North Carolina
Dominion Energy Virginia
DTE Energy
Duke Energy Carolinas
Duke Energy Florida
Duke Energy Indiana
Duke Energy Ohio
Eagle River Light & Water Utility
Eau Claire Energy Cooperative
El Paso Electric Co—NM
El Paso Electric Co—TX
Entergy Arkansas, Inc.
Entergy Louisiana, LLC
Entergy Mississippi, Inc.
Entergy New Orleans, Inc.
Entergy Texas, Inc.
Evansville Water & Light
Farmers Electric Cooperative
Florence Utilities
Florida Power & Light Company
Gainesville Regional Utilities
Gladstone Power & Light
Glasgow Electric Plant Board
Glendale Water & Power
Green Mountain Power
Guadalupe Valley Electric Cooperative, Inc.
Hartford Electric
Hawaii Electric Light Company
Hawaiian Electric
Heber Light & Power
Henderson Municipal Power and Light
Holy Cross Energy
Hustisford Utilities
Imperial Irrigation District
Independence Light & Power, Telecommunications
Indiana Michigan Power—IN
Indiana Michigan Power—MI

APPENDIX E: SURVEY PARTICIPANTS, CONTINUED

Indianapolis Power & Light Company
Jefferson Utilities
Jersey Central Power & Light
Juneau Utilities
Kauai Island Utility Cooperative
Kaukauna Utilities
Kentucky Power
Kingsport Power
L'Anse Electric Utility
Lake Mills Light & Water
LG&E/KU
Lodi Utilities
Los Angeles Department of Water and Power
Maquoketa Municipal Electric Utility
Maui Electric
Medina Electric Co-op
Memphis Light, Gas and Water
Menasha Utilities
Metropolitan Edison Company
Middle Tennessee Electric Membership Corporation
Monongahela Power Company
Mount Horeb Utilities
Muscoda Utilities
National Grid—MA
Negaunee Electric Department
New Glarus Utilities
New Hampshire Electric Cooperative
New Holstein Utilities
New London Utilities
New Richmond Utilities
Niagara Mohawk Power Corporation
Northern States Power Minnesota—MN
Northern States Power Minnesota—ND
Northern States Power Minnesota—SD
Northern States Power Wisconsin—MI
Northern States Power Wisconsin—WI
NV Energy
Oconomowoc Utilities
Oconto Falls Municipal Utilities
OGE Energy Corp
Ohio Edison Company
Oncor
Orlando Utilities Commission
Otero County Electric Cooperative Inc.
Otter Tail Power Company
Pacific Gas & Electric
PECO
Pedernales Electric Cooperative
Pennsylvania Electric Company
Pennsylvania Power Company
Piedmont EMC
Plymouth Utilities
Portland General Electric
PPL Electric Utilities
Prairie Du Sac Utilities
Preston Municipal Electric Utility
Public Service Colorado
Public Service Company of New Mexico
Public Service Company of Oklahoma
Public Service Electric and Gas
Public Utility District No. 1 of Benton County
Puget Sound Energy
Randolph Electric Membership Corporation
Rappahannock Electric Cooperative
Reedsburg Utility Commission
River Falls Municipal Utilities
Riverside Public Utilities
Roseville Electric
Sacramento Municipal Utility District
Salt River Project
San Diego Gas & Electric
Santee Cooper
Seattle City Light
Slinger Utilities
Snohomish County Public Utility District No. 1

APPENDIX E: SURVEY PARTICIPANTS, CONTINUED

South Carolina Electric & Gas
Southern California Edison
Southern Maryland Electric Cooperative
Southwestern Electric Power—AR
Southwestern Electric Power—LA
Southwestern Electric Power—TX
Southwestern Public Service—NM
Southwestern Public Service—TX
Sterling Municipal Light Dept
Stoughton Utilities
Sturgeon Bay Utilities
Sun Prairie Utilities
Tampa Electric Company
Taylor Electric Cooperative
The City of Norway Department of Power & Light
The Illuminating Company
The Narragansett Electric Co.
The Potomac Edison Company—MD
The Potomac Edison Company—VA
The Potomac Edison Company—WV
Toledo Edison Company
Trico Electric Cooperative, Inc.
Truckee Donner Public Utility District
Tucson Electric Power Company
Two Rivers Water & Light
UNS Electric, Inc
Vectren
Vernon Electric Cooperative
Village of Minster
Vineland Municipal Electric Utility
Waterloo Utilities
Waunakee Utilities
Waupun Utilities
West Penn Power Company
Westar Energy, Inc.
Westby Utilities
Wheeling Power
Whitehall Electric Utility

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