Maryland Energy Administration in consultation with
Maryland Public Service Commission

Energy Storage: Considerations for Maryland

House Economic Matters Committee, Maryland General Assembly

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Contents

Overview

Energy storage is a maturing technology, with a history of serving both end users and the electric grid at large. Storage can provide a variety of functions in our electricity system, from supporting the efficient operation of the electric grid by regulating voltage, to providing backup power in emergency situations. Storage may also help reduce the need for transmission and distribution infrastructure investments by providing power during peak times on congested lines, shifting power consumption away from costly peak-demand periods, and balancing intermittent renewable energy sources. Batteries are the most recognizable form of energy storage, and for the most part this report will focus on battery storage; however, it is important to note that other forms of storage can play valuable roles in the energy system. The cost of battery storage is decreasing, increasing its deployment across all types of uses. Despite the decrease in cost, significant regulatory and market barriers exist to their deployment. This report provides background on various storage systems, details some of these barriers and identifies ways other states have addressed them. Additionally, there is consideration for Maryland's implementation of storage to meet Renewable Portfolio Standard (RPS) goals.

Types of Energy Storage

The type of energy storage system deployed in a given situation depends on the end use. Broad categories of end use are outlined in a later section, but generally the different types of storage options are selected based upon variables like storage duration, energy density (amount of energy a system can store) and power density (the speed with which the system can charge or discharge). For example, using storage to manage fluctuations in power quality may not require long storage duration, but would likely require a battery with high power density. Storage used for backup at a small business may require higher energy density, but lower power density. Various types of storage are displayed below, along with a chart showing the relative merits of several of the storage types.

Storage Technology	Main Advantage (Relative)	Disadvantage (Relative)	Power Application	Energy Application
High-Speed Flywheels	High power	Low energy density	●	X
Electrochemical Capacitors	Long cycle life	Very low energy density	●	X
Traditional Lead Acid (LA)	Low capital cost	Limited cycle life	●	◦
Advanced LA Batteries w/ Carbon Enhanced Electrodes	Low capital cost	Low energy density	●	●
Sodium-Based	High power & energy density	Cost and requirement to run at high temperatures	●	●
Lithium-Ion	High power & energy density	Cost and increase circuit control needs	●	○
Zinc Bromine	Independent power & energy	Medium energy density	○	●
Pumped Hydro Storage	High energy	Special site requirements	●	●
Compressed Air	High energy, low cost	Special site requirements	X	●

Key: ● = Fully capable and reasonable; ○ = Reasonable for this application; ◦ = Feasible, but not quite practical or economical; X = Not feasible or economical
Source: Adapted from *Grid Energy Storage,* U.S. Department of Energy, December 2013

Batteries

There are many types of batteries, characterized by the chemical components of the storage materials. Some examples of battery types are lithium-ion, lead acid and zinc-bromine. Each of these options boasts unique attributes that can determine what battery type is most effective for the desired application. For an overview of these attributes, see the chart above.

Flywheels

Flywheels are usually designed to store energy for very short periods of time, ideally for the purpose of maintaining the quality of electricity provided by the grid. Electric quality includes characteristics like frequency and voltage, which can fluctuate with the introduction or removal of electricity from the grid. This can cause grid disruptions that cause temporary power loss or damage energy system components. The key component of a flywheel is the composite rim, which resembles a barrel with the top and bottom removed. This rim is then placed in a vacuum chamber and levitated using magnets. When excess energy is pumped into the grid, the flywheel is used as an energy sink, where excess energy is used to rotate the levitating rim, much like a pottery wheel. The momentum of the rim in the vacuum is effectively storing energy that can be removed in the same way that a gas turbine works: turning the mechanical energy in the rotation of the rim into electrical energy through the same technology as a fossil-fuel turbine generator. When voltage levels normalize, the stored energy is gradually transferred back to the grid.

Pumped Hydro Storage

Pumped Hydro Storage (PHS) is by far the most mature and cost-effective means of storing large amounts of energy, depending upon the local topography and landscape characteristics and accounts for 98% of the energy storage capacity in the United States.[1] According to the Electric Power Research Institute (EPRI), 127,000 MW of PHS capacity exists around the world. PHS technology mainly relies on the force generated by gravity to store potential energy on a massive scale. While there are a variety of applications, the basic concept is to utilize excess energy generated in times of low demand to pump water to an elevated reservoir that can be released and ran through a generator system to effectively store low cost energy for use during times of peak demand, when energy is expensive. Major advantages of PHS over other systems include high levels of efficiency (up to 80% with new systems), very large storage scales and low costs. The challenge is that topography and environmental characteristics can cause additional costs and logistical challenges. There are five pumped hydro storage plants in the PJM Interconnection (two in Pennsylvania, two in Virginia and one in New Jersey). According to the DOE's Energy Storage Database, these plants provide energy time shifting, spinning reserve capacity and energy supply.

Owned by FirstEnergy, the Seneca Pumped Storage Generating Station functions like a battery. It absorbs excess power generated by plants such as FirstEnergy nuclear and fossil-fuel fired baseload plants in off-peak hours, such as nighttime, using it to pump water into a reservoir. Later, when demand exceeds the base load, the flow of water from the reservoir generates additional electrical power to meet peak load demands.

[1] Marcy, Cara. "Nonhydro Electricity Storage Increasing as New Policies Are Implemented." April 3, 2015. Accessed December 30, 2015. http://www.eia.gov/todayinenergy/detail.cfm?id=20652.

Compressed Air Energy Storage

Compressed Air Energy Storage (CAES) relies on similar principles to that of pumped hydro storage. However, instead of the potential energy being stored and captured using gravity, CAES instead compresses air in an underground cavern that is then released through a turbine generator.
While this technology has more flexibility of implementation than PHS technologies, it is considerably more expensive and less efficient. Accordingly, only a few major CAES installations are operational including systems in Alabama and in Germany.

Costs

The cost of various storage technologies varies widely. The costs are summarized in the table below, along with the maturity of the technology. The maturity categories include research (least mature), development, demonstration, deployment, and mature.

Lithium-ion batteries are currently experiencing the most rapid growth and investment. These batteries are leading the deployment of energy storage due to cost reductions and their ability to efficiently store energy for relatively long periods of time.

Technology	Maturity	Cost ($/kW)	Cost ($/kWh)
Pumped Hydro	Mature	1,500-2,700	250 - 270
Compressed Air (Underground)	Demo to Mature	960-1,250	60 - 120
Compressed Air (Aboveground)	Demo to Deploy	1,950-2,150	390 - 430
Flywheels	Demo to Mature	1,950-2,200	7,800 - 8,800
Lead Acid Batteries	Demo to Mature	950-4,900	425 - 3,800
Lithium-Ion	Demo to Mature	1,085-4,400	900 - 6,200
Flow Batteries (Vanadium Redox)	Develop to Demo	3,000-3,700	620 - 830
Flow Batteries (Zinc Bromide)	Demo to Deploy	1,450-2,420	290 - 1,350
Sodium Sulfur	Demo to Deploy	3,100-4,000	445 - 555

Source: Adapted from Electricity Energy Storage Technology Options, Electric Power Research Institute, December 2010.

Uses for Energy Storage

Energy storage can have a wide variety of end uses, from reliability to grid support. Layering uses, such as those outlined below, can allow a battery system to leverage multiple revenue streams and improve the economics of the system. Below is a brief summary of various uses for energy storage.

Wholesale Supply

Storage facilities can provide power into the electric system. One compelling case for their use is to provide electricity during times of peak demand on the electric system. The Energy Storage Association notes that there is a significant amount of utility-owned pumped hydroelectric storage capacity installed that is used extensively as peaking resources.[2] Storage of significant capacity can offset the dirtiest peaker plants. Although it may be more costly than a typical peaker plant storage can provide additional values to the grid as outlined below. [3]

Ancillary Services

Ancillary services help support the transmission system as it moves electricity from generation to load. There are three broad categories of ancillary services in which batteries could theoretically participate: reserves, black start service and regulation. Reserves provide power on short notice in the case of unexpected drops in generation or increases in load. Black start service includes generators that can start without using electricity – in case that the entire grid loses power. Regulation service is a generator or load that can help correct for short-term fluctuations in power quality. Batteries operate in these markets by either charging or discharging in response to signals from the grid operators to help maintain the desired voltage or frequency. Not all grid operators have markets for these services; however, those that do may or may not allow energy storage systems to participate in them. PJM has some of the most active ancillary services markets in the county, particularly for fast-responding regulation service, a market to which batteries are particularly well-suited. As a result, PJM has one of the most developed markets for storage.

As an example of the influence of policy structure on the adoption of storage, FERC Order 755 helps structure payments and sets contracts for frequency regulation, and the order changes the market for frequency-regulation applications. PJM was the first Regional Transmission Organization (RTO) to adopt Order 755, and the results have significantly improved the commercial viability of frequency regulation.[4]

Grid Support

Energy storage systems can help improve the transmission of electricity over long distances by compensating for electrical anomalies such as unstable voltage. It could also be used to relieve congestion on the grid if installed downstream of congested areas, by storing energy during times when there is no congestion on the grid and releasing energy during times of high congestion. Because prices increase during times of high congestion, this strategy has potential to reduce energy costs. Storage can also be used at load centers to reduce demand when congestion occurs. The same concept can apply to the distribution system. Since electric distribution systems are sized to be able to handle the peak demand that may only occur a few days a year, storage systems can help to defer the need to upgrade

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[2] "Flexible Peaking Resource." Flexible Peaking Resource. Accessed December 29, 2015. http://energystorage.org/energy-storage/technology-applications/flexible-peaking-resource.

[3] Ibid.

[4] "Grid Energy Storage." December 1, 2013. Accessed December 29, 2015. http://energy.gov/sites/prod/files/2014/09/f18/Grid Energy Storage December 2013.pdf.

transmission and/or distribution infrastructure. Using storage for transmission and distribution system deferral may require a change to the way that utilities are compensated for their investments.

Behind-the-Meter Uses

Reliability and cost management are the two primary uses for storage from a customer perspective. The reliability benefits are clear – energy storage can keep loads powered during times of grid outage. Customers may place a higher value on reliability during severe weather events. Cost management may also present an opportunity for energy storage systems. Residential and commercial customers on time of use meters could store energy during low cost periods of the day and draw that power during high cost periods. Commercial customers are currently assessed demand charges in Maryland and can already take advantage of storage to offset demand charges.

Renewable Integration

Energy storage allows for the offset of electricity generated by renewable energy technologies such as solar and wind from times of low demand to times of high demand. This allows producers to sell renewable energy at a time when it is more valuable. Energy storage can also be used to "smooth" out intermittent renewable generation so output is more constant. In effect, it can help reduce the volatility of output from a renewable energy system (for example when a cloud passes over a photovoltaic system) and improve the power quality that a renewable energy system produces. Storage of a sufficient scale can also "firm up" the output of a renewable energy system on a larger scale; that is, rather than correcting for minute-by-minute fluctuations, a system can store energy when power is being produced (during a period of high wind, for example) for later release when less energy is being produced. If coupled with large-scale storage, certain renewable systems may be able to participate in more valuable markets operated by the regional transmission operator.

State Energy Storage Programs and Policies

Policies and programs to encourage energy storage take one of several forms – utility-driven, state-funded incentive programs, or other state policies. The states below are generally the leading markets for energy storage. Each state has implemented policies and programs to encourage the development of energy storage.

Utility-Driven Programs

Several electric utilities have implemented programs to incorporate storage into their planning and infrastructure development. As noted above, storage can play an important role in reducing congestion costs on the transmission and distribution systems and can help defer the need to upgrade parts of the system by shifting supply and demand to times that allow the system to operate more efficiently. In most cases where utilities have begun using storage for these purposes, it has been in response to a shift in policy from the state public utility commission or legislature.

New York

One of the most interesting and innovative approaches to deploying energy storage and other dispatchable technologies is being undertaken by New York, where the state Public Service Commission is looking to deploy storage and other distributed energy resources to lower the cost of utility service. The biggest energy challenge in Brooklyn and Queens is that these growing boroughs are experiencing growth in population and peak energy demand. The electric distribution system needs to be upgraded to continue to deliver reliable service. The Brooklyn-Queens Demand Management Program (BQDM) looks to offset $1 billion in required utility infrastructure investments with $200 million in technologies like battery storage that can provide reliable service at a lower cost.[5]

The BQDM project is one of the most interesting case studies available, and Maryland should continue to explore market-based solutions that can lower the total cost of the system. A very important component of this strategy is being able to target when and where the grid is becoming strained so planning and project development can realistically be done to maximize the value of these assets.

Hawaii

Hawaii has one of the highest levels of renewable energy penetration of any state, particularly solar and wind technologies. In 2014, Hawaiian Electric Company (HECO) issued a request for proposal (RFP) seeking an energy storage system 60 to 200 MW of storage to help it "meet its goal of adding more renewable generation to the O'ahu grid."[6] According to the language of the RFP, "Hawaiian Electric anticipates that the ESS (energy storage system) will assist in addressing these challenges and allow for more of O'ahu's electricity to come from variable renewable resources by providing certain functions, including but not limited to sub-second frequency response and minute-to-minute load following, to the extent it is cost effective. " The RFP did not require a specific technology, but did require that the resource be available in 30-minute increments. The nature of uses specified indicated that battery storage would be the logical resource. After receiving more than 60 proposals, the company selected three. In June 2015, HECO announced that it would delay service by one year from 2017 to 2018 and would vet the storage contracts with the Hawaii Public Service Commission later, according to Pacific Business News[7].

State-Driven Programs

States have started to look at policies to encourage the use of more storage, recognizing the possible benefits that can be achieved. From reliability in the face of weather events to assisting with the integration of renewable energy that results from renewable portfolio standards, states have been devoting funds or passing legislation to encourage more storage. Most state that do so are also

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[5] Petition of Consolidated Edison Company of New York, Inc. for Approval of Brooklyn Queens Demand Management Program, Case Number 14-E-0302, Order (December 12, 2014).

[6]"Request for Proposals - Energy Storage System." Hawaiian Electric:. Accessed December 28, 2015. http://www.hawaiianelectric.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnextoid=03ebf219fe9a5410VgnVCM10000005041aacRCRD&vgnextchannel=a595ec523c4ae010VgnVCM1000005c011bacRCRD&appInstanceName=default.

[7] Shimogawa, Duane. "Hawaii's Largest Electric Utility Puts off Plans for Major Energy Storage Systems to 2018 - Pacific Business News." Pacific Business News. June 30, 2015. Accessed December 30, 2015. http://www.bizjournals.com/pacific/news/2015/06/30/hawaiian-electric-pushes-back-major-energy-storage.html.

recognizing the economic development benefit. In addition to storage policies and programs, these states are finding ways to position themselves as a leader in this emerging market.

California

In 2010, the California legislature passed a law directing the California Public Utility Commission (CPUC) to set targets for utilities to procure cost-effective energy storage systems. [8] In 2013, the CPUC established a mandate that the California utilities purchase a total of 1.3 GW of storage capacity by 2020.

One utility, Southern California Edison, signed contracts for over five times the amount of storage required by the mandate. According to an official from the company, it did not plan to exceed the requirement, but the offers in response to the solicitation were more "competitive" with other resources than the utility had anticipated.[9]

Recognizing that significant barriers to deploying energy storage exist, the CPUC paired its storage mandate with a plan to develop policies and guidelines for energy storage. Working with the California Energy Commission (CEC) and the California Independent System Operation (CAISO), the CPUC created an Energy Storage Roadmap that identified actions to help create a sound market for energy storage resources. The roadmap focuses on three areas: expanding revenue opportunities, reducing costs, and streamlining policies to provide more certainty to storage developers.[10]

Texas

The Texas legislature enacted a law in 2011 clarifying that storage can be a generation asset and is thus eligible to interconnect, obtain transmission service, and sell electricity or ancillary services at wholesale rates. [11] In 2015, another bill was introduced in the legislature that would make large-scale (250MW or greater) compressed air energy storage projects eligible for Texas Economic Development Act tax credits. The bill was voted favorably out of committee but the Texas House of Representatives did not vote on the measure before it adjourned.[12] With its high volumes of renewable (wind) generation, there is potential for storage in Texas.[13] ERCOT, the grid operator that covers most of Texas, is currently

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[8] 2010-ab2514 Cal. Adv. Legis. Serv. n. (LexisNexis).

[9] Chediak, Mark. "Battery Makers See a Big Break Coming -- No, Seriously This Time." Bloomberg.com. October 19, 2015. Accessed December 30, 2015. http://www.bloomberg.com/news/articles/2015-10-16/batterymakers-see-a-big-break-coming-no-seriously-this-time.

[10]Leon, Warren. "Clean Energy Champions." Clean Energy States Alliance. June 1, 2015. Accessed December 30, 2015. http://www.cesa.org/assets/2015-Files/Clean-Energy-Champions-LR.pdf. Case Study 17

[11] 2011 sb943 Tex. Sess. Law Serv. (West).

[12] 2015 hb3732 Tex. Sess. Law Serv. (West).

[13] Van Loon, Jeremy. "Ancient Greek Technology Tests Musk Batteries on Storage." Bloomberg.com. May 6, 2015. Accessed December 30, 2015. http://www.bloomberg.com/news/articles/2015-05-06/compressed-air-to-challenge-batteries-in-energy-storage-race.

evaluating redesigning its ancillary services markets in such a way that storage may have an additional value stream. Texas currently has several CAES projects under development.[14]

Washington

In 2014, Washington State announced over $14 million in grants to be directed to its utilities to implement grid-scale storage projects. The funds were used to "demonstrate improved integration of renewables through energy storage and information technology, improve reliability and reduce the costs of intermittent renewable or distributed energy."[15] All of the storage projects were deployed at utility substations in the state. The goals of the storage system projects include substation peak shaving, system peaking, ancillary services, and outage mitigation. The projects are designed to help Washington's regulated electric utilities gain valuable experience with energy storage. In addition, the State has engaged Pacific Northwest National Labs (PNNL) to perform a use case analysis on all of the projects. Through the use case analysis, PNNL will gather and analyze data on system technical and economic performance. Another important component of Washington State's efforts is the requirement that the projects use a common technology standard to manage them.

New Jersey

In 2012, New Jersey began working towards a storage program when a consultant issued a report identifying opportunities for the state to use energy storage to integrate renewable energy into the grid. After Superstorm Sandy hit, the state also started focusing on storage to improve resiliency. In 2014, the state issued an RFP for the Renewable Electric Storage Program. The program targeted behind-the-meter storage systems tied to a renewable energy system. The storage had to provide a reliability benefit to the host institution. New Jersey awarded $3 million for 13 projects and has renewed the program at double the funding level for the next round. The New Jersey Board of Public Works is also hosting a working group to develop methods for electric distribution companies to handle interconnection of storage integrated with net-metered renewable energy systems.

Market Opportunity

According to GTM Research, a market analysis firm focused on the evolution of the electric utility industry, growth in the market for residential, non-residential, and utility-scale storage is accelerating.[16] In 2014, the total market size was $134 million. In 2019, according to GTM estimates, the total market size will be nearly $1.5 billion with $705 million in utility-scale storage and nearly $750 in residential and non-residential market opportunities.

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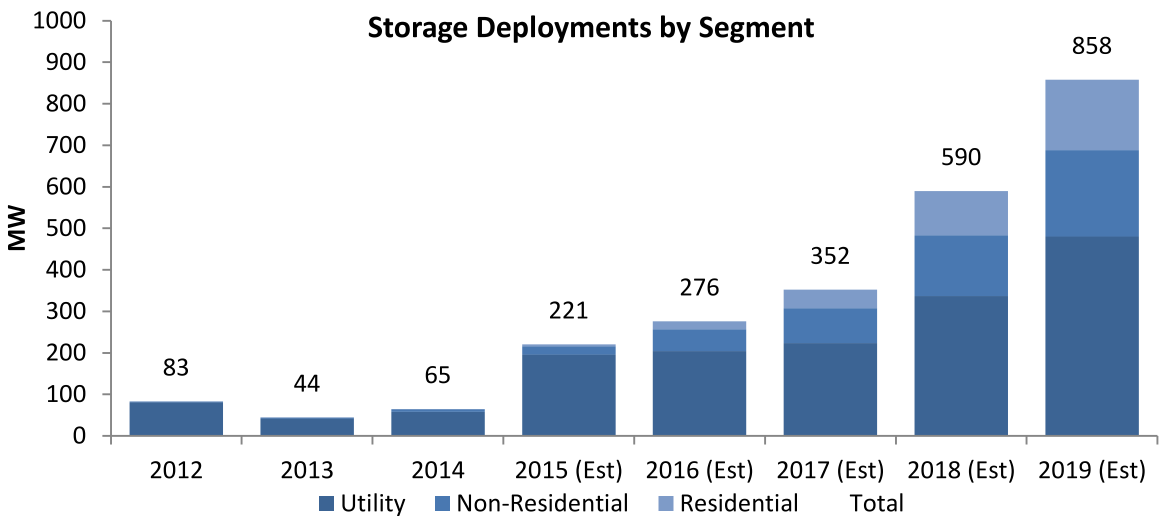
[14] Ibid.

[15] "Clean Energy Fund Update." October 1, 2015. Accessed December 30, 2015. http://www.commerce.wa.gov/Documents/Clean-Energy-Fund-Update.pdf.

[16] Green Tech Media, Q2 2015 Energy Storage Monitor, September 2015.

An analysis by ECG Consulting Group performed for the New York Battery and Energy Storage Consortium (NY-BEST) in 2012 suggests that through 2020, the market for electricity storage will have a compound annual growth rate of nearly 20 percent, and from 2021 through 2030, the growth rate will be slightly lower, at 12.5 percent. This analysis identifies the community and residential energy storage segments of the market as having the highest growth potential through 2020, followed by commercial buildings and grid storage.[17]



Source: GTM Research, Q2 2015 Energy Storage Monitor

Regulatory Issues

From a regulatory perspective, issues surrounding the deployment of energy storage assets differ markedly based on several factors. Both the capacity of the energy storage asset and the proposed ownership entity may require different regulatory standards. At a minimum, regulators must consider: appropriate protocols for the interconnection of energy storage assets to the electric distribution system; ownership structures; and potential cost recovery mechanisms.

The Maryland Public Service Commission (the "Commission") has existing regulations pertaining to the interconnection of a small generator, which is defined in part as equipment used to generate or *store electricity*. (emphasis added). A "small generator" energy storage asset that bears a nameplate capacity equal to or less than 10 MW may seek to interconnect to the electric distribution system using the aforementioned streamlined Commission regulations, provided that the asset is designed to operate in parallel with the grid. An energy storage asset that exceeds 10 MW or is otherwise subject to the interconnection requirements of PJM Interconnection, LLC falls outside the scope of the Commission's small generator interconnection standards.

[17] ECG Consulting Group, Inc., The Economic Impact of Developing an Energy Storage Industry In New York State, NY-BEST. October 2012.
http://nybest.org/sites/default/files/typepage/4254/attachments/2012%2010%2005%20NY%20BEST%20Final%20Report%20%282%29.pdf.

Recognizing that the interconnection protocols differ for small-scale versus utility-scale energy storage assets yields two important areas for further regulatory exploration. First, whether the customer-owner of a small energy storage asset should be subject to a cost allocation tariff for the recovery of distribution costs comparable to that utilized by PJM for large interconnection requests. And second, whether the penetration of energy storage assets commensurate to distributed solar generation will alleviate distribution feeder restrictions. The Commission initiated a dialogue with respect to these issues in an October 2015 technical conference. Utility and industry experts testified before the Commission regarding methods of integrated distribution planning, methods to reduce the cost of interconnection, and cost allocation methods, such as the serial and cluster processes.

As part of the October 2015 technical conference, the Commission also invited testimony regarding the appropriate valuation factors to use in regard to energy storage assets and other small distributed energy resources. Other states, however, sometimes expand valuation policies to include factors such as the resource’s geographic location and its ability to reduce transmission or distribution network development expenses. Current net energy metering regulations in Maryland provide for monetary payment for net excess generation, with the associated dollar value equal to the generation or commodity portion of the rate that the eligible customer-generator would have been charged by the electric company.

With respect to larger energy storage projects, the regulatory paradigm shifts given that the financial (and technical) barriers to the deployment of utility-scale assets are different than those experienced by smaller, distributed assets, which may be adequately addressed through net-metering policies and streamlined interconnection protocols. Specifically, the regulatory discussion shifts with respect to ownership models for the energy storage assets. Decisions regarding whether energy storage constitutes an infrastructure investment or a generation resource will determine whether utilities in a deregulated state may own energy storage assets and recover costs from ratepayers. In the event that energy storage assets are categorized as recoverable infrastructure investments, utilities may pursue alternative ratemaking mechanisms that provide some degree of commensurate cost recovery, or other regulatory assurances that the investment will be deemed prudent.

MEA Experiences, RPS Considerations, and Conclusions

In recent years, Maryland Energy Administration (MEA) has made grant awards through its Game Change program for projects involving energy storage deployment installed in conjunction with residential solar photovoltaic technologies. In Fiscal Year 2016, the Game Changers program solicited applications focused on commercial, customer-sited electric storage systems integrated with Tier 1 renewable energy sources. The existing grant awards, as well as any future awards made in Fiscal Year 2016, should help provide further insight into the deployment of energy storage technologies in Maryland.

Energy storage presents interesting opportunities in Maryland. The Maryland General Assembly previously considered legislation in the 2015 session that would have adopted storage as a component of the State's Renewable Portfolio Standard (RPS). The State's RPS in its current composition includes tiers of renewable generation. While some component technologies are variable in nature, each is capable of producing electricity. Energy storage does not share this attribute.

Energy storage is different than other RPS technologies. Its value is in its ability to partner with both generation and transmission assets. In this respect, storage has the potential to enhance existing assets.

As examined in the "Uses for Energy Storage" section of this report, there are a variety of valuable deployments for energy storage technologies. Whether it is bulk storage, grid support, behind-the-meter applications, or renewable integration, energy storage technologies could play an important role in Maryland's energy future.

Notwithstanding its benefits, the current cost of energy storage systems makes it difficult for broad deployment. However, if technology improves to the point where costs fall, generators and electric utilities may adopt storage to increase the efficiencies of their respective operations.

Maryland Energy Administration will continue to monitor energy storage and the progress of the technology, and consider possibilities for future implementation.