Advancing Batteries to Enhance the Electric Grid
Chapter One: Front-of-Meter Applications

July 13, 2017
The GridWise Alliance, Inc. – Washington, DC
info@gridwise.org

To download this white paper, please click here.

About the GridWise Alliance:

The GridWise Alliance (GWA) represents the broad and diverse stakeholders that design, build and operate the electric grid, and consists of: electric utilities; information and communications technologies (ICT); and other service and equipment providers; Independent System Operators (ISOs) & Regional Transmission Organizations (RTOs); colleges and universities; and, energy consulting firms. Since 2003, the GridWise Alliance has been at the forefront of educating legislators and regulators on the critical need to modernize our nation's electricity system.

Table of Contents – Full Report

Executive Summary

Energy storage is the only technology that can bank generated electricity and dispatch it later when needed. In recent years, advanced energy storage technologies[1], specifically batteries, have evolved substantially and their costs continue to decline significantly, amplifying the value they can provide to our electric grid. As intermittent generation continues to be added to the grid, fast and flexible resources such as batteries are increasingly needed to balance wind and solar's variable output. With their unique physical and operational characteristics, batteries directly connected to the transmission and/or distribution systems (front-of-the meter") have the potential to cost-effectively increase the electric grid's reliability, resiliency and operational flexibility and facilitate integration of intermittent resources. Customer–sited battery systems ("behind-the-meter") also can provide a variety of cost and reliability benefits. This white paper, however, focuses on battery systems deployed in front-of-the meter.

Significant Potential Benefits of Batteries

Reduce grid operation costs	Enhance grid operations and customer service	Promote highly skilled jobs and public policy goals
Defer or avoid the need for new power plants	Improve reliability for customers with frequent outages	Support effective integration and operation of intermittent generation
Defer or avoid the need for grid infrastructure projects	Help ensure power quality across the grid by stabilizing grid operations	Reduce emissions
Lower ongoing electricity production costs	Provide vital ancillary services	Mitigate over generation events and curtailment of intermittent generation
Minimize line losses	Improve resiliency for critical customers and through Black Start capability	Reduce inefficient ramping of conventional generation
	Enable aggregation and coordinated dispatch	Promote innovation and highly skilled jobs

Although batteries have the potential to offer numerous value streams to enhance the electric grid's efficiency and operations, existing laws, regulations, and market treatment highlighted below often artificially restrict batteries from leveraging and

[1] Conventional energy storage includes pumped hydroelectric and thermal. Advanced energy storage comprises newer, more flexible forms such as batteries, flywheels. This white paper focuses on batteries.

maximizing their multiple capabilities, resulting in missed opportunities and substantial lost value[2].

Significant Challenges to Batteries' Widespread Deployment

Challenges Regarding Existing Laws and Regulations Impacting Ownership and Allowed Usage

- Because most laws and regulations when originally drafted did not even consider battery technology, they will need to be clarified and adapted to this rapidly emerging technology.
- In several states, batteries are misclassified as generation assets even when their primary application is as transmission or distribution assets, which can prohibit or hamper electric distribution companies ("EDCs") from owning batteries, and receiving regulated cost recovery for them.
- Laws and regulations also often restrict battery projects from participating in the energy, capacity and ancillary services markets when they are available to do so.

Challenges Regarding Market Mechanisms

- The numerous potential system-wide efficiencies and enhancements batteries can offer often are not compensated.
- Market classification rules often fail to reflect batteries' potential multiple services and thus artificially limit their value and full participation.
- Wholesale market rules focusing on a specific type of resource rather than on the service needed prevent batteries from offering all of the capacity, energy and ancillary services they technically are capable of providing.

Challenges Regarding System Planning

- EDC's long range integrated resource and distribution planning generally have not considered the value batteries can provide, in part

[2] As highlighted in a recent comprehensive report by the Interstate Renewable Energy Council, "[Energy storage assets'] unique ability to act as supply, demand and infrastructure and to switch between these roles is what makes storage valuable, but also what challenges its integration into the system." Charging Ahead: An Energy Storage Guide for Policymakers, IREC, April 2017, p. 2 (hereinafter "IREC")

because they were expensive and not well proven technically and commercially.

Recommended Actions

To overcome these challenges and artificial barriers to batteries' widespread implementation, it is vitally important to recognize the full range of functions and services batteries can provide and to enact business model, rate structure and regulatory reforms which reflect batteries' unique characteristics and enable EDCs and third party competitive providers to own and operate these valuable grid assets. In particular, the GridWise Alliance[3] recommends policy makers consider the following steps:

- ☑ Batteries with a primary purpose of supporting the transmission or distribution system should be allowed to be classified as transmission or distributions assets, respectively.
- ☑ Subject to a streamlined project review process, EDCs should be allowed to own, and apply rate-based treatment as grid assets to, batteries and their associated control systems.
- ☑ To maximize the benefits of batteries connected to the distribution system, EDCs should have visibility into and some level of input into and control of, such projects.
- ☑ To help ensure a level playing field for third-party competitive providers, policy makers should encourage that EDC-owned and rate-based battery projects pass a reasonable economic benefit-to-cost screen before implementation.
- ☑ Policy makers should encourage EDCs to proactively evaluate batteries side-by-side with conventional resources.
- ☑ Policy makers should allow EDC-owned and rate-based battery projects to participate in the energy, capacity and ancillary services markets.
- ☑ Policy makers must ensure that batteries can offer all of the services they are technically capable of offering and be compensated fairly for those multiple services. In particular, policy makers should remove artificial barriers to market participation by implementing technology neutral rules and definitions, focusing not on specific resource types, but rather on a resource's ability to provide the service needed.

[3] The GridWise Alliance comprises a unique cross-section of members, including EDCs, information and technology equipment and service providers, national laboratories, academic institutions, Regional Transmission Organizations ("RTOs"), and Independent System Operators ("ISOs"). GridWise Alliance has been working since 2003 to advance the modernization of the electric system.

- ☑ To effectively assess batteries' optimal applications, societal benefits and system impacts, state policy makers should establish well-designed demonstration projects and pilot programs, ("referred to collectively as "Pilots") with clear objectives and transparent evaluation processes. Such Pilots are needed not only to test, measure and verify this emerging technology's costs and benefits, but also to help identify preferred business and regulatory models and rate design structures.
- ☑ The Department of Energy ("DOE") should continue to fund demonstration projects and pilots that promote sharing lessons-learned and leveraging best practices among grid operators.
- ☑ The DOE also should continue to fund robust research and development efforts to further expand battery capabilities and lower costs.

In addition to discussing batteries' wide-ranging potential benefits, the most significant barriers to their broad deployment and possible strategies to overcome these challenges, this white paper also contains an Appendix highlighting technology advances and cost trends in batteries and current state actions to promote their implementation.

I. Batteries' Potential Substantial Benefits

A. Reduce Grid Operation Costs

i. Defer or Avoid Generation and Grid Infrastructure Projects

EDCs' fundamental statutory and regulatory obligation is to provide their customers safe, reliable affordable electric service in an environmentally sustainable manner. To ensure their customers have the energy they need when they need it, the power grid must be built to handle the highest (i.e., peak usage), although average usage throughout the year is a fraction of that. For example, according to the U.S. Energy Information Administration ("EIA") each year nationally natural gas "peaker" plants operate on average merely 2%-7% of the hours.[4]

Unlike conventional generation, batteries can be sited easily in populated areas where high load exists. A grid-scale battery project requires a much smaller footprint and can be constructed within months, not years. Further, the modular design of storage installations enables sizing the project so that they can be built and configured to meet the exact system need. Such "plug and play" capability also simplifies adding capacity increments as needed.

During off peak periods, batteries strategically configured on the grid close to load centers can be charged from the grid. Then, during times of system peak they can be discharged to supply nearby customers, thus reducing the peak quantities of electricity transported across the grid. Because batteries can provide additional capacity during such peak demand periods, fewer generation plants will need to be built to ensure resource adequacy. Also, by reducing the amount of electricity that must be transported across the grid, batteries may enable EDCs to defer, or possibly avoid, distribution and transmission system investments such as upgrading a substation or feeder or upgrading a transmission line.

ii. Lower Ongoing Electricity Production Costs and Minimize Line Losses

Batteries can also lower ongoing electricity production costs. Without batteries, during peak usage grid operators must either dispatch the generation resource with the most expensive dispatch costs, which then sets electricity prices, or even interrupt customers' service. Conversely, grid integrated batteries can be charged during lower priced, lower load hours and discharge stored energy during higher priced, higher load hours. Over time, batteries have the potential to

---

[4] Massachusetts Department of Energy Resources, et al., State of Charge: Massachusetts Energy Storage Initiative Study, available at http://www.mass.gov/ees/docs/doer/state-of-charge report/pdf., at p. vii, Fig. 8 (hereinafter "State of Charge")

minimize line losses on the system as well. The quantity of losses at any time is due in part to converting electric energy to heat at a rate proportional to the square of the current. Therefore, the line loss factor may be higher during higher priced, higher load hours when batteries discharge, than during lower priced, lower load charging hours. Across time, this could translate into a net line loss reduction.[5]

B. Enhance Grid Operations and Customer Service

i. Improve Reliability

Batteries can improve customers' reliability by avoiding or reducing the duration of outages. For example, when a system disruption between a customer site and supplying power plant causes an outage, batteries sited close to the customer can discharge, either preventing an outage entirely or at least decreasing its duration. Having batteries mitigates sudden outages. Further, EDCs can notify customers on battery power because of a grid outage the battery's estimated duration so they can conserve energy and plan for a possible loss of power once the battery is fully discharged.

Batteries also can improve reliability by stabilizing grid operations. When electricity supply and demand match perfectly the grid operates at a specific frequency (60 hertz). Significant deviations from this frequency, such as when supply exceeds demand or vice versa, can harm power system equipment or even cause blackouts. Given their unique ability to charge and discharge power rapidly, batteries can provide vital ancillary services to help stabilize the grid at the 60 MHz frequency required to operate the grid reliably. Such ancillary services include frequency regulation to maintain alternating electric current cycle rates, operating reserves to provide power on short notice to satisfy short term demand increases, and voltage support to stabilize the level of current customers receive.

Frequency regulation manages deviations of grid frequency by increasing output from a dispatchable resource -- such as storage -- to offset reduced output from a non-dispatchable resource -- such as wind --, or to match increasing load. Batteries providing frequency regulation respond to grid signals to either inject more or less energy for a short period, or alternatively charge more or less quickly. They can also offer reserve capacity, which is available almost instantaneously for unanticipated and immediate system capacity needs.

[5] Energy losses associated with the round-trip efficiency of a given battery project are a separate consideration, and should be considered when performing the economic evaluation of any such project.

Batteries also can help to maintain grid stability by absorbing or injecting power to ensure proper voltage levels. Voltage support is especially important with increasing penetration of intermittent generation. When region-wide or local voltage emergencies occur, voltage support from batteries can defer the need for traditional voltage support upgrades (e.g., installing capacitors), as well as offset the need to use large, central generation to provide reactive power to the grid.

Further, as more customer-sited solar generation is connected to the grid, power flows change. Rather than flowing only from the substation to consumers, at any time power can flow in either direction. Batteries at substations enable the grid operators to safely and reliably handle reverse power flows, while also deferring or avoiding the need for costly system infrastructure investments.

ii. Improve Resiliency

Whether based on the threat of terrorism or severe weather, those charged with protecting our country's vital infrastructure agree electric grid resilience is essential. Grid resilience reflects the system's capacity to recover quickly from a severe disruption such as extreme weather event or other disaster. Strategically placed batteries can provide the power required to help keep emergency response services and critical facilities on line during a disruption. For longer duration grid outages, batteries can provide valuable quick response, help balance load changes to reduce fuel use and wear and tear on generation, and facilitate integration of any functioning on-site solar.

Batteries also can offer some Black Start capabilities, i.e., the power required to jump-start an off-line power plant after an outage. After a grid-wide outage, Black Start resources are the first to power-up to reenergize the grid. Significantly, Black Start resources must be able to start up without power from the grid and, while disconnected from the grid, must continue to operate in standby mode until called upon. Batteries, which require no special equipment and need not operate while awaiting dispatch, have the potential to serve a valuable Black Start role as discretionary load during the bulk power grid process, when the grid can be rather fragile.

iii. Support Effective Integration and Operation of Intermittent Generation

The increasing deployment of intermittent generation such as wind and solar can create significant, and potentially costly, grid management and reliability issues. With such variable power supply, the primary challenge is to keep the grid in balance, meaning that on a second-to-second basis supply must be closely matched to load to maintain the required frequency and voltage levels. Uncontrollable weather changes such as rapidly shifting wind patterns and unpredictable cloud migration, however, can immediately reduce generation output, causing instability issues. Similarly, solar output increases rapidly when the sun rises and decreases quickly when the sun sets. Batteries are especially well positioned to balance such fluctuations. A recent report from the Interstate

Renewable Energy Council underscored batteries' value in integrating intermittent generation, noting "The inherent flexibility of energy storage systems makes them optimal candidates to help smooth the variability associated with integrating high volumes of renewable resources."[6]

Batteries strategically sited in areas with substantial intermittent generation or where large systems are interconnected on very lengthy or lightly loaded distribution feeders, can charge or discharge extremely rapidly, absorbing any power flow fluctuations that result when the wind stops blowing or clouds cover the sun.

With increasing penetration of variable resources, occasionally the grid experiences "over generation". Over generation occurs when power supply exceeds real-time demand and is driven principally by an oversupply of solar. Without energy storage, operators in general will intentionally reduce or curtail intermittent generation to stabilize the grid. When co-located on the grid with variable power supply or deployed nearby, however, batteries can mitigate curtailment of such intermittent generation by absorbing energy when output exceeds demand and discharging that energy when demand exceeds supply.

iv. Enable Aggregation and Dispatch

Not only can each battery system independently offer these system benefits, but also advances in system controls enable combining multiple systems at different sites to work together as a coordinated asset, thus increasing their net benefit to the grid and to society. At times called "Virtual Power Plants", these aggregated networks could, for example, export energy simultaneously from separate locations and participate in a competitive market as one combined system, or during system peaks, could simultaneously reduce their loads to lower demand and thus lower system operating costs. To the extent necessary to ensure safe, reliable service to customers, as the distribution system operator, EDCs would need to maintain a "line of sight" to any such portfolio of assets. This could be accomplished, for example, by requiring the inclusion of communications and control facilities such as a smart inverter, which provides two-way communications capability with the EDC. Such enhanced coordination through open management systems will help maximize the societal value of batteries, but would not preclude merchant developers from developing, owning and operating battery projects.

---

[6] IREC at 42. See also, Energy Storage - Balancing the 21st century power grid, by Terry Boston and Scott Baker, IEEE Electrification Magazine, September 2015, Volume 3, Number 3, (hereinafter "Balancing the 21st century grid") at 53. "Energy storage devices may provide the best resource for services needed to maintain grid reliability in a scenario where a large percentage of generation will come from variable resources."

C. Promote Public Policy Goals and Highly Skilled Jobs

i. Reduce Emissions

Batteries' ability and economic incentive to charge during off-peak periods and discharge during on-peak periods shifts electricity generation to off peak hours. During off peak hours, power generation facilities with lower dispatch costs and lower emission rates, such as nuclear and wind, are more likely to be the marginal resources for dispatch. Thus, charging and discharging batteries tends to increase dispatch of lower emission resources while decreasing dispatch of higher-emission units.

Similarly, with greater penetration of variable resources such as wind and solar, over generation events and curtailment of intermittent generation could increase. In the absence of batteries, when intermittent generation is curtailed, the system often relies upon fossil-fueled dispatchable resources to compensate for intermittency. With their long start times these resources, however, must run continuously, even when not needed, to rapidly meet the substantial demand increases in the afternoon hours. This inefficient on-off, fast ramping use of fossil-fired units increases air pollution and undermines emission goals.[7] As noted previously, however, batteries can mitigate over generation and curtailment events and thus can help reduce emissions.

ii. Promote Innovation and Highly Skilled Jobs

Increased demand for batteries should drive expanded research and development in the U.S. to further reduce the costs and enhance the capabilities of this rapidly evolving, potentially game changing technology. In addition, such increased demand should help expand jobs in batteries' supply chain, including hardware and associated software support. Also, because strategically placed batteries can facilitate both distributed and utility scale intermittent generation their widespread deployment also should increase jobs in wind and solar.

Grid-integrated batteries also provide EDCs and other operators invaluable first-hand experience to assess the capabilities, effective uses and overall value of this promising technology. As batteries' deployment grows, operators will gain critical expertise on how best to use batteries to optimize grid reliability, resiliency, sustainability and operational flexibility while facilitating integration of intermittent generation and lowering costs for society. Such increased expertise and learning may include, for example, what software and controls are required to maximize batteries' operations in different environments and the effectiveness of batteries in providing multiple services.

[7] CAISO. What the Duck Curve Tells Us About Managing a Green Grid.doi:CommPR/HS/10.2013

II. Significant Challenges to Batteries' Widespread Deployment

A. Challenges Regarding Existing Laws and Regulations Impacting Battery Ownership and Allowed Uses

Several of the potential benefits of batteries we have described pertain directly to their application as valuable distribution and transmission assets, which can cost-effectively increase the electric grid's reliability, resiliency, and operational flexibility. For example, a given battery project's ability to defer the need for other grid infrastructure projects, to help ensure reliability and power quality across the grid, and to facilitate the integration of intermittent and distributed generation on the grid are attributable to how the project enhances the grid's effectiveness in handling power flows, changes to voltage levels, and other disruptions on the grid. Indeed, much like capacitors, static VAR compensators, phase angle regulators, and other power electronics, batteries can provide a host of customer benefits and operational enhancements to the grid. And in many cases, the same battery project also can provide other benefits described above (often related to the energy, capacity, and ancillary services markets)[8] that make the project's economics more attractive, thereby providing the greatest value for society and expanding the opportunities for economic energy storage deployment.

As with other transmission and distribution assets, EDCs are well positioned to identify and implement battery projects that will enhance the grid's capabilities if processes are established for them to do so. So, facilitating EDC ownership and operation of batteries promotes efficiency and helps to ensure reliability. For example, integration of batteries for system purposes requires careful planning and coordination with the overall distribution system, and (just as with any grid asset) the EDC as the distribution system operator is well positioned to make and execute decisions about optimal battery placement and operations. Furthermore, to the extent the batteries are needed for system reliability purposes, the EDC requires control of them as the distribution system operator, and ownership facilitates that control.

Unfortunately, however, laws and regulations often limit the ability to execute battery projects to enhance grid capabilities, and/or they limit extracting the maximum value from such projects. Because most laws and regulations when originally drafted did not even consider battery technology, they will need to be updated and adapted to this highly flexible, versatile and rapidly evolving technology. Further, in several states, laws or regulations prohibit or hamper utility ownership and regulated cost recovery of batteries, often by misclassifying batteries

---

[8] Although batteries can provide multiple services, in some circumstances, such as when used for one application (e.g., T&D deferral), they may not be available for other applications (e.g., peak load dispatch).

as a generation asset even when their primary application is as a transmission or distribution system asset.[9] As GridWise Alliance has stressed in various regulatory forums, it is "important to establish a permissive ownership structure that promotes the expanded use of storage, while ensuring a level playing field exists for both utilities and third party competitive providers."[10]

Furthermore, even if EDC ownership and regulatory cost recovery is allowed, laws and regulations often restrict such battery projects from participating in the energy, capacity, and ancillary services markets when they are technically capable and available to do so. Indeed, when not needed for its primary system/reliability purpose, a battery project should be dispatched in a way that maximizes its value, by, for instance, cyclically charging and discharging in response to energy market prices, providing operating reserves or frequency regulation services, and participating in the capacity market. Artificially restricting batteries from leveraging and maximizing their multiple value streams limits the benefits and value they can offer to the electric grid and to society.

B. Challenges Regarding Market Mechanisms

Batteries' cost-competitiveness depends on regulations that allow full and fair compensation for all of its services.[11] Notably, however, the numerous system-wide efficiencies and enhancements batteries can offer often are not compensated.[12] In a recent report, the Edison Electric Institute (EEI) noted that current regulations developed when pumped hydro was the only form of energy storage fail to consider the characteristics and "intrinsic flexibility" of newer, advanced energy storage such as batteries.[13] Accordingly, most current state, regional and federal regulations prevent batteries from offering and monetizing its multiple value streams, resulting in storage being "effectively underutilized and undervalued".[14]

A related critical barrier to broad deployment of batteries is their inability to effectively access wholesale markets. For example, wholesale price signals lack transparency and market classification rules often fail to reflect batteries' potential multiple services and thus artificially limit batteries' full participation. Rules may focus on a specific type of resource rather than on the service needed, preventing batteries from offering all of the capacity, energy and ancillary services they technically are capable of providing. For instance, although under California

---

[9] EDC owned energy storage with rate recovery is, or soon could become, a reality in some jurisdictions. See, e.g., NYPSC System Implementation Plan Filings at pp.29-30; NYPSC Clean Energy Standard at p.104; State of Charge recommending EDC-owned, rate-based storage located at MA utility substations.
[10] NYPSC, Reforming the Energy Vision 2/26/15 Order at p. 124
[11] IREC at 14
[12] Ibid. at 10
[13] Edison Electric Institute, Harnessing the Potential of Energy Storage: Storage Technologies, Services, and Policy Recommendations, April 2017 at 15 (hereinafter "EEI")
[14] IREC at 2

Independent System Operator (CAISO) rules, energy producers' batteries are counted for resource adequacy purposes if they can supply electricity for four hours[15], in other wholesale markets related rules may be unclear or non-existent.

Subject to the fundamental principles of safety, reliability and well-functioning markets, RTOs and ISOs should remove any artificial barriers to batteries' full participation, while maintaining the right to develop reasonable requirements specific to their markets. More accurate and precise market mechanisms are needed to help capture the full value stream of batteries' multiple services, including, for instance, how quickly a resource can be operational to provide flexibility, or how frequently a resource can be cycled on and off the system to provide support.[16] In recognition of this need, the Federal Energy Regulatory Commission ("FERC") issued Order 755 in 2011, which, in part, directed the nation's competitive wholesale markets to compensate fast-responding (i.e., "dynamic") regulation resources appropriately.[17] In response, PJM developed a more transparent, intricate "pay-for-performance" valuation mechanism reflecting the value of faster response and greater accuracy in following regulation signals, which drove significant deployment of batteries.[18] Too, FERC recently issued a policy statement that provides guidance and clarification for batteries seeking cost-based rate recovery for services such as transmission or grid support services, while also receiving market-based revenues for providing separate market- based services.[19]

C. Challenges Regarding System Planning

Another barrier to broad deployment of batteries is that EDCs' long range integrated resource and distribution planning generally have not considered the value batteries can provide, in part because they were expensive and not well proven technically and commercially. As a rule, planning proceedings focus on how best to meet forecasted energy demand over a ten year or longer horizon. In the process, EDCs evaluate the costs and benefits of various options to address their future system needs. The distribution planning process typically is conducted bottom-up by planning engineers whose traditional planning tools do not include batteries. Further, given the potential multiple functions and services batteries can perform, including them in system planning is more complex as it would require addressing not just peak load, but also energy, especially the timing of charge and discharge, as well as system protection.

---

[15] See http://docs.cpuc.ca.gov/Published Docs/Published/G000/M097/K619/97619935.PDF
[16] ICF, Energizing Policy Evolution for the Grid Revolution, September 2016, at 13.
[17] FERC Order 755 (Docket Numbers RM11-7-000 and AD 10-11-000), Frequency Regulation Compensation in the Organized Wholesale Power Markets, October 20, 2011.
[18] Balancing the 21st century grid at 55.
[19] Federal Energy Regulatory Commission, Docket No. PL17-2-000, Utilization of Electric Storage Resources for Multiple Services When Receiving Cost-Based Recovery, Policy Statement, January 19,2017, available at: https://www.ferc.gov/whats-new/comm-meet/2017/011917/E-2.pdf.

Most significantly, once finalized, these system plans determine major investments for many years. Therefore, failing to evaluate batteries as a viable option in these long-term planning efforts undermines their meaningful deployment, creating a "domino effect of lost opportunities."[20]

III. Recommended Actions

As detailed above, batteries can serve as extremely valuable grid modernization distribution or transmission assets which have the potential to cost-effectively enhance the grid's reliability, resiliency, flexibility and sustainability. To maximize batteries' benefits to society it is vitally important to recognize the full range of functions and services batteries can perform and implement reforms which reflect their unique capabilities. As such, we recommend policy makers pursue the following steps:

- ☑ Batteries with a primary purpose of supporting the transmission or distribution system should be allowed to be classified as transmission or distribution assets, respectively.
- ☑ Subject to a streamlined project review process, EDCs should be allowed to own batteries, and to apply rate-based treatment as grid assets to batteries and their associated control systems.
- ☑ Further, to help ensure effective coordination to maximize the benefits of battery projects connected to the distribution system, EDCs should have visibility into, and some level of input into and control of, such projects.
- ☑ To help ensure a level playing field for third-party competitive providers, policy makers should encourage having EDC-owned and rate-based battery projects pass a reasonable economic benefit-to-cost screen before implementation.
- ☑ Policy makers should encourage EDCs to proactively evaluate batteries fairly, side-by-side with conventional resources.
- ☑ EDC-owned and rate-based battery projects should be allowed to participate in the energy, capacity, and ancillary services markets.
- ☑ Policy makers must ensure that batteries can offer all of the services they are technically capable of offering and be compensated fairly for the multiple services provided. To help accomplish this, policy makers should remove artificial barriers to market participation by implementing technology neutral rules and definitions for market products such as ancillary and reliability services, focusing not on specific resource types, but rather on a resource's ability to provide the service needed. Too, they should create more precise and accurate price signals, rates, and compensation and

[20] IREC at 31

valuation mechanisms.[21] Such modifications will help ensure "product and eligibility are tied to the underlying operational needs of the system and not the characteristics of specific types of generation".[22]

- ☑ To effectively assess batteries' optimal applications, societal benefits and system impacts, state policy makers should establish Pilots, with clearly defined objectives and transparent processes to track, measure and evaluate the outcomes. Pilots are needed not only to test, measure and verify this emerging technology's costs and benefits, but also to help identify the best business and regulatory models and rate design structures. Pilots can enhance participants' expertise with batteries by providing them invaluable first-hand operational experience. To expedite widespread battery deployment, Pilots also should include a knowledge/technology sharing requirement.[23] Such vital peer-to-peer sharing of best practices will enable other states to leverage the critical lessons learned and the reliable "real world" data produced to avoid unnecessary duplication of efforts. This will help ensure successful approaches can be replicated more rapidly, allowing states "to plan for more immediate regulatory actions rather than needing to take as many exploratory steps up front…."[24] To promote valuable Pilots, states can, for example, fund them through direct financial incentives, or clean energy funds or grants.
- ☑ Given the tremendous value they offer, DOE should continue to fund those Pilots that promote sharing lessons-learned and leveraging best practices among grid operators.
- ☑ Through its Joint Center for Energy Storage Research, particularly its Battery/Energy Storage Innovation Hub, DOE should continue to fund robust research and development efforts to further expand battery capabilities and lower the costs of this rapidly evolving technology.

IV. Conclusion

Batteries are uniquely versatile grid modernization assets, which can help the nation advance a reliable, resilient, affordable, and sustainable electric system. Increasingly, fast and flexible resources such as batteries are needed to balance intermittent resources and help maintain grid reliability. Yet despite declining costs and technological advances, numerous obstacles remain to wide-scale

---

[21] For example, batteries' locational and rapid response values may not be included in a straightforward cost- benefit ratio or average value per kWh.
[22] IREC at 15
[23] In its report on the outcomes and key accomplishments of a three-year pilot project using batteries, Pacific Gas and Electric Company ("PG&E") highlighted that "A primary benefit of the EPIC program is the technology and knowledge sharing that occurs…." EPIC Final Report, September 13, 2016, at 63. PG&E highlighted numerous benefits from the Pilot, noting "the project's learnings will enable more efficient and cost-effective integration of future battery storage resources…." Ibid at 66.
[24] IREC at 18

implementation of economic battery projects. As often happens with rapidly evolving new technologies, existing cost mechanisms, regulations, market rules and policies have not kept pace with recent technological advances in batteries and do not reflect the multiple potential benefits highly flexible and versatile assets can offer to maximize the benefits batteries can provide to the grid and to society, policy makers should reexamine existing policies and modify or create new ones as needed.

This page is intentionally blank.

Appendix A

Technology Advances and Costs Trends

Among the various battery technologies, lithium-ion ("Li-ion") batteries generally offer the greatest value for the foreseeable future. Li-ion batteries can provide a wide range of services, and are the easiest technology to site, permit and finance.[25] Furthermore, their cost effectiveness is bolstered by the economies of scale from their increasing adoption. In 2016, Li-ion batteries comprised about 97%[26] of the nation's grid-connected storage, with over 280MW of such utility-side batteries deployed.[27]

Recently, prices for Li-ion battery projects have decreased significantly. IHS, a recognized business data provider, stated that between 2012 and 2015 the average cost of Li-ion batteries decreased over 50%, with prices forecast to decrease over 50 % again by 2019.[28] In recent guidance, the Electric Power Research Institute ("EPRI") highlights that current installed costs of batteries in $/kW differ based on project size, duration and technology[29], with the most competitive suppliers estimated to offer large scale (50-100 MW, 4-hour) batteries for capacity applications for as low as $1,600/kW.[30]

As batteries' costs decrease, the capabilities of this rapidly evolving technology grow. Li-ion batteries are a mature technology suited to both power and energy-centric applications, and generally last 5-15 years.[31] Today some vendors can offer warranties of ten or more years.[32] Such systems can provide storage durations ranging from minutes to four or more hours and range in size up to utility scale systems interconnected to the bulk power grid. In 2016, the average system discharge duration for EDC deployments increased to 1.8 hours from only 30 minutes in 2015[33], signaling batteries no longer are limited to short duration applications such as frequency regulation, voltage stabilization and renewables

---

[25] GTM U.S. Energy Storage Monitor: Q4 2016 Full Report at 25 (hereinafter "U.S. Energy Storage Monitor
[26] Ibid. at 17. Lead acid batteries came in second with 2.7% of the market in Q3 of 2016.
[27] Ibid. at 25; U.S. Department of Energy, Global Energy Storage Database.
[28] IHS, Price Declines Expected to Broaden the Energy Storage Market, IHS Says, November 25, 2015.
[29] Batteries' different durations create additional cost complexities. Although most generation technologies have a relatively narrow range in $/W, this can vary widely for batteries depending on the ratio between power and energy. For example, a 15-minute system will have a lower $/kW, but higher 4/kWh, whereas a 4-hour system will have a higher 4/kW, but lower $/kWh.
[30] EPRI, Energy Storage Cost Summary for Utility Planning, November 2016, available at http://www.tdworld.com/sites/tdworld.com/files/uploads/2016/04/energy-storage-epri-report.pdf
[31] Lazard's Levelized Cost of Storage Analysis – Version 2.0, December 2016
[32] U.S. Energy Storage Monitor at 25
[33] Ibid. at 23

smoothing, but also can provide energy centric applications such as peak load shaving.

With such recent advances in new energy storage technologies as grid scale batteries, and declining costs, achieving significant value from broad deployment of batteries is increasingly viable. Provided existing obstacles to implementation are addressed, batteries have the potential to offer numerous societal benefits as detailed in the white paper.

Appendix B

State Level Support for Battery Deployment – First Movers

An EDCs' core obligation is to provide customers, in an environmentally sustainable manner, the safe, reliable, affordable electricity they need, when they need it. Recognizing batteries tremendous potential to help them fulfill this fundamental obligation, several states have proactively undertaken policy and regulatory actions to investigate and advance batteries' deployment. The following discussion provides illustrative examples of the variety of state efforts currently underway.

California

California has been the most active state in advancing batteries for grid services such as ancillary services, demand response and local capacity. In September 2010 the legislature enacted Assembly Bill (AB) 2514, the country's first energy storage mandate, requiring the state set energy storage procurement requirements for the state's three largest EDCs.[34] Pursuant to AB 2514, in October 2014, the California Public Utility Commission ("CPUC") approved requiring those EDCs to deploy 1.325 gigawatts of energy storage by 2020, 50 % of which the EDCs may own.[35]

In September 2016, California enacted AB 2868[36] requiring EDCs explore the feasibility of installing up to an additional 500 MW of energy storage, financed by ratepayers, with 75% allocated to front-of- the meter. In 2016, the legislature also passed AB 33 which directs the CPUC to analyze the potential for bulk energy storage to help integrate renewable generation.[37]

In May 2016, in response to limited gas supplies resulting from a natural gas leak and partial shutdown at Aliso Canyon, the governor issued a State of Emergency Proclamation. In part, the proclamation mandated expedited energy storage procurement as a potential solution to this unanticipated supply emergency because firm, dispatchable storage could be constructed, interconnected and deployed rapidly.[38] In fact, 60 MW of grid scale batteries were sited, constructed and put into operation in less than nine months, a fraction of the time required to permit and

[34] AB 2514, "Energy Storage System Procurement Targets from Publicly Owned Utilities was approved September 29, 2010 and entered into California Public Utilities Code, Chapter 7.7, Sections 2835-2839.
[35] CPUC decision D14-10-045, October 16, 2014 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M078/K929/78929853.pdf
[36] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160AB2868
[37] https://leginfo.legislature.ca.gov/billTextClient.xhtml?bill_id=20152016AB33
[38] CPUC Resolution E-4791 Authorizing expedited procurement of storage resources to ensure electric reliability in the Los Angeles Basin due to limited operations of Aliso Canyon Gas Storage Facility. May 26,2016

build a natural gas peaker. As of April 2017, all but 5 MW of the contracted 104.5 MW had come on-line.[39]

Significantly as well, before the Aliso Canyon procurement, most front-of-the meter systems were sub-hour durations designed to provide short-term generation for such power applications as frequency regulation. Conversely, all six systems in this procurement are 4-hour duration, representing one of the first large-scale opportunities for batteries to prove they can provide value to the grid beyond ancillary services and can serve as a rapid response capacity resource.[40]

Maryland

In May 2017 Maryland enacted SB 758, which establishes a five-year program offering up to $750,000 in income tax credits yearly for residential and commercial energy storage systems installed between January 1, 2018 and December 31, 2022.[41] Maryland is the first state to offer such a credit. Maryland also recently passed HB 773 which provides for a study of regulatory reforms and market incentives to promote deployment of energy storage systems in the state.[42] The Maryland public service commission also is considering energy storage as part of its distribution system transformation proceeding.

Massachusetts

In August 2016, Massachusetts enacted H. 4568 authorizing the DOER to set appropriate targets for EDCs to procure cost effective energy storage systems.[43] The bill explicitly permits EDC ownership of those systems in this deregulated market which limits EDC ownership of generation. Pursuant to H. 4568, in December 2016, the DOER decided it will adopt a storage procurement mandate by July 2017, which will be evaluated at least once every three years. In its related September 2016 State of Charge report, the DOER recommended a 600 MW storage procurement target by 2025, with 50% of the applications allocated to Commission-approved, EDC-owned, rate-based storage sited at EDC substations.[44] Highlighting batteries' ability to shave peak loads and thereby reduce customers' rates, as well as to facilitate integration of renewables, the DOER also recommended numerous policy changes to grow the state's storage market, including: allowing EDC ownership of energy storage as a grid modernization asset; amending the

---

[39] See Utility Dive
[40] U.S. Energy Storage Monitor at 40. In the mandate, the Commission specifically acknowledged that any storage procured provides reliability benefits benefitting all grid users, not just those in the EDC's service area, which allowed the EDC to apply the state's Cost Allocation Mechanism spreading their costs over all of the ISO's ratepayers.
[41] http://www.jdsupra.com/legalnews/maryland-enacts-first-in-the-nation-49486/
[42] Ibid.
[43] https://ma/legislative.gov./Bills/189/H4568.pdf
[44] State of Charge at 149.

Alternative Portfolio Standard to include all types of storage; and pairing storage with renewables in long term clean energy procurements.

Nevada

SB 204, which recently passed both chambers, requires the public utilities commission ("PUCN") to investigate and determine by October 1, 2018 whether to establish biennial energy storage procurement targets for the state's electric utilities.[45] In making its determination, the PUCN must consider, for example, whether storage will cost effectively improve grid reliability, facilitate integration of renewables and reduce greenhouse gas emissions. The Governor is expected to sign the bill.

New York

New York has undertaken modernization of its electrical infrastructure through its Reforming the Energy Vision ("REV") program. REV has entered the demonstration phase with several energy storage pilots.

In January 2016, the New York Public Service Commission ("NYPSC") approved a ten-year, $5.322 billion Clean Energy Fund, which includes funding for energy storage projects.[46] In March of 2017, the NY PSC required that by the end of 2018 each EDC must deploy and operate at least two energy storage projects at distribution substations or feeders.[47] Bill A6571, which would direct the NYPSC to establish a storage procurement target for 2030, has passed out of its first committee.

Notably as well, the NY PSC order on Clean Energy Standards[48] permits EDC ownership of storage in this deregulated market. Furthermore, the ConEd Brooklyn Queens Demand Management Program order[49] allows ConEd to pay third parties for storage projects that defer the need for a $1 billion substation and to receive full recovery plus a return on equity over ten years.

Ohio

In 2016, the public utility commission ("PUC") approved a joint settlement among AEP, PUC staff and ten intervenors agreeing AEP will include battery resources in future PUC filings, provided such resources are eligible for rate recovery as

---

[45] See http://www.leg.state.NV.US/Session/79th 2012/Bills/SB/SB204.pdf
[46] DPS, Docket No. 14-M-0094, Proceeding on Motion of the Commission to Consider a Clean Energy Fund, opened 2014
[47] NYPSC, Docket No. 16-M-0411, Order on Distributed System Implementation Plan Filings, at 33, March 2017 (hereinafter NYPSC Implementation Filings)
[48] NYPSC, Order Adopting A Clean Energy Standard, August 1, 2016 (hereinafter NYPSC Clean Energy Standard)
[49] New York DPS, Case Number 14-E-0302, Petition of Consolidated Edison Company of New York, Inc. for Approval of Brooklyn/Queens Demand Management Program

distribution assets. That same day, the PUC entered a similar finding for First Energy.

Oregon

In June 2015, Oregon enacted HB 2193, the nation's second energy storage mandate, which requires the state's two largest EDCs procure by 2020 a minimum of 5 MWh and up to one percent 2014 peak load of advanced energy storage. It also requires that the public utility commission conduct proceedings to create guidelines for the EDCs' procurement and approve EDC- specific project portfolios.[50]

The Commission determined that each EDC should, by January 1, 2020, procure aggregate storage capacity close to one percent of its 2014 load, the maximum amount allowed by HB 2193. In August 2016, the Commission submitted UM 1751, and circulated draft procurement guidelines for stakeholder input, with the goal of finalizing these guidelines by January 2017. By January 2018, the Commission must begin reviewing storage project proposals for implementation by the January 2020 deadline.

In a related proceeding, the Commission ordered Portland General Electric to address storage in its 2016 integrated resource planning ("IRP") in part to meet the EDC's procurement requirement. Notably the IRP includes an energy storage valuation mechanism to apply in future procurements identifying the following five value streams: energy shifting; ancillary services; avoided renewable curtailment; system peaking or capacity value; and locational value.[51]

---

[50] See http://www.leg.state.OR.US/Session 78th 2015/bills/HB/HB2193.pdf
[51] See Portland General Electric, 2016 Integrated Resource Plan, available at https://www.portlandgeneral.com/our-company/energy-strategy/resource-planning/integrated-resource-planning