NYSERDA ENERGY STORAGE AND NY-BEST PROGRAM: MARKET CHARACTERIZATION AND ASSESSMENT

Final

Prepared For:

New York State Energy Research and Development Authority (NYSERDA)
Albany, NY

Jennifer Phelps
NYSERDA Project Manager

Prepared By:

EMI CONSULTING

83 Columbia Street
Seattle, WA 98104
206/621-1160

Todd Malinick, Project Manager

Kara Crohn, Senior Technical Lead

INDUSTRIAL ECONOMICS, INCORPORATED (IEc)

2067 Massachusetts Avenue
Cambridge, Massachusetts 02140
617/354-0074

Angela Helman, Project Manager

NYSERDA Contract 32883 February 2017

Notice

This report was prepared by EMI Consulting in the course of performing work contracted for and sponsored by the New York State Energy Research and Development Authority (hereafter "NYSERDA"). The opinions expressed in this report do not necessarily reflect those of NYSERDA or the State of New York, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, NYSERDA, the State of New York, and the contractor make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report. NYSERDA, the State of New York, and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

NYSERDA makes every effort to provide accurate information about copyright owners and related matters in the reports we publish. Contractors are responsible for determining and satisfying copyright or other use restrictions regarding the content of reports that they write, in compliance with NYSERDA's policies and federal law. If you are the copyright owner and believe a NYSERDA report has not properly attributed your work to you or has used it without permission, please email print@nyserda.ny.gov.

Table of Contents

List of Figures

List of Tables

Executive Summary

Recent advances in energy storage technologies have laid the foundation for major changes in the electric grid, the transportation sector, and myriad other applications from portable military batteries to industrial fork lift batteries. The New York State Energy Research and Development Authority (NYSERDA) and the New York Battery and Energy Storage Technology Consortium (NY-BEST) seek to catalyze and grow the energy storage industry and establish New York State as a global leader in these markets. This market characterization report explores the role New York State plays in the energy storage market, with a focus on understanding how this market is developing around the globe and how New York State compares to other key regions.

Research Overview

This market characterization and assessment (MCA) focuses on determining the status of the global energy storage market, with particular focus on states actively supporting energy storage and a close review of the energy storage industry in New York State. The assessment includes a review of existing New York State energy storage industry resources and capabilities and provides NYSERDA staff with a baseline against which future assessments can be measured. Ultimately, this information may NYSERDA document progress toward the goal of positioning the State as a global leader in energy storage technology.

Key Findings

The global market for energy storage technologies has experienced substantial growth over the past few years due to cost reductions, improved technical performance, increased deployment of renewable energy sources, and industrialization in many parts of Asia.

Types of Energy Storage Technologies and Associated Global Market Demand

Energy storage technologies have proliferated since 2010, with a large number focused on grid storage (both customer-side and utility-side) and transportation applications. Estimates for the global energy storage market vary, but are typically in the tens of billions of dollars (USD) for batteries alone. Until recently, market demand for grid storage had been limited, as the cost of energy storage was prohibitively high and there was not significant renewable energy penetration. However, demand has increased over the past four years, with the most impressive growth occurring since 2014. Demand for these technologies is projected to increase in the near term, though the magnitude of demand will vary slightly by sector and application as described below.

- **In the commercial and residential grid storage market segment, a number of new technologies on the cusp of commercial viability portend important changes for residential and commercial energy storage markets in the U.S. and around the world.** In the grid storage market, demand for new types of commercial storage systems (sited at the customer's facility) and residential storage are projected to drive rapid growth in the next five years as an increased number of homeowners and businesses become aware of the benefits of such systems and as system costs continue to decline. This growth will also be influenced by the market for distributed energy resources, such as photovoltaic (PV) solar, which are increasingly integrated with energy storage devices (Harris 2015).

- **Larger utility-scale grid projects will also experience growth (in terms of storage capacity deployed), though the relative rate of growth may be less than that for the smaller behind-the-meter (BTM) market segment.** Overall, while most projections for emerging grid storage markets are optimistic, policy barriers must be overcome before these markets can realize their full potential—these barriers primarily revolve around the value proposition for such devices (e.g., that both the customer and the utility will realize benefits). Concurrently, substantial and increasing activity by firms developing software will allow integration of grid storage technologies with distributed energy resources (e.g., PV solar) and with the grid itself.
- **In the transportation sector**, **storage technologies that support the operation of electric vehicles and electric buses will experience rapid growth**. This growth is due to decreases in cost and improvements in battery capacity.

Key Actors in the Global Market

The supply chain for battery and energy storage technologies is global and highly fragmented. For some energy storage technologies, raw materials come from different global regions (e.g., lithium from South America) and are brought to Asia, where they are used in the manufacture of battery cells. These cells are then combined with other cells to create modules, which are in turn assembled into battery packs (sometimes by the same vendor and sometimes by a different vendor). Finally, system integrators or developers place these battery packs into an application-specific system (e.g., a backup power storage unit located at a commercial facility). The overall vendor landscape has become more competitive as new entrants like Tesla have brought potentially disruptive products to the emerging grid storage and transportation battery markets. Additionally, market actors are vertically integrated throughout multiple areas of the vendor landscape (for instance Bosch, which produces power electronics, energy storage management systems (ESMSs), and energy storage systems).

The Market for Energy Storage Technology Development and Production in New York State

The research team has determined that New York State is frequently recognized as one of the leading U.S. states in the development of energy storage markets, particularly in the *research and development* of energy storage technologies. However, like other parts of the world outside the Asia Pacific region, New York State has a less developed manufacturing base for batteries and energy storage technologies.

- Since 2012, the New York State energy storage industry has grown steadily across production markets (i.e., grid storage, transportation storage, and traditional storage) during this period, exhibiting an increase in both industry revenues and employment.
- Although it is difficult to make a direct comparison, New York State exhibits employment numbers similar to or better than other leading states when such numbers are normalized to account for differences in size. Estimates of energy storage-related employment using North American Industrial Classification System (NAICS) data suggest that, per capita, New York State is on par with California and slightly ahead of Texas.

- Experts interviewed as part of this study generally felt that New York State policy is making strides in promoting the adoption of energy storage, but that permitting policies remain restrictive for some market segments (namely, for the commercial behind-the-meter segment in dense urban areas).
- A common sentiment among industry stakeholders interviewed as part of this study is that while Reforming the Energy Vision (REV)[1] attempts to facilitate greater market development within the State, it does not address all the concerns necessary for optimizing energy storage market development. Rather than introducing specific mandates directly related to the implementation of grid storage capacity (which some stakeholders felt would directly spur the market), the REV proceeding will more likely serve as an indirect driver of adoption of energy storage in New York State.
- New York is likely to remain an appealing market for additional investment in grid storage, particularly as a result of the Public Service Commission's decision to limit the ownership of distributed energy resources by utilities, and instead rely primarily on third-party providers (Opalka and Heidorn 2015). Investment in energy markets (including storage markets) in New York State will also likely benefit from the Clean Energy Standard, which mandates the state obtain 50% of its electricity from renewable sources by 2030 (New York State Governor's Press Office 2016).

The Role of the New York Battery and Energy Storage Technology Consortium

The New York State Battery and Energy Storage Technology (NY-BEST) Consortium was created in 2010 to serve as an expert resource for energy storage-related companies and organizations, to facilitate financing for new ventures, enhance research capabilities, and to generally act as a connector in establishing a strong energy storage economy within the State.

- In the research team's assessment, NY-BEST is now broadly recognized in the industry as an advocate for advancing battery and energy storage markets (including both production and adoption) within the United States. General perceptions of NY-BEST among members are very positive, with most members indicating they were either "satisfied" or "very satisfied" with the organization.
- There is evidence to suggest that NY-BEST members are having a positive impact on the New York energy storage market – an analysis of grid storage technology providers for projects located in New York State shows that 11 of the 19 vendors are members of NY-BEST.[2] Their capacity share of this market (in terms of rated power) accounts for roughly 44% of the total aggregate, revealing that NY-BEST members account for a substantial portion of the grid storage market for New York State-based projects.

---

[1] Reforming the Energy Vision is New York State's energy policy, launched in 2014. REV is designed to foster the development of an integrated energy network that can combine the benefits of the central grid with distributed renewable power sources.

[2] This analysis was performed using data from the DOE Energy Storage database using data updated through December 2016. Energy storage technology providers were cross-referenced with the NY-BEST member list.

- A qualitative assessment of NY-BEST's role in the marketplace suggests that while it has not yet attracted major new manufacturing activity to the State for many types of more established technologies, membership in the Consortium has grown steadily year-over-year and the Consortium represents national and international market actors involved in the development of emerging technologies.
- Additionally, the Consortium has been involved with a number of policy movements in New York State. In its 2016 Energy Storage Roadmap for New York's Electric Grid, the Consortium suggested specific recommendations that could advance the energy storage sector in New York State, including through the REV. Such goals appear symbolic of NY-BEST's role as a driver of energy storage in the New York State.

1 Introduction

EMI Consulting was selected to evaluate the NY-BEST program and to provide market characterization and baseline information to support NYSERDA's energy storage activities. The overall evaluation effort aims to assess the impact on New York State's energy storage industry and market by the NYSERDA-supported programs comprising the NY-BEST Consortium, in the period from 2010 to 2015.

The evaluation effort includes three distinct analyses presented in three reports:

1. A 2015 market characterization and assessment of the New York energy storage industry (this report),
2. An economic analysis of potential future market and economic impacts, and
3. An impact evaluation of the NY-BEST program since 2010.

This report constitutes **the market characterization and assessment,** which describes the status of the global energy storage market, with a particular focus on states actively supporting energy storage and a close review of energy storage in New York State. The assessment includes a review of existing New York State energy storage industry resources and capabilities and provides NYSERDA staff with a baseline against which future assessments can be measured to understand progress toward its goals in the energy storage space. Exhibit 1-1 lists key research questions.

Exhibit 1-1. Key Research Questions

Key research questions addressed in this report include:

- Who are the key energy storage market actors in New York State, in the broader United States, and globally in 2015?
- What is the market demand for energy storage technologies and services in 2015? To what extent is the market able to fulfill that demand?
- What types of energy storage technologies and services are available in the market in 2015?
- How does New York State compare in 2015 to other states or international regions that emphasize energy storage efforts in terms of the type, number, revenue, investment dollars, and employment of energy storage market actors?
- In 2015, what are the barriers to increasing energy storage R&D and market development in New York State?
- To what extent does New York State policy in 2015 support or impede energy storage market growth?
- How has the energy storage industry changed in New York since the 2012 Economic Impact Assessment?[1]

In developing this report, the research team relied on the following sources of information to answer the key research questions:

- Program data and records, including financial and membership records
- (30-60 minute) in-depth interviews with:
  - NY-BEST program staff
  - NY-BEST members, including key personnel from CAIR-funded projects
  - NY-BEST non-members
  - Energy storage industry experts (non-members)
  - Representatives from other grid storage stakeholders
- Market trend research and literature review
- Energy storage regulatory policy review

Exhibit 1-2 shows how the research team used each of these information sources to address the research questions.

Exhibit 1-2. Mapping of Research Objectives to Information Sources

	Program Data/Records	In-Depth Interviews with NY-BEST Staff, NY-BEST Members, Non-Members, Industry Experts, and Stakeholders	Market Trend Research and Literature Review	Energy Storage Regulatory Policy Review
Key Market Actors	●	●	●	
Market Demand Estimates		●	●	
Types of Technologies and Services Available			●	
Comparison of New York State to Other Regions		●	●	●
Barriers to R&D, Market Development		●		●
Assessment of New York State Policy				●
Changes in New York State Energy Storage Industry Since 2012	●	●	●	●

In this assessment, the research team used an energy storage classification that closely aligns with the categories used in the 2012 and 2016 economic impact assessments prepared for NY-BEST and reflects current NY-BEST priorities. The classification groups energy storage technologies and services under two broad categories:

1. **Emerging markets** based on new (non-traditional) applications for energy storage technologies. Emerging markets are further broken out into electricity (grid) storage (e.g., customer-sited energy storage batteries including those tied to solar systems or utility-side storage sited near distribution substations), and transportation (e.g., batteries for electric vehicles).

2. **"Traditional markets"** that are relatively stable, comprising energy storage products based on established market segments (e.g., automotive lead-acid batteries, portable military batteries, etc.).

A more detailed classification is shown in Table 1-1.

Table 1-1. Classification of Energy Storage Technologies

<table>
<tr><th colspan="2">Market[(a)]</th><th>Market Segment/Technology</th></tr>
<tr><td rowspan="8">Emerging Markets</td><td rowspan="5">Grid (Electricity) Storage[(b)]</td><td>Residential Energy Storage (behind the meter)</td></tr>
<tr><td>Commercial Energy Storage (behind the meter)</td></tr>
<tr><td>Energy Storage on the Grid (front-of-the-meter)</td></tr>
<tr><td>Community Energy Storage (front-of-the-meter)</td></tr>
<tr><td>Energy Storage Management Systems [(c)]</td></tr>
<tr><td rowspan="3">Transportation Storage</td><td>Light-Duty Electric Vehicle Batteries</td></tr>
<tr><td>Medium and Heavy-Duty Electric Truck Batteries</td></tr>
<tr><td>Electric Vehicle Charging Equipment</td></tr>
<tr><td colspan="2" rowspan="9">Traditional Markets</td><td>Automotive Energy Storage (Lead-Acid Batteries)</td></tr>
<tr><td>Industrial Fork Lift Trucks</td></tr>
<tr><td>Medical
Technologies: Batteries & Ultracapacitors</td></tr>
<tr><td>Military
Technologies: Portable Batteries</td></tr>
<tr><td>Fuel Cells[(d)]</td></tr>
<tr><td>Materials</td></tr>
<tr><td>R&D Supporting New Technologies</td></tr>
<tr><td>Others</td></tr>
</table>

(a) This classification is applicable to all energy storage technologies, not just those found in New York State.

(b) Grid (electricity) storage is sometimes referred to as stationary (grid) storage.

(c) Though Energy Storage Management Systems are not broken out as a separate market segment in the corresponding economic analysis, we include it in this report to more easily discuss the market for these systems.

(d) While fuel cells are more of a technology than an application, this row in our table represents companies engaging in fairly mature fuel cell-related activities rather than fuel cell development for novel applications.

2 Emerging Grid Storage Markets and Market Demand

In this section, we focus on one segment of the emerging market—grid storage—which includes "behind-the-meter" storage for both residential and commercial applications, "front-of-the-meter" storage for utility applications, community energy storage, and energy storage management systems. We also discuss the projected market demand for each of these technologies.

2.1 Grid Storage Market Segments and Technologies

Grid storage (also referred to as Stationary Storage) can be classified as either "behind-the-meter" (BTM) storage or "front-of-the-meter" (FOM) storage. Within the BTM storage market segment, we can further categorize projects into residential or commercial systems,[3] involving technologies that aim to provide small-scale energy storage for residential and commercial facilities. The FOM segment mainly includes larger-scale storage projects located on the distribution or transmission system, and serves grid applications such as frequency response, renewable integration, non-wires alternatives, and energy arbitrage. These applications help make the grid more efficient and resilient by storing energy which can be injected back into the grid as needed. Community storage systems, which typically include a number of small or medium-sized storage units situated on the periphery of the distribution network near end-users' facilities, represent a special type of FOM storage because in some cases they are designed to act as "microgrids" or "islands" that can provide power during power outages.

- To date, global grid energy storage capacity is still relatively small compared to global generation capacity. (As of 2013, U.S. grid storage accounted for only 2.3% of the nation's total electric production capacity.) Additionally, the bulk of the world's energy storage is held in traditional pumped storage hydro facilities (Johnson et al. 2013).
- To put the relative sizes of the BTM and FOM categories in perspective, it is estimated in 2014, that FOM accounted for 90% of energy storage deployments by capacity while BTM deployments accounted for only 10% (Hamilton 2015).
- However, within the next five years, it is expected that the BTM market will grow more rapidly than the FOM market, achieving an estimated 45% market share (capacity) by 2019 (GTM Research 2015c).[4]

We discuss each of these subcategories in more detail below.

---

[3] In this context, "commercial" systems include systems used for both commercial and industrial purposes.

[4] It is important to note this is a comparison of capacity. In terms of global revenues, the ratio of FOM to BTM is close to 60/40. This ratio is expected to reverse itself to 60/40 in favor of BTM storage by 2019, which supports the prediction that BTM storage is set to grow more quickly than FOM storage within the next few years.

2.1.1 Behind-the-meter (BTM) Storage

BTM storage is a class of energy storage technologies positioned on the customer side of the meter. A simple example of BTM storage is a Li-ion battery system such as the Tesla Powerwall, which may be installed in homes or businesses.

BTM Storage Applications

Onsite BTM energy storage, for both Residential and Commercial facilities, can be used for specific applications including but not limited to:

- Back-up power, which enables electricity usage during a grid outage,
- Load shifting, which lowers the end-user's electricity bill by charging during low rate periods and discharging during more expensive rate periods,
- Peak shaving/demand management, which reduces peak demand,
- Self-storage for on-site solar power generation, which allows for storage of excess energy produced by onsite solar PV and can reduce costs, and
- Price arbitrage, which optimizes time-of-use rates to buy electricity when it is cheapest and potentially selling power back to the utility or other third-party providers.

The current cost effectiveness of BTM storage is highly dependent on policies such as net energy metering. In states with active net energy metering policies, BTM storage presents a less compelling return on investment and therefor other needs such as resiliency during grid outages are more likely to drive a customer's decision.

There are also a number of *emerging* applications for BTM storage, many of which involve integrating BTM technologies into the grid. BTM systems are typically controlled by the end-user; however, in cases where stored energy exceeds the demand of the end-user, there is the potential for customer-sited batteries to contribute to wholesale (and, through REV, retail) markets and thereby help manage the grid. There is also potential for BTM storage to be used for non-outage utility applications, including but not limited to:

- Frequency regulation, which provides grid operators the ability to quickly inject power into the grid as needed to maintain a 60 Hz frequency (in place of ramping up generation assets, which typically take longer to come online and incur wear and tear from ramping),
- Volt/VAR support, which can reduce system losses by regulating distribution flows, and
- Additional system capacity, which may obviate the need for expensive infrastructure projects such as major substation upgrades.

For many BTM applications, the precise connection protocols handling these communications are still developing, as are the laws and policies governing such activities. Any additional grid benefits, such as virtual power supply and demand response capabilities, could improve the cost-effectiveness of the system once implemented. Accordingly, the value proposition for end-users and the utilities will be most attractive for customer-sited batteries that can provide both customer- and grid-facing services (Fitzgerald 2015).

BTM Storage Market Trends

There are several notable trends in this market segment:

- **Projects using BTM storage for traditional applications are underway; many of these are aimed at catalyzing the deployment and installation of residential energy storage systems.** In California, for example, Edison International has partnered with Tesla to provide Powerwall units to a small number of residential customers specifically for use with solar PV systems (Colthorpe 2015).[5] In Vermont, Green Mountain Power offers customers the option to purchase or lease the Tesla Powerwall battery, with no upfront cost. At the same time, Green Mountain Power should benefit from the ability to reduce peak demand on the system which, in turn, will provide additional cost savings to the customers (Lundin 2015).
- **Other projects are investigating how BTM storage may be used to combine traditional BTM applications with utility applications.** For example, Con Edison, in partnership with SunPower and SunVerge, is currently working on a project in the Greater New York Metro area where multiple BTM units are aggregated to supply demand response and other grid-side services as a "virtual power plant" (Wesoff 2016). Another example of using BTM storage to address utility needs is underway in Hawaii, where Stem, Inc. and Hawaiian Electric have collaborated to install a 2 MWh energy storage system on the island of Oahu. The project is designed to help Hawaiian businesses reduce peak demand charges, and will help stabilize the grid by leveling the generation spikes produced by distributed solar systems.
- **A handful of global firms are emerging as leaders in this space**. In Germany, Sonnen has sold over 10,000 of its sonnenBatterie eco™ residential battery storage systems and has recently expanded into the U.S. market, placing them in direct competition with firms like Tesla. Key market actors focused on the residential sector include SunVerge, Outback Power, and Deka. Key market actors focused on the non-residential sector include CODA Energy, Stem. Inc., and Green Charge Networks (Manghani 2015).
- **A movement toward strategic alliances and consolidation between companies is emerging, focused on different aspects of energy storage.** Tesla has developed partnerships with several businesses in the U.S., including Target and Amazon, and continues to attract great attention from solar providers interested in integrating their systems with Tesla's commercial storage battery packs. Recently, Tesla has begun the process of merging with SolarCity, the largest residential solar installer in the US, to more easily deploy storage systems integrated with PV solar systems.

2.1.2 Front-of-the-meter (FOM) Storage

FOM storage, also referred to as "grid-side storage" or "utility-sited storage," is defined as energy storage installed on the utility side of the meter, and includes a number of different specific technologies and applications, as discussed below.

[5] Home battery storage units like the Powerwall are designed to be able to work with or without PV solar, though a slightly different set of electrical components are required for each type of configuration.

FOM Storage Applications

Different types of FOM storage systems are suitable for different grid applications (Table 2-1). For example, fast-ramping technologies like flywheels and certain batteries are designed for applications such as frequency regulation and voltage control. In contrast, large, long-term systems like pumped hydro, flow batteries, and compressed air systems are better suited to meet long duration energy requirements.

Table 2-1. Potential Applications for Front-of-the-Meter Storage

Application	Description	CAES	Pumped Hydro	Flywheels	Lead-Acid	NaS	Li-ion	Flow Batteries
Off-to-on peak intermittent shifting and firming	Charge at the site of off-peak renewable and/or intermittent energy sources; discharge energy into the grid during on-peak periods	Possible	Possible	Unsuitable	Definite	Definite	Definite	Definite
On-peak intermittent energy smoothing and shaping	Charge/discharge seconds to minutes to smooth intermittent generation and/or charge/discharge minute to hours to shape energy profile	Unsuitable	Possible	Possible	Definite	Definite	Definite	Definite
Ancillary service provision	Provide ancillary service capacity in day ahead markets and respond to ISO signaling in real time	Possible	Possible	Possible	Possible	Possible	Possible	Possible
Black start provision	Unit sits fully charged, discharging when black start capability is required	Possible	Possible	Unsuitable	Definite	Definite	Definite	Definite
Transmission infrastructure	Use an energy storage device to defer upgrades in transmission	Unsuitable	Unsuitable	Unsuitable	Definite	Definite	Definite	Definite
Distribution infrastructure	Use an energy storage device to defer upgrades in distribution	Unsuitable	Unsuitable	Unsuitable	Definite	Definite	Definite	Definite
Transportable distribution-level outage mitigation	Use a transportable storage unit to provide supplemental power to end users during outages due to short term distribution overload situations	Unsuitable	Unsuitable	Unsuitable	Possible	Definite	Definite	Definite
Peak load shifting downstream of distribution system	Charge device during off peak downstream of the distribution system (below secondary transformer); discharge during 2-4 hour daily peak	Unsuitable	Unsuitable	Unsuitable	Definite	Definite	Definite	Definite
Intermittent distributed generation integration	Charge/discharge device to balance local energy use with generation. Sited between the distributed and generation and distribution grid to defer otherwise necessary distribution infrastructure upgrades	Unsuitable	Unsuitable	Unsuitable	Definite	Possible	Possible	Possible
End-user time-of-use rate optimization	Charge device when retail TOU prices are low and discharge when prices are high	Possible	Possible	Unsuitable	Possible	Possible	Possible	Possible
Uninterruptible power supply	End user deploys energy storage to improve power quality and/or provide backup power during outages	Unsuitable	Unsuitable	Possible	Definite	Definite	Definite	Definite
Micro grid formation	Energy storage is deployed in conjunction with local generation to separate from the grid, creating an islanded micro grid	Unsuitable	Unsuitable	Unsuitable	Definite	Definite	Definite	Definite

Definite suitability for application   Possible use for application   Unsuitable use for application

Adapted from DOE/Sandia National Lab. Grid Energy Storage. (2013)

The benefits provided by FOM storage systems are similar to the benefits previously described for BTM storage systems, including backup power applications (like black start capabilities and UPS), ancillary services (like voltage and frequency regulation), and improved integration of distributed generation. Utilities, independent power producers, or third parties that own these FOM resources can also benefit from:

- Price arbitrage, which effectively lowers cost of purchasing electricity through the wholesale market by charging (buying) during low rate periods and discharging (selling) during high rate periods,
- Peak reduction, which lowers the system peak load to defer distribution, transmission, or generation investments,
- "Load leveling," which evens out the system load to improve electricity quality and efficiency or to allow for additional intermittent resources, and
- Participation in capacity and energy markets.

There are also examples of FOM storage being used in novel ways. For example, community energy refers to storage that is primarily FOM and typically consists of storage located within the utility distribution system, close to end-users. Community energy storage offers many of the distribution benefits associated with energy storage sited directly on residential or commercial end-users' facilities, including peak shaving, voltage support, demand response, emergency load relief, integration of renewable generation, and power supply during system outages (Energy Storage Association, n.d.). Community energy storage with integrated renewable generation sources may be attractive to utilities that are looking for new ways to maintain grid reliability as more renewable energy is incorporated into the grid. Interviews conducted with experts as part of this study indicated that, in urban areas, the current utility-ownership model was likely to persist because the cost of real estate for siting energy storage equipment may be prohibitive for end-users.

FOM Technologies

As shown in Table 2-2, there are currently few types of energy storage technologies that capture a majority of the grid storage project capacity, either installed or in the project pipeline for projects around the world. These technologies include lithium-ion batteries, molten salt thermal storage, and to lesser degree, flywheels. (Note this table does not include pumped storage hydro or compressed air storage.)

Table 2-2. Aggregated Power Capacity of Grid Storage Technologies by Type, Worldwide Projects

Technology Type	Specific Technology	Agg. Rated Power (kW)	Percent of Total (all categories)
Electro-chemical	Lithium-ion Battery	1,721,906	22.51%
	Electro-chemical (not otherwise specified)	279,347	3.65%
	Sodium-sulfur Battery	188,900	2.47%
	Lithium Iron Phosphate Battery	186,458	2.44%
	Lithium Nickel Manganese Cobalt Battery	112,785	1.47%
	Electro-chemical Capacitor	79,273	1.04%
	Vanadium Redox Flow Battery	73,830	0.97%
	Advanced Lead-acid Battery	61,875	0.81%
	Zinc Bromine Flow Battery	57,353	0.75%
	Lead-acid Battery	43,845	0.57%
	Lithium Ion Titanate Battery	36,505	0.48%
	Nickel-cadmium Battery	32,000	0.42%
	Sodium-nickel-chloride Battery	23,181	0.30%
	Lead Carbon Battery	22,516	0.29%
	Zinc Air Battery	19,588	0.26%
	Valve Regulated Lead-acid Battery	16,214	0.21%
	Lithium Polymer Battery	9,468	0.12%
	Hybrid Lead-acid Battery/Electro-chemical capacitor	6,732	0.09%
	Zinc Iron Flow Battery	3,320	0.04%
	Lithium Nickel Cobalt Aluminum Battery	2,600	0.03%
	Lithium Manganese Oxide Battery	1,100	0.01%
	Sodium-ion Battery	860	0.01%
	Flow Battery	700	0.01%
	Other	1,310	0.02%
Electro-mechanical	Flywheel	971,925	12.71%
	Gravitational Storage	50,000	0.65%
Hydrogen Storage	Hydrogen Storage	18,420	0.24%
Liquid Air Energy Storage	Liquid Air Energy Storage	5,000	0.07%
Thermal Storage	Molten Salt Thermal Storage	2,751,920	35.97%
	Thermal Storage (not otherwise specified)	491,400	6.42%
	Chilled Water Thermal Storage	137,206	1.79%
	Heat Thermal Storage	129,755	1.70%
	Ice Thermal Storage	112,394	1.47%
	Concrete Thermal Storage	100	<0.01%

Source: DOE Energy Storage Database. Accessed December 2016. Dismantled projects not included. Pumped storage hydro and compressed air projects not included.

FOM Storage Market Trends

Our research identified two key trends in the FOM market, including:

- **Utilities are beginning to develop larger-scale FOM systems for various grid-related applications.** In California, Southern California Edison is working with several contractors to install a total of 263 MW of storage, including a contract for a 100-MW storage facility being installed by AES Corporation. In Indiana, the 20 MW Harding Street Battery Energy Storage System went into service in May 2016, providing Indianapolis Power and Light with a greater degree of frequency control than was previously possible (Walton 2016).
- **Community energy storage continues to diversify**. While a number of different models of community energy storage have emerged in the past few years, the most frequent model encountered in this research is a third-party implementer model. In this model, a third-party installer and/or operator partners with a utility to provide community storage that is integrated with distributed renewables such as solar PV. Such a setup has worked for SunShare (which has partnered with Xcel Energy in Minnesota) and Clean Energy Collective (which has partnered with 25 utilities across the United States) (H. Trabish 2015).

2.1.3 Energy Storage Management Systems

While more of a technology than market segment, a relatively small number of companies are leading the niche area of energy storage management systems (ESMSs). ESMSs provide the software required to manage storage devices (both FOM and BTM) and are critical for interconnecting distributed energy storage systems to the grid. More than a dozen companies are currently involved in the development of proprietary ESMSs, including ABB, AES Energy Storage, Demand Energy Networks, Eaton, Princeton Power Systems, Green Charge Networks, Greensmith, Intelligent Generation, S&C Electric, Tesla, Stem, Sunverge, and Younicos (GTM Research 2015a).[6] More recently, high-profile market actors Siemens, Samsung SDI, and Eaton have signaled their support for an open, non-proprietary standard such as that offered by the Modular Energy Storage Architecture (MESA) organization (MESA 2016).

As shown in Table 2-3, most market actors providing ESMSs focus on multiple applications. However, most confirmed deployments are limited to only a handful of key firms. Though still a nascent industry, projections for the growth of the ESMS market are optimistic. Analysts have estimated the market for ESMSs will increase ten-fold between 2014 and 2019, at which point the market will hit $136M (GTM Research 2015a).

[6] Of these firms, our research indicated that only Green Charge Networks had a primary office in New York State.

Table 2-3. Energy Storage Management System Vendor Capability Matrix

	1Energy Systems	ABB	AES Energy Storage	Coda	Demand Energy Networks	Eaton	Geli	Green Charge Networks	Greensmith	Intelligent Generation	Princeton Power	S&C Electric	SolarCity/ Tesla	Stem	Sunverge
Bulk Energy Services															
Electric Energy Time-Shift (Arbitrage)	●	○	○	●	○	○			●	●	○	●	●	●	●
Electric Supply Capacity	●	○	○	●		○			●	●	●	●	○	●	●
Ancillary Services															
Regulation	○	●	●	●		○			●	●		●		○	●
Spinning, Non-spinning and Supllemental Reserves	●	●	○			○			●			●			●
Volarge Support	●	●			○	○			●	○		●		○	●
Black Start	○	●		●	○	○			●		●	●	○		
Load Following/Ramping Support for Renewables	●	●	○	●	○	○			●	○	●	●		○	●
Frequency Response	●	●	○			○			●	●	●	●		○	●
Transmission Infrastructure Services															
Transmission Upgrade Deferral	●	○				○			●		●	●		●	●
Transmission Congestion Relief	●	○	○			○			●		●	●		●	●
Distribution Infrastructure Ser-vices															
Distribution Upgrade Deferral	●	○			○	○			●		●	●		●	●
Voltage Support	○	●	○		○	○			●		●	●		●	●
Customer Energy Management Services															
Power Quality		●		●	○	○	●		●	○		●	○	○	●
Power Reliability		●		●	○	○	●	○	●	○	●	●	○	○	●
Retail Electric Energy Time-shift		●		●	○	○	●	○	●	●	●	●	○	●	●
Demand Charge Management		●		●	○	○	●	○	○	○	●	●		●	●

○ Vendor has capability ● Vendor has deployed project

Source: Adapted from GTM Research

2.2 Market Demand for Grid Storage

Until recently, market demand for grid storage had been limited, as the cost of energy storage was prohibitively high and there was not significant renewable energy penetration. However, demand has increased over the past four years, with the most impressive growth occurring since 2014. In the U.S. alone, FOM deployments increased 223% from 2014 to 2015; BTM deployments increased 405% during that same time period (GTM Research 2016a). And though BTM energy storage has only accounted for roughly 10% of grid storage capacity to date, it is expected to grow very quickly through 2025, with most of the growth attributable to residential and commercial energy storage BTM deployments (GTM Research 2016b).

In the U.S., demand is driven by state policies like California's 1.3 GW storage mandate. It is estimated that in 2013, the U.S. had approximately 24.6 GW (just over 2% of total electric production capacity) of grid-scale storage, 95% of which is pumped hydroelectric storage (Johnson et al. 2013). Most indications suggest that the tremendous industry growth seen from 2013 to 2015 will continue over the next few years as more technologies enter the market and existing technologies mature.[7]

Projections from several secondary sources support the notion that grid storage market growth will continue:

- The global pipeline for grid-connected storage already contains about 900 megawatts (MW) expected to be commissioned in 2016, which will effectively double the global installed capacity of energy storage systems by 2017 (Pentland 2016).
- A report by Citigroup estimates that the global battery storage market (not including car batteries) will increase to 240 gigawatts (GW) by the year 2030. The bulk of this growth will come from lithium-ion technologies (Citigroup 2015).
- Commercial and industrial building BTM energy storage system power capacity deployments are expected to grow from roughly 500 MW in 2016 to over 9 GW by 2025. Industrial buildings will lead this growth, followed by office buildings and educational facilities (Navigant Research 2016).

The U.S. is expected to contribute significantly to this growth:

- Of new grid energy storage capacity coming online in 2016, roughly 45% is slated for deployment in the United States. In second place, Japan will claim about 20% of the total capacity (Pentland 2016).
- One recent NREL study estimated a market potential of 7,100 megawatt-hours and 10,700 megawatts (MW) of BTM batteries used for demand charge management.[8] They further suggested that, if properly deployed and utilized, BTM storage alone may represent a viable

[7] Pumped storage hydro will continue to play a role in the growth of this segment, though its growth relative to its current size will be less than the relative growth of newer technologies.

[8] For this estimate the authors assumed all facilities become subject to a demand charge tariff, and did not include buildings less than 25,000 square feet.

pathway to reaching storage targets such as those set by California (Neubauer and Simpson 2015).[9]

There is no indication from secondary data sources or from interviews that the market will be unable to meet this projected demand. As discussed in Section 3.2 (Market Demand for Emerging Transportation Storage), there is evidence of excess global production capacity for automotive lithium-ion batteries. Because grid storage technologies are also highly reliant on lithium-ion technologies, it is the research team's assessment that this excess capacity also applies to the grid storage market. However, as with other technologies used for new applications, it may be too early to answer this question. It appears likely that latent demand exists for these products and, as barriers related to lack of familiarity, regulatory uncertainty and customer cost concerns are overcome, this demand will be actualized. It is also worth noting that multiple large corporations (e.g., Panasonic, LG Chem, etc.) are involved in these markets, and are likely to possess the resources required to meet market demand.

[9] The extent to which BTM storage will compete with FOM storage remains to be seen.

3 Emerging Transportation Storage Markets and Market Demand

In this section, we describe the different types of transportation storage technologies currently available. Market segments included in the transportation market can be classified as light-duty electric vehicle, medium- and heavy-duty electric truck, and electric vehicle charging equipment. We discuss each of these in more detail below.[10] We also discuss projected market demand for these markets.[11]

3.1 Light-, Medium-, and Heavy-Duty Electric Vehicle Batteries

Electric vehicles (EVs) can be classified as follows:

- Battery electric vehicles (BEVs), which are powered solely by the electricity stored in their batteries.
- Plug-in hybrid electric vehicles (PHEVs), which use battery power to extend the range of an internal combustion vehicle. PHEVs can also operate solely on gasoline or diesel.
- Hybrid electric vehicles (HEVs), which use batteries to store energy generated from braking to supplement regular engine propulsion capabilities. HEVs are not plugged in to charge (U.S. Department of Energy, n.d.).

Storage technologies used by electric vehicles include Li-ion batteries, lead acid batteries, and ultracapacitors. Most of the BEVs and PHEVs currently on the market use lithium-ion batteries, though the exact chemistry often varies.[12] While several types of Li-ion battery chemistries currently compete in the market, no single chemistry is optimal for all transportation storage applications.

- Currently, the size of the global market for Li-ion and nickel metal hydride (NiMH) automotive batteries (for light-, medium-, and heavy-duty vehicles) is estimated to be about $9.4B in 2015 and is projected to more than triple to roughly $30.6B by 2024. However, the contribution of NiMH batteries to these figures is negligible.
- It is estimated that the overall market (again including both light-, medium-, and heavy-duty vehicles) constituted about 15.9 GWh in 2015 and will increase to 93.1 GWh in 2024. During this period, a decrease in the per-kilowatt-hour cost for storage will increase the attractiveness of the value proposition of electric vehicles for consumers (Navigant Research 2015b).

---

[10] For discussion purposes, we place light-duty and medium/heavy-duty vehicle batteries in the same market segment. However, in the economic analysis provided by Industrial Economics, Inc., these are considered to be separate market segments.

[11] Fuel cells represent another emerging technology in the transportation market. However, in order to maintain alignment with the corresponding economic analysis included in this research, we keep fuel cells as a separate segment.

[12] While most electric vehicles now use Li-ion battery chemistries, some hybrid vehicles (for example, the Toyota Prius family) still use NiMH battery chemistries.

In addition, recent policy efforts within the U.S. were aimed at increasing the share of the country's advanced battery manufacturing capability from two plants and a 2% global market share to more than 20 manufacturers and a global market share of 40% by 2015. This included $1.5B in funding as part of the American Recovery and Reinvestment Act of 2009 to battery and cell manufacturers and their suppliers to expand manufacturing capacity. However, as of 2016, these goals had not been reached and the bulk of Li-ion batteries for automotive applications are still produced in Asia (Navigant Research 2015b).

Other technologies relating to electric vehicle applications include:

- **Advanced lead-acid batteries**, which provide another alternative to Li-ion batteries for use in electric vehicles. Conventional lead-acid batteries are relatively inexpensive, safe, reliable, and have an established manufacturing base. However, lead-acid batteries are limited by their low energy density and a short cycle life (U.S. Department of Energy, n.d.). More advanced, higher-performance lead-acid batteries are currently under development, but are far from commercialization for most applications.
- **Ultracapacitors,** which store energy in a polarized liquid between an electrode and an electrolyte, offer another potential energy storage technology for electric vehicles. They also charge and discharge more quickly than conventional batteries. However, until ultracapacitors are able to achieve a higher energy density, they are unlikely to compete with conventional batteries in transportation applications because they can discharge their power only for a few minutes (ARPA-E 2009).
- **Fuel cells,** primarily use a Proton Exchange Membrane Fuel Cell (PEMFC) to power the vehicle. A PEMFC uses a layer of solid polymer as an electrolyte that allows protons to be transmitted from one face to the other, creating electricity. PEMFCs are fueled by hydrogen (National Fuel Cell Research Center, n.d.). One of the few widely-available fuel cell vehicles currently on the market is the Toyota Mirai, which was first released in 2015 (Voelcker 2016b).

Competition for battery storage types in electric vehicles varies depending on the vehicle type and application. Medium- and heavy-duty electric vehicle batteries compete with hydraulic hybrid systems, which use pressurized fluid instead of electricity to help power vehicles (ECG Consulting Group 2012). Fuel cell powered vehicles are better suited than batteries for long-haul and heavy-duty applications.

3.2 Market Demand for Emerging Transportation Storage

Compared to demand for all types of vehicles, demand for light-duty electric and hybrid vehicles has been relatively weak since 2010. In 2015, automakers sold fewer than 500,000 electric and hybrid vehicles in the United States, even though the overall automobile market achieved record sales of $17.5M (Vlasic 2016). There are some reasons to believe this may change in the near future:

- Tesla announced in April 2016 that it had booked reservations for nearly 400,000 Model 3 sedans, which will not be available until next year (Vlasic 2016).
- General Motors will begin shipping the Bolt, a modestly-priced EV with 200-mile range in late 2017. Initial reviews and expected demand are positive.

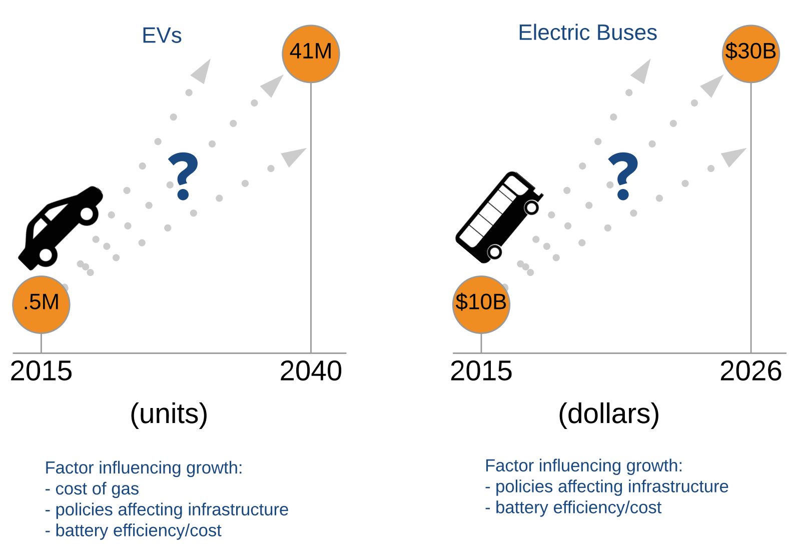
- Bloomberg New Energy Finance released a report in early 2016 that predicted global annual sales of light-duty electric vehicles will hit 41 million by 2040, representing over a third (35%) of new light-duty vehicle sales. This would be almost 90 times the equivalent figure for 2015, when annual EV sales are estimated to have been 462,000, some 60% up from 2014 primarily due to projected cost reductions in Li-ion batteries (Bloomberg New Energy Finance 2016).
- Expected increases in the energy density of EV batteries expected through 2017-2018 will extend the range of EVs to over 200 miles between charges. This will likely address barriers currently preventing some people from purchasing EVs (i.e. limited range) (Voelcker 2016a).
- Improvements in "quick charging" will also happen over the next couple of years—meaning that cars can charge in 20-30 min instead of overnight, allowing them to go even further (Mearian 2016).

Like the demand for light-duty vehicles, the demand for medium- and heavy-duty electric vehicles has also been relatively modest since 2012. Currently, it is estimated that over 94% of medium- and heavy-duty vehicles on the road today use a conventional internal combustion engine (ICE) powered by either gasoline or diesel. Demand for medium- and heavy-duty electric vehicles is also projected to increase over the next 20 years.

- The demand for electric buses is expected to lead this increase. One recent report projects the global electric bus market growing from roughly $10 billion in 2015 to $30 billion in 2026, potentially making it the largest segment of the overall battery market. This implies the electric bus market will overtake the consumer electronic battery sector by 2019-2020 (Research and Markets 2016).

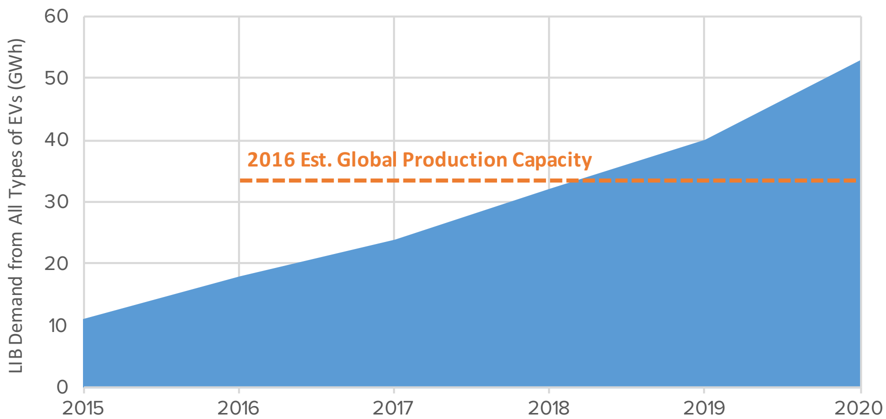
Figure 3-1 depicts the uncertainty surrounding projections for the demand of light-duty EVs and electric buses.

Figure 3-1. Uncertainty Surrounding Projections of Demand for Light-Duty EVs and Electric Buses



As with grid storage, it is difficult to know at this stage whether or not the market can meet demand for emerging transportation storage technologies. At present, it appears that market participants will be capable of meeting the expected demand in the short term, and that there may even be excess production capacity in 2016. As shown in Figure 3-2, one report from the National Renewable Energy Laboratory (NREL) estimates global demand by all types of EVs for lithium-ion batteries to be approximately 18 GWh in 2016, while the estimated current global production capacity in 2016 is between 30 and 35 GWh.

Figure 3-2. Comparison of Estimated Lithium-ion Battery Demand for EVs between 2015 – 2020 to 2016 Estimated Production Capacity[13]

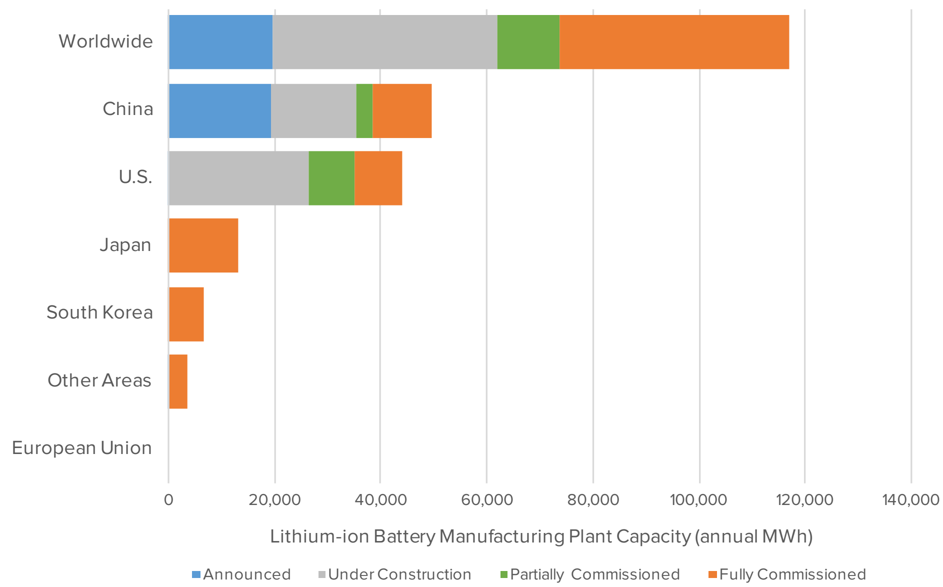


By the estimates provided above, the global supply of automotive lithium-ion batteries could meet demand through early 2018 with no change in production capacity. Yet the global production capacity is also increasing, with approximately 70 GWh of production capacity in the pipeline (i.e., announced, under construction, or partially commissioned, as shown in Figure 3-3). For example, in the U.S., Tesla's Gigafactory alone is planned to produce 35 GWh of battery cells per year (according to the company's website).

---

[13] Source: Chung, Donald, Emma Elgqvist, and Shriram Santhanagopalan. 2016. "Automotive Lithium-Ion Cell Manufacturing: Regional Cost Structures and Supply Chain Considerations." http://www.nrel.gov/docs/fy16osti/66086.pdf.

Figure 3-3. Estimates of Annual Production Capacity for Automotive Lithium-ion Batteries (2015)[14]



There are exceptional scenarios in which the projections discussed above may be invalid. For instance, if the cost of gasoline increases rapidly, there may be a short lag before auto manufacturers are able to meet the resulting demand for electric and electric hybrid vehicles. A prime example of this situation involves Tesla's Model 3 sedan, for which the company has received nearly 400,000 pre-orders. Some analysts question whether the company will be able to meet this supply in the short-term (Shahan 2016).

[14] Source: Chung, Donald, Emma Elgqvist, and Shriram Santhanagopalan. 2016. "Automotive Lithium-Ion Cell Manufacturing: Regional Cost Structures and Supply Chain Considerations." http://www.nrel.gov/docs/fy16osti/66086.pdf.

4 Traditional Storage Markets and Market Demand

In this section, we describe estimates of demand for the different types of storage technologies currently available in traditional storage market segments. These market segments are labeled “traditional” (i.e., existing uses and applications) to distinguish them from the emerging (i.e., expanded and new uses and applications) market segments discussed previously and to align them with market actors in New York State. These categories also align with the 2012 economic assessment by ECG Consulting and its 2015 update by Industrial Economics, Inc. For this report, the research team provides only a high-level overview of traditional storage markets, as NY-BEST’s priorities are focused on grid storage and electric vehicles (discussed in previous sections).[15]

It is important to note that while the technologies in traditional storage market segments may be more established than technologies in the emerging market segments, new technological developments are still occurring within traditional market segments.[16] For example, the recent popularity of drones has created new *applications* for traditional storage technologies. However, the traditional market as a whole is expected to grow less rapidly (relative to its current size) than the emerging markets discussed previously in this report.

4.1 Market Demand in Traditional Storage Markets

Drivers in the traditional storage market are centered on energy density, cost, size and cycle life. Several traditional storage segments—in particular consumer electronics—experienced rapid growth over the past 15 years as technical advances coincided with millions of people around the globe adopting smart phones, tablets, and other electronic devices. Incremental advances in Li-ion chemistries for medical batteries and consumer electronics will likely continue in the near future, and the growth of these market segments should continue at a slow but steady pace. However, new developments in potentially disruptive technologies such as graphene pose a competitive risk to these business-as-usual projections (Douthwaite 2015). Several data points shed light on the immensity of this market:

- For the year 2014, Navigant Research estimated that advanced batteries used for consumer electronics accounted for 44.8 GWh in global shipments (compared to 8.2 GWh for transportation applications and 0.3 GWh for grid storage applications) (Navigant Research 2015a).
- This corresponds to an estimated revenue of $11.3 billion for consumer electronics batteries in 2014 (compared to $2.7 billion for transportation applications and $0.1 billion for grid storage applications).

---

[15] More information on traditional battery/storage markets can be found in market research reports by Freedonia Group (http://www.freedoniagroup.com/industry-study/world-batteries-2939.htm) and Grand View Research (http://www.grandviewresearch.com/industry-analysis/lead-acid-battery-market).

[16] As explained previously in this report, these traditional markets should be considered global markets (i.e., not specific to New York State).

As with previous markets, it appears from secondary sources or from interviews that the market will be able to meet the demand for traditional storage technologies in most applications. Cost serves as a natural impediment to this market, which will continue to limit demand to certain levels. However, it is important to recognize that traditional storage markets will be affected in the future by recent developments in emerging markets. Specifically, advances in battery storage in traditional markets, to an extent, is being driven by advances in the transportation market where the competition is fierce and every incremental improvement in battery technology potentially translates to significant gains in market share. As transportation battery costs continue to fall and capacities continue to increase, technology spillover will likely continue to occur in more traditional markets (Lee 2016).

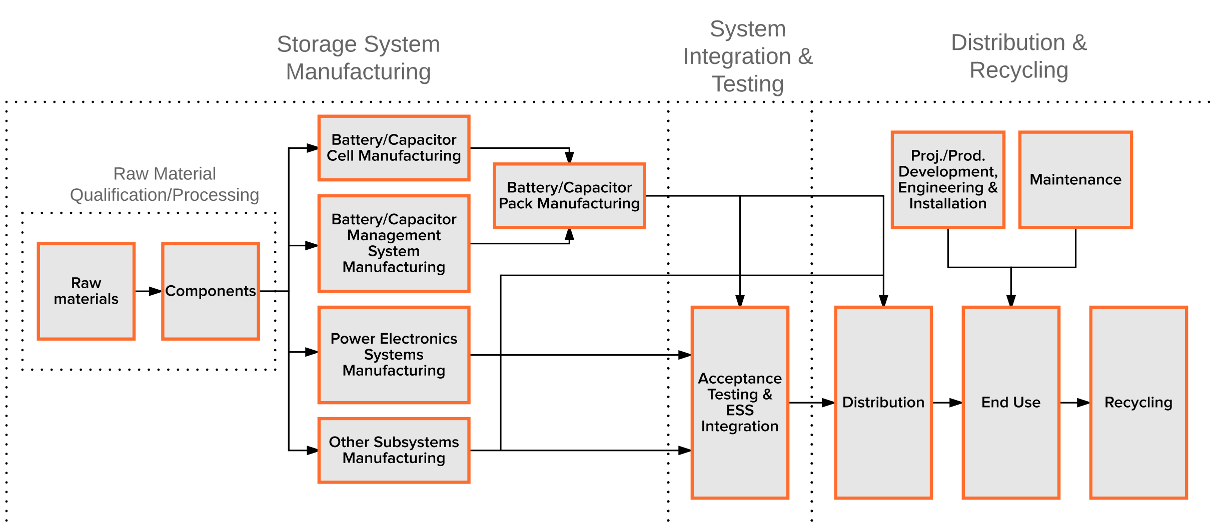
5 Key Market Actors

In this section, we describe the market actor landscape for energy storage technologies, including global market actors and those local to New York State.

The energy storage market is made up of a number of vendors focused on different technologies and different applications for those technologies. The vendor ecosystem is dispersed across the globe, with several regions featuring higher numbers of key market actors at different points along the supply chain. Many of the larger market actors have a presence in *multiple* geographic areas. Thus, it is not always possible to draw strict distinctions between market activity in different geographic regions. To the degree possible, we discuss market actors in the context of their respective geographies, noting where there may be overlap.

A simplified supply chain diagram is shown below in Figure 5-1. The supply chain differs by application segment, with transportation having relatively few vendors and traditional markets having many vendors. The degree of vertical integration also varies greatly between market actors, with many smaller actors focusing only on one part of the supply chain (e.g., raw materials) and some of the larger actors covering the supply chain spectrum from raw materials to systems integration. Geographically, it is typical for many of the raw materials to come from various locations around the world (for instance, lithium from South America), for these materials to be processed and formed into basic components in Asia, for the components to be assembled into systems and installed wherever the end-user may be located.

Figure 5-1. Simplified Battery/Energy Storage Supply Chain Diagram



Source: Adapted from NY-BEST.

5.1 Supply Chain Taxonomy of Market Actors

In this section, we present a summary taxonomy of energy storage market actors by their position in the supply chain and by a qualitative estimate of their market position. In general, "large" indicates organizations with an established global presence, "medium" indicates organizations operating in national markets, and "small" indicates emerging organizations that are operating regionally. Highlighted organizations indicate those with NY-BEST membership.

Table 5-1. Taxonomy of Market Actors

Market Share	Components		Systems/Integrators		Software
	Cells/Modules	Electronics			
Large	A123 Systems	ABB	ABB	**Navitas Systems**	1 Energy Systems
	AES	Bosch	Abeinsa	NEC Corporation	ABB
	Ashlawn Energy	Dynapower	Advanced Microgrid Solutions	Parker	**AES**
	BYD	Eaton Corp.	**AES**	PowerTree	Bosch
	Blue Energy	**GE**	Beacon Power	Powin Energy	greencharge
	GS Yuasa	Ingeteam	Bosch	RES Americas	Greensmith
	Gildemeister	**LG Chem**	BYD	**S&C Electric Co.**	OutBack Power
	Hitachi	Nidec ASI	CODA Energy	Saft	stem
	NEC Energy Solutions	OutBack Power	Demand Energy	Sener	sunverge
	Johnson Controls	Parker	Durion	SHARP	Toshiba
	Kokam	Princeton Power Systems	Kokam	Solar Grid Storage	Viridity Energy
	Lithium Energy Japan (LEJ)	**S&C Electric Co.**	Korea Electric Power Corp.	Sonnen Batterie	Xtreme Power
	LG Chem	**Schneider Electric**	**GE**	stem	Younicos
	Litec	SciEssence Intl.	Green Charge	Storage Battery Systems	
	Panasonic Sanyo	Siemens	Greensmith	Sunverge	
	Saft	SMA	Hitachi	TAS Energy	
	Samsung	Woojin Industrial Systems	JLM Energy	Tesla	
	SK Energy	Younicos	Johnson Controls	Younicos	
	Sony		**LG CNS**		
	Toshiba		**Lockheed Martin**		
	UniEnergy Technologies		**Mercedes-Benz Energy**		
Medium	Altairnano	**Custom Electronics, Inc.**	**Adara Power**		CODA Energy
	AA Portable Power Corp.	Eguana	Altairnano		**Demand Energy**
	Beckett Energy	Microvast Power Systems	C&D Integrated Power Systems		Enbala
	Valence Technology	**SolarEdge**	EaglePicher		Geli
	EaglePicher	Tabuchi Electric	**Electrochem/Greatbatch**		Intelligent Generation
	Electrovaya		Electrovaya		Nation-E
	Electrochem/Greatbatch		Ener1/EnerDel		**Novele**
	Primus Power		**Fluidic Energy**		Voltaiq
	Urban Electric Power		Microvast Power Systems (EV power systems)		
			Optigrid Stored Energy		
			Orison Energy (formerly peakNRG)		
Small	**Active Signal Technologies**	**Sendyne Corp.**	**Peak Power**		
	Applied Power Systems		**Primus Power**		
	Bettergy Corp.		**Storage Power Solutions Inc.**		
	EnerMat Technologies		**UniEnergy Technologies**		
	J&M Schaefer		Vanadis Power		
	Paper Battery Company				
	Sendyne Corp.				
	24M				
	Seeo Inc.				
	Vionx Energy (flow batteries)				
	Widetronix				

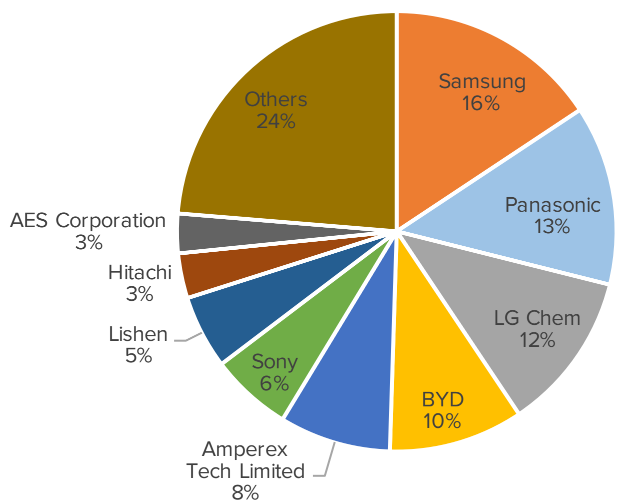
Orange text denotes NY-BEST membership.

In the following sections, we discuss market actors in more detail, focusing first on global actors, then national actors and finally actors with activity in New York State.

5.2 Key Market Actors Globally

Energy storage comprises a wide variety of technology types, of which batteries are the easiest to track across different geographic areas. Looking at energy storage capacity market share for production of all types of advanced batteries for grid storage, transportation, and consumer electronics, the major players are located in Asia. Navigant Research reports that, in 2014, market share (by energy capacity) was held predominantly by China (35.2%), Japan (30.8%), and South Korea (28.5%). Collectively, the Asia Pacific region produced 96% of the advanced batteries in the world in 2014. (Navigant Research 2015a) Key market actors in this arena, listed by market share of capacity, include:

Figure 5-2. Market Share (by Capacity) for Advanced Batteries, 2014



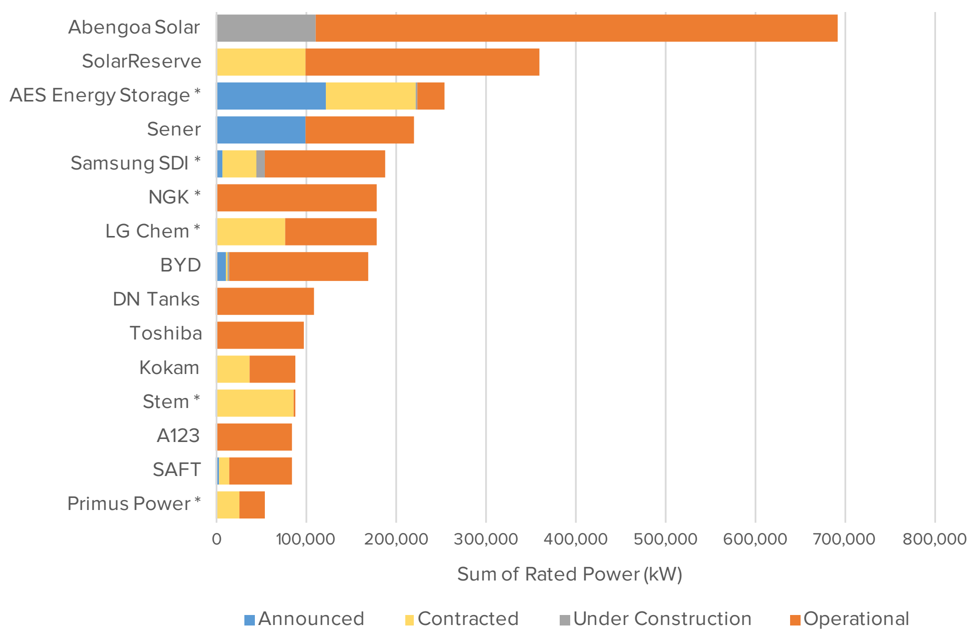
Source: Navigant Research. 2015a. "Advanced Battery Tracker 4Q15."

In the following sections we present information on grid storage deployment share for projects in all geographies.

5.2.1 Global Grid Storage Market Share by Project Capacity

The top 15 energy storage technology providers account for more than 250 MW of grid storage (including both planned and operational). As shown in Figure 5-2, the top two technology providers (Abengoa from Spain and U.S.-based SolarReserve) focus on solar integration projects. Notably, there are six NY-BEST members included in this shortlist (denoted by asterisks).

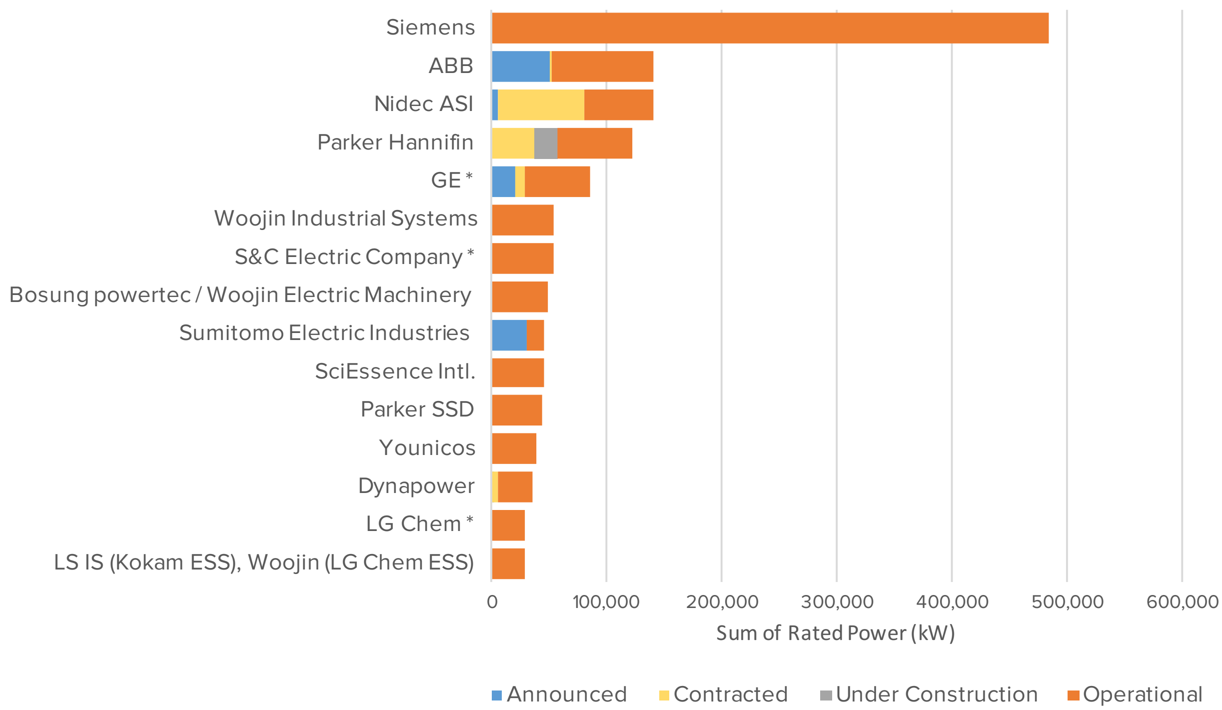
Figure 5-3. Top 15 Energy Storage Technology Providers by Rated Power, Worldwide Projects



Source: DOE Energy Storage Database, accessed December 2016. Asterisks represent membership in NY-BEST.

An analysis of capacity share for electronics providers (shown in Figure 5-4) reveals that German company Siemens has a significant lead compared to its nearest competitor, ABB. Finally, U.S.-based GE (a NY-BEST member) places fifth.

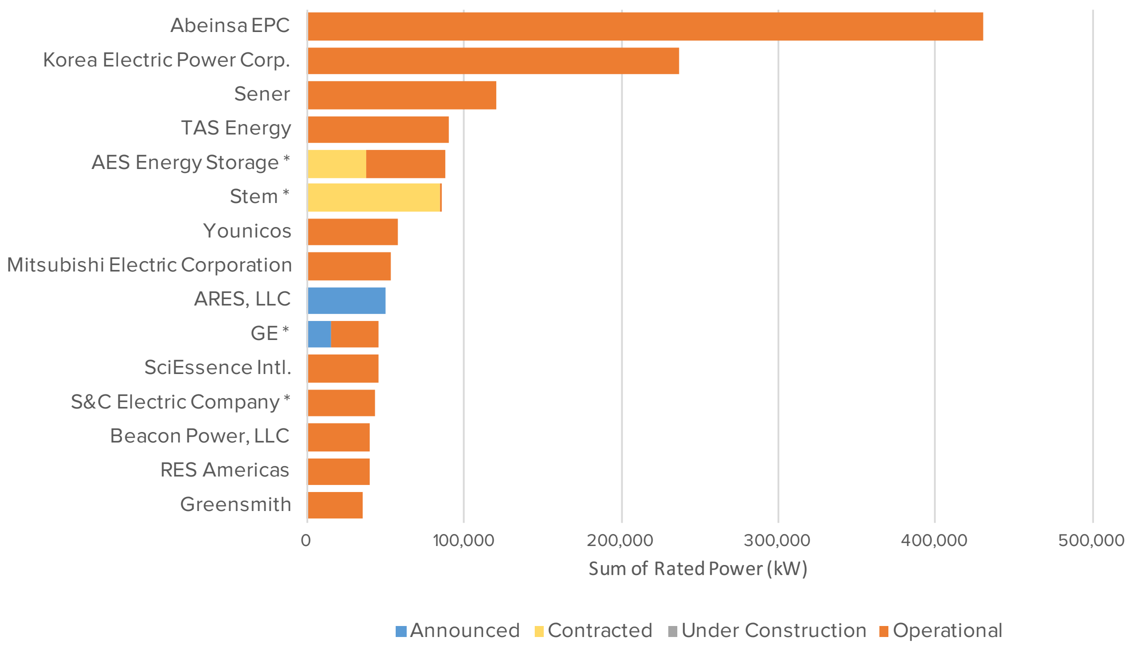
Figure 5-4. Top 15 Electronics Providers by Rated Power, Worldwide Projects



Source: DOE Energy Storage Database, accessed December 2016. Asterisks represent membership in NY-BEST.

As shown in Figure 5-5, several of the major market actors in the grid storage space are vertically integrated. Companies like AES Energy Storage, GE, and Stem are present on multiple lists.

Figure 5-5. Top 15 Integrators by Rated Power, Worldwide Projects



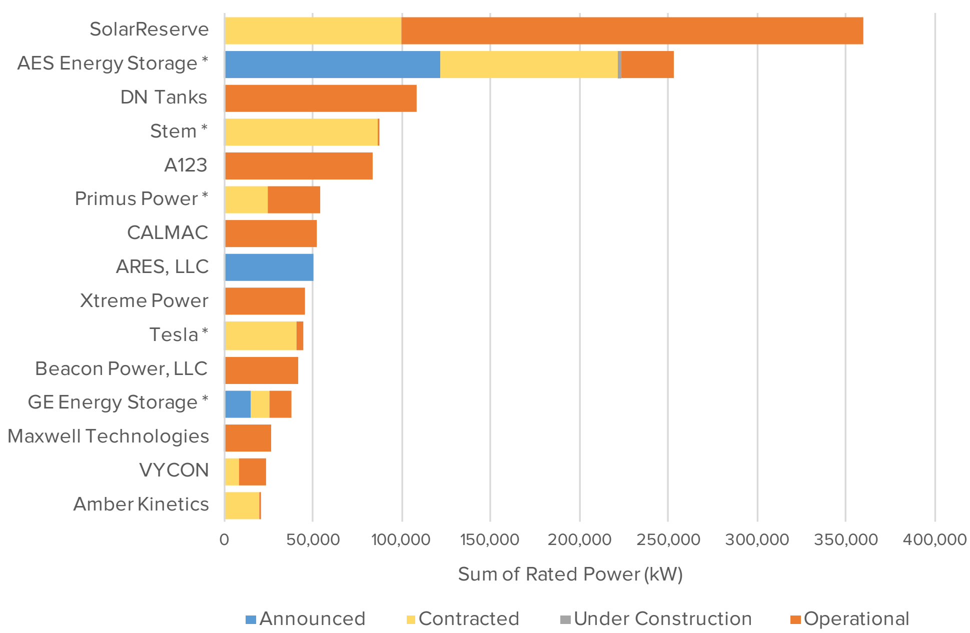
Source: DOE Energy Storage Database, accessed December 2016. Asterisks represent membership in NY-BEST.

5.3 Key Market Actors Within the US

While many of the biggest players in the battery storage market are from the Asia Pacific region, the U.S. boasts a small but highly innovative group of market actors. In this section, we examine estimates of market share for the top 15 U.S.-based energy storage technology providers, electronics providers, and integrators for grid storage systems (in terms of deployed capacity, including announced, contracted, in construction, and operational utility-scale projects).

An examination of the project status of the top 15 U.S.-based energy storage technology providers reveals that a substantial portion of this project work is contracted but not yet operational (Figure 5-6). This is particularly true for Stem, Tesla, and Amber Kinetics, whose contracted work far outpaces operational work. NY-BEST members claim a substantial portion of current and planned capacity, claiming five of the top 15 slots.

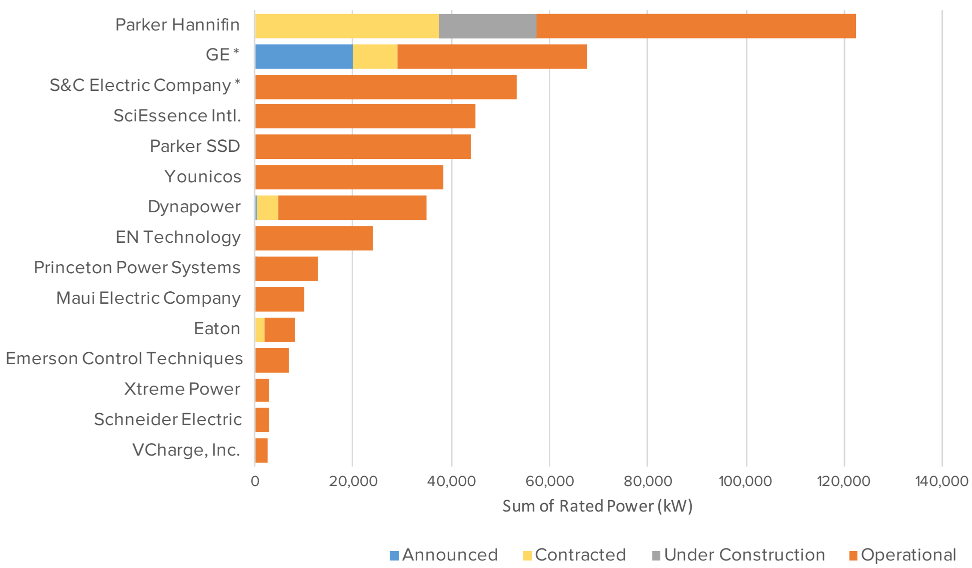
Figure 5-6. Top 15 U.S. Energy Storage Technology Providers by Rated Power, Worldwide Projects



Source: DOE Energy Storage Database, accessed December 2016. Asterisks represent membership in NY-BEST.

The top 15 U.S.-based electronics providers include two NY-BEST members—GE and S&C Electric Company (Figure 5-7).

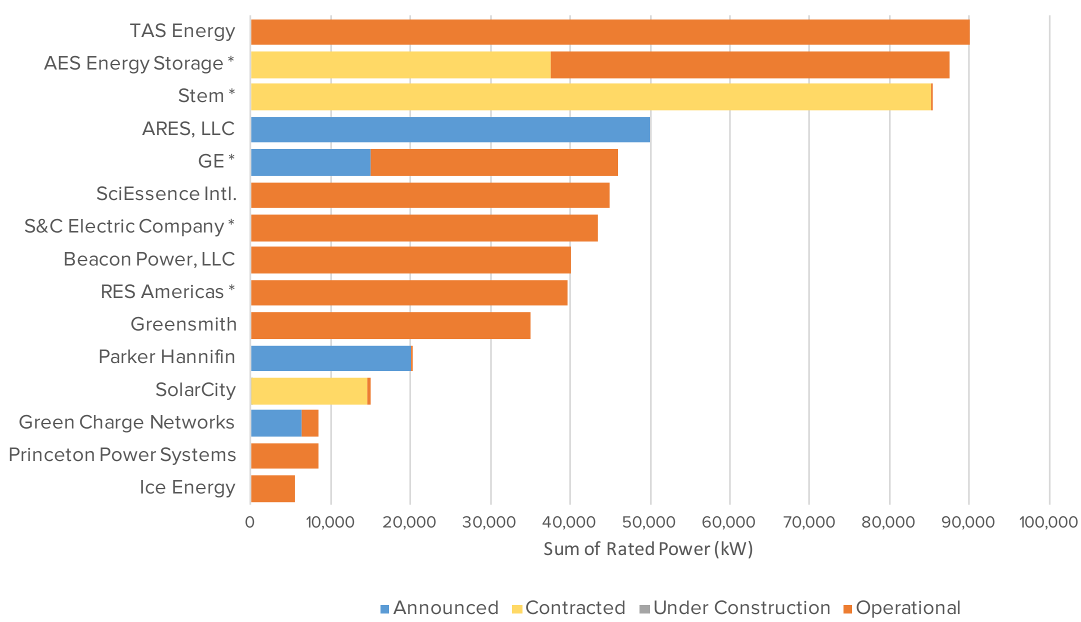
Figure 5-7. Top 15 U.S. Electronics Providers by Rated Power, Worldwide Projects



Source: DOE Energy Storage Database, accessed December 2016. Asterisks represent membership in NY-BEST.

The top 15 U.S.-based systems integrators also include several NY-BEST members, including AES Energy Storage, Stem, GE, S&C Electric Company, and RES Americas.

Figure 5-8. Top 15 U.S. Integrators by Rated Power, Worldwide Projects



Source: DOE Energy Storage Database, accessed December 2016. Asterisks represent membership in NY-BEST.

There are many reasons to believe the U.S will continue to be a leader in both the production and adoption of energy storage, including supporting technologies such as energy storage management systems. Industry drivers in the near future include increased variable renewable energy due to state renewable portfolio standards and regulations that value and pay for fast frequency response. Other drivers are the falling costs of solar PV power, increasing retail electricity rates and the cost and technological development of battery storage (Kempener and Borden 2015).

5.4 Key Market Actors Within New York State

The supply chain for energy storage technologies is complex, with key market actors located around the world. In many cases, key market actors are multinational corporations (e.g., Toshiba) which may have a presence in New York State, but are headquartered elsewhere. For the purposes of this report, we consider key market actors in New York State to include entities with a physical presence in the State, regardless of where they are headquartered. Overall, it appears that NY-BEST has attracted many of the key market actors in the New York State energy storage industry and currently retains them as members. We discuss this in more detail below.

5.4.1 NY-BEST Membership

In this section, we discuss the extent to which NY-BEST represents the energy storage market in New York State. We also note which types of market actors do *not* belong to NY-BEST, and how this may influence the broader energy storage market in New York State.

NY-BEST has attracted many key market actors to become members of the Consortium. However, few of the major battery manufacturers are members. Additionally, only a few members focus exclusively on transportation storage applications or on energy storage management (software) systems (though at least two member organizations—including AES and Tesla/SolarCity—do provide energy management systems as part of their products).

From our review of program tracking data supplied by NY-BEST, we found that the typical NY-BEST member organization is a start-up company or established corporation with fewer than 50 employees. Just over one-fifth (21.2%) of member organizations have projects funded through NYSERDA. More detailed statistics are listed below:

- **Type of Organization:** NY-BEST member organizations are classified as follows:
  - 47.0% of members (n =71) are start-ups.
  - 42.4% of members (n = 64) are corporate organizations.
  - 10.6% of members (n = 16) represent academic, government, or non-profit organizations.
- **Size of Organization:** Many NY-BEST member organizations are relatively small companies:
  - 55.6% of members (n = 69) have 50 or fewer employees.
  - 21.8% of members (n = 27) have between 51 and 500 employees.

    - 22.6% of members (n = 28) have more than 500 employees.[17]
    - An additional 27 members did not report their staffing.
- **Members with NYSERDA-funded R&D Projects:** 32 member organizations (21.2%) have at least one NYSERDA-funded R&D project.

Interviews with experts and non-members identified notable members of NY-BEST, including (but not limited to):

- **AES Energy Storage (**also discussed above) is a commercial developer and system integrator.
- **Convergent Energy** develops, finances, and operates cost-effective energy storage assets for utilities and commercial end use customers.
- **Demand Energy** is an energy storage designer and developer in New York State, focusing on building, installing, and operating energy storage systems for utilities and commercial customers to achieve economic savings through energy cost reductions.
- **Enersys** is a global leader in energy storage solutions. They manufacture and distribute batteries for material handling equipment and commercial electric vehicles.
- **General Motors (GM)** is one of the largest producers of electric vehicles in the U.S. Headquartered in Detroit (but with a presence in New York State), GM is increasing their production of electric vehicles with an electric model available across most of their product line.
- **Greensmith** is a provider of energy storage software and integration services for grid-scale applications. Greensmith has 70 megawatts of energy storage under management, and accounts for one-third of all energy storage installed in the U.S.
- **NextEra Energy** is one of the leading producers of wind and solar power in the world. NextEra Energy has utility revenues of $17 billion and 44,900 megawatts of total generating capacity. Recently, NextEra announced plans to deploy $100 million in energy storage projects in the next 12 months in places like California and Arizona.
- **Res Americas** has constructed over 160 renewable energy projects totaling more than 9,000 megawatts around the world. Res Americas is also a leader in wind and solar energy storage projects.
- **Stem** provides cloud-based software solutions to C&I customers to help with peak shaving needs and to utilize storage for gird services. Grid projects include an installation in Hawaii that is a megawatt resource for Hawaii Electric and an 85 MW contract with Southern California Edison.

[17] This membership category includes some universities, although typically only a small proportion of employees at the university (for instance, a single department or research group) is involved with the consortium.

Comparison of NY-BEST Member and Non-members

The research team analyzed a list of NY-BEST non-member organizations provided by NYSERDA to better understand the types of organizations with a presence (but not necessarily headquartered) in New York State who are *not* members of NY-BEST. After processing the data and removing duplicates, the non-member list contained 474 unique organizations. A review of these organizations suggested that while some of them were energy storage companies or manufacturing firms, a great number of them were firms likely to provide auxiliary services to the energy storage market—including law firms, investment firms, capital management firms, nonprofit development organizations, and consulting/research firms. This suggests that NY-BEST has captured many of the firms in the State (other than those offering services such as investment or consulting) that stand to benefit from membership in the consortium.

There is evidence to suggest that NY-BEST members are having a positive impact on the New York energy storage market. An analysis of grid storage technology providers for projects located in New York State shows that 11 of the 19 vendors are members of NY-BEST.[18] Their capacity share of this market (in terms of rated power) accounts for roughly 44% of the total aggregate, revealing that NY-BEST members account for a substantial portion of the grid storage market for New York State-based projects. However, interviews conducted as part of this research did not present strong evidence that non-members are faring better or worse than members in terms of revenue, sales, investment dollars, or employment.

It is also notable that substantial overlap exists between the three largest energy storage associations in the U.S.—the Energy Storage Association (ESA), the California Energy Storage Association (CESA), and NY-BEST. NY-BEST shares 21 members with CESA and 31 members with ESA. This suggests that NY-BEST has captured a number of market actors active in multiple regions in the national energy storage market.

---

[18] This analysis was performed using data from the DOE Energy Storage database using data updated through December 2016. Energy storage technology providers were cross-referenced with the NY-BEST member list.

6 The Energy Storage Market in New York State

In this section, we discuss how the energy storage market in New York State has changed since 2012, how New York State compares to other states in the U.S., and how New York State compares to key regions internationally. Where data are available, we highlight economic and policy differences across regions. New York State's energy storage market has continued to develop since 2012, with increases in both employment and revenue, and is generally recognized as one of the energy storage leaders among U.S. states. However, New York does not have as much energy storage deployed as do some other U.S. states or several other regions around the world.

6.1 Changes in New York State Since 2012 Economic Assessment

As described in the economic analysis report published separately as part of this evaluation effort, the energy storage market in New York State has steadily increased both in terms of revenue and employment since 2012, with revenues increasing from $598M in 2012 to $906M in 2015 (estimated) [19]. Similarly, the State has experienced an increase in energy storage industry employment from 2,992 jobs in 2012 to 3,931 jobs in 2015 (estimated). This trend is present in both the emerging and traditional market sectors, though a direct comparison between the two is difficult due to limited data from 2012. These figures are roughly consistent with the "base case" market projection estimated in a 2012 market report prepared for NY-BEST, which assumed that New York State would continue to cultivate a strong economic development program focused on the emerging electricity storage and transportation battery sectors, and implement incentives to help develop existing New York State companies and attract new companies to the state.

Generally, there have been few major unforeseen developments in the evolution of New York State's energy storage market since 2012. One exception was the closure of GE's Durathon plant in Schenectady and which repositioned to a system integrator from a cell manufacturer. The plant was slated to employ 350 people, but the plant only employed this many employees for a short time before reducing the plant's workforce through relocation and layoffs (Stanforth 2016).

6.2 Domestic Comparison of New York State

In a pattern similar to that seen in the U.S. solar industry, energy storage projects within the U.S. tend to cluster in a handful of states with incentives and policies that allow monetization of their applications. New York State is often mentioned as one of the leading U.S. states in these markets, along with California, Hawaii, and Texas.

New York State has not implemented large grid-connected energy storage projects to the same degree as states like California. As shown in Table 6-1, New York State ranks 10th of U.S. states in terms of aggregate rated power of energy storage projects included in the Department of Energy's Energy Storage

---

[19] For more information, please see Industrial Economics, Inc.'s The Energy Storage Industry in New York: Recent Growth and Projections, 2015 Update.

database when pumped storage hydro and compressed air storage are included. As Virginia is home to the largest pumped storage hydro facility in the world, it ranks second in the nation despite a lack of battery storage. When pumped storage hydro is excluded, New York State moves up slightly in these rankings to 8th place.

Table 6-1. Top Ten States for Energy Storage Project Deployment in the Continental U.S.[20]

Including Pumped Storage Hydro		Excluding Pumped Storage Hydro	
State	**Rated Power of Energy Storage Projects (aggregate KW)**	**State**	**Rated Power of Energy Storage Projects (aggregate KW)**
California	7,445,313	California	1,058,313
Virginia	3,564,847	Texas	499,492
Nevada	3,232,152	Arizona	313,635
South Carolina	2,286,200	Nevada	232,152
Georgia	2,154,000	Illinois	116,435
Pennsylvania	1,897,415	Alabama	110,515
Michigan	1,877,410	Pennsylvania	87,415
Massachusetts	1,723,490	**New York**	**74,607**
Tennessee	1,652,100	West Virginia	66,724
New York	**1,474,607**	Hawaii	63,371

Source: DOE Global Energy Storage Database, accessed August 2016. Decommissioned projects not included.

New York State ranks favorably when it comes to investment in energy storage technologies. While sales data specific to New York State is limited, according to the venture capital database CB Insights, investment in energy storage firms in the New York Metro area has experienced a positive net growth from 2011-2015, with an average deal increase of 5.92%. Compared to other regions in the U.S., this

[20] Aggregated KW values include pumped storage hydro and compressed air storage projects.

average deal growth ranks second highest (behind Massachusetts, at +8.45%). The New York Metro area also ranks highly in terms of number of deals, securing 9.73% of all the deals recorded (the only regions with a greater percentage of deals were Silicon Valley with 17.3% and Massachusetts with 11.3%).[21]

Going forward, New York is likely to remain an appealing market for additional investment in grid storage, particularly as a result of the Public Service Commission's decision to limit the ownership of distributed energy resources by utilities and, instead, to rely primarily on third-party providers (Opalka and Heidorn 2015). Investment in energy markets (including storage markets) in New York State will also likely benefit from the Clean Energy Standard, which mandates the state obtain 50% of its electricity from renewable sources by 2030 (New York State Governor's Press Office 2016).

6.2.1 California

California has been on the forefront of the energy storage industry in terms of both R&D and deployment for the last few years. Ambitious legislation and natural demand created by the closure or pending closure of several nuclear plants, a large natural gas facility disruption, and extensive amounts of intermittent PV have combined to propel California past many other states in terms of energy storage deployments:

- Assembly Bill (AB) 2514, passed in 2010, compelled the state's investor-owned utilities to procure 1.3 GW of storage capacity by 2020, and has led to substantial interest in grid storage technologies (Charles 2014).
- The law requires investor-owned utilities to procure storage based on their size; targets include FOM and BTM storage.

As of 2015, California already had approximately 378 MW of new storage capacity in the pipeline. Many believe that this target could be affected by another piece of legislation signed by Governor Jerry Brown in 2015—a mandate for the state to obtain 50% of its energy from renewable sources by 2030. The California Public Utility Commission is currently considering whether the existing 1.3 GW target needs to be adjusted to account for the increased need from renewables (Blume 2015).

Though difficult to make a direct comparison between the energy storage industry in California and in New York State, there are several data points that help provide context:

- A 2014 report estimated that the total employment in California for advanced grid storage was 8,500; the report also estimated that total employment in California for advanced transportation technologies was 15,000 (AEE Institute 2014).
- By comparison, New York State employment estimates for all energy storage sectors was 3,391 in 2015.

To put these numbers in context, Table 6-2 provides these same estimates as a percentage of all nonfarm[22] employees for each state.[23] The resulting values are similar when not considering advanced transportation employment in California (0.05% for California and 0.04% for New York State).[24]

[21] For more detailed investment information, please see the corresponding impact evaluation report.

Table 6-2. Normalized Energy Storage Employment Estimates for CA and NYS

Market/Industry	Employees	Total Nonfarm Employees	% Energy Storage Industry Employees of All Nonfarm Employees
California (2014)			
Grid Storage	8,500	15,585,600	0.05%
Advanced Transportation	15,000		0.09%
New York State (2015)			
Energy Storage	3,391	9,246,500	0.04%

6.2.2 Hawaii

Hawaii has the greatest penetration of residential solar in the U.S., and is the second-largest residential domestic energy storage adoption market with 320 kW of cumulative deployments (Blume 2015). This is not surprising, given that Hawaii typically has the highest electricity costs in the nation. Recent legislation in Hawaii has been aimed at further promoting energy storage by instituting a system whereby residential consumers can install solar panels at their homes and either use the energy themselves, or have the option to sell it back to the grid at wholesale rates (instead of retail rates, which are much higher). This environment seems conducive to residential storage units like Tesla's Powerwall, and analysts believe that Hawaii will serve as a "proving ground" for the first generation of residential storage technologies.

- In 2015, Hawaii signed into law a mandate requiring the state to procure 100% of its energy from renewable sources by 2045. This will likely help drive the adoption of customer-sited energy storage integrated with PV solar.
- Also in 2015, Hawaii Electric Company (HECO) initiated a Commercial Storage Program with Stem, an energy storage integration and analytics firm, and Energy Excelerator, a program of the Pacific International Center for High Technology Research (PICHTR). The

[22] The nonfarm business sector is defined by the Bureau of Labor Statistics as "a subset of the domestic economy and excludes the economic activities of the following: general government, private households, nonprofit organizations serving individuals, and farms."

[23] Estimates of total number of nonfarm employees were taken from the Bureau of Labor Statistics 2015 Annual Average Tables. For California, 2014 values were used to align with the date of the energy storage employment information. For New York State, 2015 values were used. Available: http://www.bls.gov/sae/tables.htm

[24] Because these studies relied on different methods and definitions for "energy storage," this comparison should be considered primarily qualitative.

goal is to bring energy storage and intelligent software to businesses on Oahu via a $2.1-million pilot program.

- In January 2016, Tesla announced it had partnered with SolarCity to provide batteries for a SolarCity project on the island of Kaua‘i (Fehrenbacher 2016).

6.2.3 Texas

Although there has been significant interest in energy storage in Texas over the past few years, the state's regulatory and market structure has largely impeded growth in this industry. Texas features a highly competitive electricity market where separate entities generate, distribute, and market electricity. Importantly, revenue is not decoupled from electricity sales in the state—thus there is less incentive for generators to implement energy storage devices that might decrease demand (H. K. Trabish 2016).

In late 2014, Texas utility Oncor commissioned a report by the Brattle Group which found that up to 5 GW of energy storage could be deployed on the Electric Reliability Council of Texas (ERCOT) electric grid. Though many in the state thought this number was ambitious, it was expected that this report would help initiate several energy storage projects in the state. These projects never materialized—instead it appears that a number of market barriers prevented further progress. In Texas, utilities are classified as either transmission and distribution (T&D) utilities or as generation utilities. A T&D utility (such as Oncor) is only able to perform certain T&D-related functions. And since energy storage is classified as a "generation asset" in Texas, this means that T&D utilities are unable to use storage devices for many of the functions that make them useful (such as load-leveling or demand management) (Bade 2015). It is likely that further advances in energy storage deployment in the state will be minimal until legislative adjustments are made to the current system, such as making it legal for transmission and distribution utilities (like Oncor) to own generation assets (i.e., energy storage devices).

6.2.4 Massachusetts

Since 2015, Massachusetts has adopted legislation known as the Energy Storage Initiative to facilitate the adoption of energy storage within the Commonwealth. In a report released in August of 2016, the Massachusetts Department of Energy Resources released a report dubbed "State of Charge," calling for the state to include energy storage in existing energy efficiency programs, to encourage the integration of storage with renewable resources, and to adopt a legislative energy storage mandate of 600 MW (Maloney 2017). The report estimates that by deploying 1,766 MW of energy storage, the Commonwealth will accrue $2.2 billion in savings and benefits to ratepayers (Massachusetts Department of Energy Resources 2016).

Table 6-3. Domestic Comparison of New York State

	New York State	California	Hawaii	Texas
Investment	The New York Metro area ranks third in the US in number of energy storage investment deals, behind only California and Massachusetts.	The Silicon Valley area leads the nation in number of energy storage investment deals.	While the population of Hawaii is small compared to New York State or California, there has been substantial deployment of energy storage projects in the state (many with assistance from out-of-state vendors).	Detailed investment data was not available for Texas. However, evidence suggests that investment interest in the state is high.
Number of firms active in energy storage market[(a)]	As of 2014, there were 107 establishments in New York State classified under NAICS code 3359[a] **(0.02% of all establishments).**	As of 2014, there were 337 establishments in California classified under NAICS code 3359[a] **(0.04% of all establishments).**	Estimates of Hawaii's energy storage employment numbers were not available from specific studies or from Census data.	As of 2014, there were 118 establishments in Texas classified under NAICS code 3359[a] **(0.02% of all establishments).**
Employment[(a)]	New York State employment for NAICS code 3359[a] was 7,203 **(0.08% of nonfarm employees).**	California's employment for NAICS code 3359[a] was 13,367 **(0.08% of nonfarm employees).**	Estimates of Hawaii's energy storage employment numbers were not available from specific studies or from Census data.	Texas' employment under NAICS code 3359[a] was 5,186 **(0.04% of nonfarm employees).**
Policy environment	New York State is recognized as one of the leading US states promoting energy storage, though it has taken a different approach than states like California and Oregon (which have passed energy storage procurement mandates). The REV proceeding and Clean Energy Fund represent progressive policy steps in this area.	California has adopted the most aggressive policies supporting the adoption of energy storage in the US.	High electricity costs and island geography have made Hawaii an ideal location for deployment of residential energy storage. Net energy metering policies have promoted this adoption, though newer policies may not be so favorable.	The regulatory environment in Texas has posed problems for the widespread adoption of energy storage technologies.

(a) NAICS code 3359 is defined as "Other electrical equipment and component manufacturing". Estimates for the number of nonfarm employees were taken from Bureau of Labor Statistics data on annual average employment for 2015.

6.3 Comparison between New York State and Global Market Leaders

In the following sections we provide a more detailed discussion of key countries leading the way in energy storage policies and deployment.

6.3.1 China

China's energy storage industry will likely develop rapidly in the next few years; its electric grid is the largest in the world and the country is home to many of the world's largest wind and solar farms. Despite a slow start, analysts estimate that the Chinese energy storage market will reach annual sales of $482M (USD) and a total installed capacity of more than 750 MW in 2016. Lithium-ion technologies will primarily lead this increase, followed by more traditional lead acid batteries (Popper, Hove, and Zhang 2012). These 2016 numbers represent a significant increase over 2014 numbers, when China installed only about 31 MW of storage and the country's total cumulative energy storage capacity was estimated at only 84.4 MW (Blume 2015).

- The Chinese government is supportive of policies that will drive growth in the energy storage industry and has set ambitious renewables procurement targets. As the country continues to develop and modernize, it is expected that China will have more than 10 million electric vehicles on the road by 2020. More Specifically, China has recently set goals to achieve a 1000% increase in EV sales by the mid-2020s, and is offering subsidies that may account for up to 60% of the sticker price for an EV. It is also notable that as of 2016, BYD has currently sold more EVs than Tesla, GM, and Nissan combined (Romm 2016).
- Overall, current storage projects in China are focused on electric vehicle applications, integration with renewable energy sources, and distributed generation.
- China is home to more than 100 lithium-ion battery manufacturers, including BYD, China Aviation Lithium Battery (CALB), Lishen, and others.

6.3.2 Japan

The 2011 earthquake and subsequent tsunami that resulted in a nuclear reactor meltdown also affected Japan's energy storage trajectory. In 2010, nuclear energy had provided over 25% of the country's electricity supply but since the 2011 earthquake, most of the country's nuclear reactors have been shut down (Kempener and Borden 2015). In that time, Japan has made a substantial shift toward renewable energy sources, with the country setting ambitious goals of producing half the world's batteries by 2020 and obtaining 30% of its energy from renewable sources by 2030. Additionally, Japan subsidizes two-thirds of the cost of lithium-ion batteries installed in homes and businesses – a subsidy program worth about $100M USD (Blume 2015). Since the advent of this program, a significant share of new storage in Japan has been from these behind-the-meter installations.

- In addition, Japan already has a significant amount of energy storage (including 300MW of sodium-sulfur batteries).
- Battery development in Japan has centered on Tokyo Electric Power Company's large sodium-sulfur installations, which were prompted by concerns over the country's reliance on

pumped hydropower storage. It was seen as an attractive alternative for relatively long duration of electricity supply (i.e., multiple hours) and can also provide energy quickly when needed (Kempener and Borden 2015).

Japan is also investigating opportunities for large-scale renewable energy integration, given that the country has several "island" grids with insufficient transmission. In these cases, battery storage serves as a valuable option for increasing grid reliability, and several projects are in place or under construction. As one example, a project in Rokkasho in northern Japan combines a 51 MW wind farm with 34 MW sodium-sulfur battery to address local transmission constraints (Kempener and Borden 2015).

6.3.3 India

India is one of the fastest growing economies in the world, with a current electricity generation capacity of 250 GW. Yet many parts of India have poor quality electric power or no power at all. This presents an excellent opportunity for smaller scale backup storage and microgrids incorporating renewable resources supported by storage throughout the entire market, an opportunity that the Indian government is eager to embrace. Already the energy storage market is projected to hit 16.4 GW by 2020, and the country has instituted a target of 40 GW of renewable energy capacity by 2030. Additionally, India has also pledged $3.5B to support the development of electric vehicle markets in the country through 2022 (Blume 2015).

Additional items of interest include the following:

- As industries maintain diesel powered generators and households have inverters with batteries as backup for unscheduled power cuts, diesel replacement offers a significant commercial opportunity for energy storage in India.
- Roughly two-thirds of the roughly 400,000 telecommunications towers in India lose power on a daily basis, representing another opportunity for energy storage. (Blume 2015)
- In May 2015, India announced plans to invest up to 14,000 crore (approximately $2B) in EVs by 2020. The program will include incentives of 137,000 rupees ($2,100 USD) for a PEV made or assembled in India (Navigant Research 2015b).

6.3.4 Germany

Germany is recognized as a world leader in renewable energy implementation. Renewable energy sources currently produce around 30 percent of all electricity consumed in Germany, and is set to increase to at least 80% of electricity consumption by 2050. Along with high electricity prices, grid integration of these renewable resources has led to increased deployment of energy storage, particularly in the residential sector. Analysts estimate the entire German energy storage market will be worth $1B USD by 2020 (Munsell 2016). Solar power and wind power will anchor this renewable energy production (Blume 2015).

As wind and solar power increase in penetration, and fossil fuel plants go offline, battery storage may become an important option for short and long-term supply fluctuations. This has prompted demonstration projects and research funding for battery storage implementation (Kempener and Borden 2015).

Notably, as Germany has such extensive experience with integrating renewable energy into its grid, it is seen as having more advanced grid management software and control systems. And despite a relatively high percentage of power from wind and solar sources (which tend to be less reliable than more traditional power sources), Germany's grid remains one of the most reliable in the world (Morris 2015).

6.3.5 Australia

Research suggests that the Australian energy storage market will hit 244 MW annually by the year 2020, with a corresponding valuation of nearly $450M USD. This represents a 37-fold increase in capacity between 2015 and 2020. (GTM Research 2015b) Others predict Australia will reach 33GWh of battery storage by 2040 (Parkinson 2015).

- It is expected that behind-the-meter technologies will see significant growth due to increasing energy costs and a large number of market players offering new products. State and local policies tend to be supportive of energy storage deployments, in some part because Australia has more than a dozen remote power-generation facilities that burn fossil fuels and may be good candidates for solar generation with storage (GTM Research 2015b).
- Additionally, it is expected that demand for this type of storage will continue to grow quickly as a result of expensive electricity rates from conventional grid sources (Parkinson 2015).

A graphical comparison of New York State with these key international regions is shown in Figure 6-1.

Figure 6-1. International Comparison of New York State

(note: deployment numbers include pumped storage hydro)

Germany

Policies:
- German policy is very supportive of renewables and energy storage. Coupled with high electricity prices, these policies have made the German market one of the most advanced in the world.

Current Deployment:
- ~8,000,000 kW (rated capacity)

Market Data:
- The overall market is expected to top $1B USD by 2020. This will be buoyed by a strong residential BTM storage market.

China

Policies:
- Very aggressive policies in place for both grid storage and EVs, though most are larger projects facilitated by the government – including rural electrification projects.
- EVs include heavy subsidies for customers.

Current Deployment:
- Grid: ~33,000,000 kW (rated capacity)
- EVs: Ranked 1st in sales in 2015;

Market Data:
- 35.2% of advanced battery market share (capacity) was held by Chinese companies in 2014
- 200+ EV startup companies currently serve the Chinese market.

New York State

Policies:
- State policy (REV) is forward-looking.
- Clean Energy Fund to spur development.
- Federal solar Investment Tax Credit (ITC)

Current Deployment:
- 1,480,730 kW (rated power, NYS only)

Market Data:
- Within the US, New York Metro area ranks third in number of ES investment deals, behind CA and MA.
- Overall, the US held less than 3% of global market share for advanced batteries in 2014.

Japan

Policies:
- There has been substantial state investment in renewables and storage since the 2011 tsunami.
- A comprehensive set of incentives exists for residential energy storage.

Current Deployment:
- ~29,000,000 kW (rated capacity)

Market Data:
- In 2014, Japanese companies collectively held 30.8% market share (capacity) for advanced batteries.

South Korea

Policies:
- South Korea has been historically reliant on imported energy, but has been funding R&D of energy storage since 2011 in an effort to minimize that need. (Kempener and Borden 2015)

Current Deployment:
- ~5,000,000 kW (rated capacity)
- South Korea recently deployed one of the largest grid storage projects in the world for Korea Electric Power Corp.

Market Data:
- In 2014, Korean companies collectively held 28.5% market share (capacity) for advanced batteries.

India

Policies:
- India is aiming to achieve 100 GW of storage on grid over next 5-10 years.
- Interest in energy storage is impacted by frequent outages on current grid system.

Current Deployment:
- ~7,000,000 kW (rated capacity)
- Over 100M residences employ some type of battery storage for power outages.

Market Data:
- India claims to have attracted $14B in funding for all types of clean energy projects between 2013 and 2015 (not just energy storage).

Australia

Policies:
- Australia lacks the policy drivers that some other countries have, though subsidy programs have begun to spring up in some areas.
- Expensive electricity costs are driving many residential customers to invest in solar-plus-storage.

Current Deployment:
- <5,000,000 kW (rated power)

Market Data:
- The Australian market is being targeted by companies like Tesla because of the potential for additional residential BTM storage.

6.3.6 Barriers to Increasing R&D and Market Development for Storage Technology Production in New York State

Despite advances in technology and consumer awareness, several barriers to increasing energy storage R&D and market development in New York State remain in place. Though each of these barriers affects New York State, they may also have an impact on the broader energy storage market. We group these barriers into four main categories: economic barriers, informational barriers, institutional barriers, and technology barriers.

Economic barriers. Though lack of capital deployment remains a pervasive challenge for emerging battery and energy storage markets, there appears to be increasing recognition in the broader industry that investment in energy storage technologies can be profitable. As awareness and understanding of energy storage technologies improves, this trend seems likely to continue. Historically, up-front cost of many of these advanced systems has also posed a barrier. Yet while the cost of the core battery storage technologies has decreased dramatically over the past few years,[25] there remain substantial "balance of system" costs that must be addressed before these systems can become cost effective (or financeable) in some applications (GTM Research 2016a). For example, typical balance of system components needed for residential and small commercial BTM storage include a control device, power conditioning equipment, safety equipment, and meters and instrumentation. In some cases, these components may represent up to half the cost of the entire system. New York State has begun to address these challenges through the Clean Energy Fund, which includes a number of activities aimed at reducing soft costs of storage by 33% and allowing for multiple parties to benefit from the same system (New York State Energy Research and Development Authority 2016).

Informational barriers. Expert interview respondents generally felt that monetizing the value of energy storage is the most significant economic and informational barrier for the industry. Because energy storage is being used for novel applications and in new combinations, it can be difficult to quantify the value of storage without conducting pilot tests and analyzing the results. While monetization is mainly an informational barrier, it also relates to policy and regulatory uncertainty (discussed below) as the manner in which energy storage technologies are used (e.g., whether a grid storage device may serve multiple functions within the grid, including generation) will dictate how such devices are monetized. Monetizing the benefits of storage (particularly in grid applications) would greatly increase the perceived overall value of energy storage systems. This monetization of the value of services from distributed energy resources (DERs), as well as the ability to derive multiple benefits from DERs, are central ideas behind New York State's REV proceeding.[26]

- Multiple experts discussed the need for further support to address this barrier in terms of policymaking, research funding, and education.

[25] For example, the cost of lithium-ion battery packs has fallen roughly 65% from 2010 to 2015 (Landberg 2016).

[26] NYSERDA has recently received approval to conduct "value stacking" pilots which will test the ability for storage systems to provide benefits to multiple parties (New York State Energy Research and Development Authority 2016).

- In addition, members mentioned the need for electric grid policy to help develop clearly defined markets or incentives to increase the value of storage and spur demand.
- This barrier presents the double challenge of developing a way to accurately monetize the benefits while also raising industry awareness and acceptance of those values.

Institutional barriers. Discussion of institutional barriers centered around policy and regulatory uncertainty. More specifically, interviewees discussed the importance of having regulatory certainty for planning purposes, and noted that utilities need to ensure that they have a cost recovery mechanism in place for any infrastructure investments. Similarly, residential and business consumers want to be certain that they will save money by investing in storage technologies. In the end, there are several key policy questions that must be answered, including "Who should own the equipment?" and "What purposes should it be used for?" Ensuring that grid-connected storage devices can be used for multiple purposes (i.e., not just storage but also generation) should also be a consideration. As one interviewee explained, "The dual-use trend is the wild card in where these systems go." Utilities that are vertically integrated will have an advantage when it comes to maximizing the cost effectiveness of storage, because they will be able to monetize the full range of applications.

There are also detailed regional and municipal policy decisions that must be made before certain segments of the market can progress. In heavily urban areas like New York City, these policy decisions often relate to building codes. Note that FDNY is currently working with NYSERDA and Con Edison using facilities at DNV-GL and the NY-BEST Test Center to run safety tests on li-ion and other advanced batteries to will help FDNY establish siting requirements and first responder training protocols for energy management battery systems in New York City.

Technological barriers. The primary technological barriers focus on performance and system compatibility uncertainty. With so many competing technologies and so many market actors, the energy storage industry is highly fragmented. One outgrowth of this phenomenon is the uncertainty associated with system compatibility and standardization of communications protocols. For grid scale projects in particular, new technologies face a host of technical issues which must be solved before utilities and regulators can reliably include these technologies in their strategic planning.

- For some types of advanced batteries, another technological barrier is the lack of large-scale battery manufacturing in the United States.
- As one interviewee explained, the problem is complicated: "The biggest challenge I see in commercialization of energy storage technologies is how do you address the funding gap and the need for manufacturing, when we don't have any good manufacturing in our country (U.S.)? … I can't find even one high volume manufacturer of batteries I can work with for my technology, which means I have to build my own facility resulting in a need for capital before I even have customers signing-on because no customers will sign on without you showing you can manufacture the product."

6.4 Energy Storage Policy in New York State

In this section, we first discuss energy storage policy in New York State, and the extent to which it supports or impedes energy storage market growth. Secondly, we discuss the activities that NY-BEST has undertaken to influence this policy.

6.4.1 Current Policy

Interviewees generally felt that while New York State policy is helping the energy storage industry develop, current policies are potentially restrictive for some applications. A common sentiment among industry stakeholders interviewed as part of this study is that while Reforming the Energy Vision (REV)[27] attempts to facilitate greater market development within the State, it does not answer all the questions necessary for energy storage market development. As such, rather than introducing specific mandates, incentives, or other subsidies directly related to storage output, the REV will more likely serve as an *indirect* driver of growth in energy storage in New York State (Morley 2015).

The initiatives outlined in the REV reference the following clean energy goals:

- 40% reduction in greenhouse gas emissions from 1990 levels
- 50% of energy generation from renewable energy sources
- 600 trillion Btu increase in statewide energy efficiency (New York State 2015).

Although all three of these goals are related to energy storage in some way, none of them relate specifically to energy storage in the same way that California legislation directly calls for 1.3 GW of grid energy storage by 2020. Interviewees indicated that this lack of any specific storage mandate in New York means that it is not yet clear precisely how the energy storage market will respond.[28]

Similarly, the newly-approved Clean Energy Fund is likely to indirectly contribute to the development of the energy storage market in New York State. In January of 2016, the New York State Public Service Commission approved a 10-year, $5 billion fund to accelerate the growth of New York's clean energy economy. The fund is designed to attract third-party capital to support the Governor's aggressive Clean Energy Standard, one of the nation's most ambitious goals to meet 50 percent of New York's electricity needs with renewable resources by 2030. The energy storage market could benefit from funds that will support four major portfolios within the Fund: (1) Market Development, which includes general activities aimed at increasing consumer demand for clean energy options, (2) NY-Sun, New York's solar initiative, (3) NY Green Bank, designed to attract private sector investment, and (4) Innovation and Research, an umbrella category for all types of R&D efforts.

[27] Reforming the Energy Vision is New York State's energy policy, launched in 2014. REV is designed to foster the development of an integrated energy network that can combine the benefits of the central grid with distributed renewable power sources.

[28] The 2016 New York State Energy Storage Roadmap does establish specific energy storage goals; however, these are not legislative mandates.

6.4.2 NY-BEST Policy Activities

NY-BEST has been involved with influencing New York State policy on several levels (It should be noted that activities designed to influence public policy are funded entirely by member fees and not NYSERDA funding):

- At the municipal level, NY-BEST has worked primarily with officials in New York City in relation to permitting and siting of batteries and energy storage in buildings.
- At the State level, the bulk of their interaction has been with the Department of Public Service (DPS), Empire State Development (ESD), Department of Environmental Conservation (DEC), Department of Transportation (DOT), New York Power Authority (NYPA), Long Island Power Authority (LIPA), as well as with the Governor's Office, the State Assembly and the State Senate.
- Also at the State level, NY-BEST has been closely involved with the development of the REV proceeding.
- At the national level, NY-BEST has worked with federal officials from the U.S. Department of Energy, several national labs, the U.S. Army, several members of Congress and New York's two U.S. Senators as well as with the Energy Storage Association (NY BEST 2015).

NY-BEST has published two energy storage roadmaps for New York State, the first of which was published in 2012 and an updated version published in 2016. The roadmaps recommend a number of key actions designed to make New York State a preeminent location for research, development, manufacturing and deployment of energy storage technologies for both the electric grid and transportation. Specifically, the 2016 roadmap established explicit grid storage goals (2 GW of multi-hour storage capacity on New York State's electric grid by 2025 and 4 GW by 2030).

Exhibit 6-1. 2016 NY-BEST Energy Storage Roadmap Goals for New York State

A key goal in the 2016 roadmap is ***"…having 2 GW of multi-hour storage capacity on New York's electric grid by 2025 and 4 GW by 2030."*** The roadmap additionally outlines several specific actions that must be taken to achieve this goal:

- Create new regulatory and market mechanisms to monetize the full value of energy storage.
- Create common financing vehicles that help provide access to capital, simplify project finances and reduce perceived project risks.
- Reduce soft costs of energy storage installations related to siting, permitting, interconnection and other transactional costs.
- Create standardized methodologies, codes, and regulations that are recognized by all jurisdictions to increase commercial confidence in energy storage solutions and reduce soft costs.
- Perform a study to evaluate options and assess requirements for storage and other assets needed to support the State's renewable energy and greenhouse gas emissions goals.
- Increase the availability of information related to electric grid system needs and capabilities in order to enhance industry decision-making.
- Implement a declining bridge incentive for storage that monetizes the value energy storage delivers to the electric system and provides long term revenue confidence to investors.

Additionally, NY-BEST has been involved with ongoing codes and standards development:

- NY-BEST and their member companies assisted in the development of three standards: 1) Underwriters Laboratories (UL) 1973 - Standard for Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications; 2) UL 9540 - Outline of Investigation for Energy Storage Systems and Equipment; and 3) UL 1741 - Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources. The former two (UL 1973 and UL 9540) are viewed as industry-defining standards.
- NY-BEST and member companies also participated in three technical committees: 1) International Electrotechnical Commission (IEC) TC 21 – Secondary cells and batteries; 2) IEC TC 120 – Electrical Energy Storage Systems; and 3) the Institute of Electrical and Electronics Engineers (IEEE) Stationary Battery Technical Committee. In addition, NY-BEST and member organizations "contributed to guidance documents like GRIDSTOR and have engaged with organizations including the FDNY, the National Fire Protection Association (NFPA) and a number of the National Energy Labs on safety-related activities for energy storage system." (NYSERDA program documentation).

7 Classification Considerations for Future Research

The classification of the energy storage markets used in this report aligns with the previous economic assessment from 2012 and with the corresponding economic assessment from 2016. While the classification system used in this report is appropriate for NY-BEST's needs in the near term, the research team identified several modifications that might be made to the existing market classification when pursuing future research on this topic.[29] Table 7-1 shows how recent technological developments have begun to blur the lines between the terms "emerging" and "traditional," which will no longer be useful distinctions once grid storage and electric vehicle technology become mainstream. It may also make sense to clearly delineate what sector (e.g., residential, commercial, utility) each market or market segment references to acknowledge the fact that some market segments may span multiple sectors.

Table 7-1. Possible Market Classification for Future Research

Market	Market Segment	Sector	Application(s)
Stationary Grid (Electricity) Storage	Residential Energy Storage (behind-the-meter)	Residential	Backup power, load-shifting, renewable storage, grid services
	Commercial Energy Storage (behind-the-meter)	Commercial	Backup power, load-shifting, renewable storage, peak shaving, grid services
	Energy Storage on the Grid (front-of-the-meter)	Utility	Peak reduction/smoothing, ancillary services, spinning/non-spinning reserves, etc.
	Community Energy Storage (front-of-the-meter)	Utility	Backup power, microgrid islanding, grid services, etc.
	Stationary/Grid Energy Storage Management Systems	Varies	Control/coordination of ES components, response to market signals, economic optimization of storage assets, etc.
Transportation Storage	Light-Duty Electric Vehicles	Transportation	Motive power[(a)]
	Medium / Heavy-Duty Electric Trucks	Transportation	Motive power[(a)]
	Electric Vehicle Charging	Transportation/ Commercial	Battery charging, grid integration/demand response
	Transportation Battery Management Systems	Varies	Control/coordination of battery system components, etc.
	Traditional Automotive Energy Storage	Transportation	Motive power[(a)]
	Industrial Fork Lift Trucks	Transportation	Motive power[(a)]
Other	Medical	Varies	Life Safety, backup power, uninterruptible power supply
	Portable Power (i.e. Military)	Varies	Varies
	Materials	Varies	Varies
	R&D Supporting New Technologies	Varies	Varies
	Others	Varies	Varies

(a) Motive power is defined as power used to drive machinery, such as an engine.

[29] The research team is not recommending that further research be conducted on these topics, only that this classification system may be more appropriate than the existing classification system for future research efforts.

8 References

AEE Institute. 2014. "California Advanced Energy Employment Survey."

ARPA-E. 2009. "High Energy Density Ultracapacitors." http://arpa-e.energy.gov/?q=slick-sheet-project/high-energy-density-ultracapacitors.

Bade, Gavin. 2015. "Whatever Happened to Oncor's Big Energy Storage Plans?" *UtilityDive*. http://www.utilitydive.com/news/whatever-happened-to-oncors-big-energy-storage-plans/404949/.

Bloomberg New Energy Finance. 2016. "Electric Vehicles to Be 35% of Global New Car Sales by 2040 - Bloomberg New Energy Finance." *Bloomberg New Energy Finance*. http://about.bnef.com/press-releases/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040/.

Blume, Steve. 2015. "Global Energy Storage Market Overview & Regional Summary Report."

Charles, Melicia. 2014. "California's Energy Storage Mandate: Electricity Advisory Committee Meeting."

Citigroup. 2015. "Dealing with Divergence."

Colthorpe, Andy. 2015. "Initial Tesla Partners Include Utilities, Inverters and Sales Channels." *Energy Storage News*. http://www.energy-storage.news/news/initial-tesla-partnerships-include-utilities-inverters-and-sales-channels.

Douthwaite, Mark. 2015. "Is Graphene the Future in Battery Design?" *World Economic Forum*. https://www.weforum.org/agenda/2015/08/is-graphene-the-future-in-battery-design/.

ECG Consulting Group. 2012. "The Economic Impact of Developing an Energy Storage Industry In New York State."

Energy Storage Association. n.d. "Community Energy Storage." http://energystorage.org/energy-storage/technology-applications/community-energy-storage.

Fehrenbacher, Katie. 2016. "SolarCity to Use Tesla Batteries for Project in Hawaii." *Fortune*. http://fortune.com/2016/02/16/solarcity-tesla-batteries-hawaii/.

Fitzgerald, Garrett. 2015. "First Aggregated Customer-Sited Energy Storage Hits California Energy Market." *RMI Outlet*. http://cleantechnica.com/2015/10/05/first-aggregated-customer-sited-energy-storage-hits-california-energy-market/.

GTM Research. 2015a. "Energy Storage Management Systems 2015-2019."

———. 2015b. "The Australian Energy Storage Market: Downstream Drivers and Opportunities."

———. 2015c. "US Energy Storage Market to Grow 250% in 2015 | Greentech Media."

http://www.greentechmedia.com/articles/read/us-energy-storage-market-grew-400-in-2014.

———. 2016a. “Grid-Scale Energy Storage Balance of Systems 2015-2020.”

———. 2016b. “U.S. Energy Storage Monitor: 2015 Year in Review Executive Summary.” *GTM Research*, no. December.

Hamilton, Katherine. 2015. “Energy Storage: State of the Industry.”

Harris, Brent. 2015. “Understanding Growth Drivers for Residential Battery Storage | Greentech Media.” *Greentech Media*. https://www.greentechmedia.com/articles/read/residential-storage-growth-drivers.

Johnson, M., J. Vetrano, K. Lynn, W. Parks, R. Handa, L. Kannberg, S. Hearne, K. Waldrip, and R. Braccio. 2013. “Grid Energy Storage.”

Kempener, Ruud, and Eric Borden. 2015. “Battery Storage for Renewables: Market Status and Technology Outlook.”

Landberg, Reed. 2016. “Battery Cost Plunge Seen Changing Automakers Most in 100 Years - Bloomberg.” *Bloomberg Technology*. https://www.bloomberg.com/news/articles/2016-10-11/battery-cost-plunge-seen-changing-automakers-most-in-100-years.

Lee, David D. 2016. “Why the Success of Key Industries Depends on Future Battery Technology Innovation.” *Renewable Energy World*. http://www.renewableenergyworld.com/articles/2016/08/why-the-success-of-key-industries-depend-on-future-battery-technology-innovation.html.

Lundin, Barbara. 2015. “Green Mountain Power Changing the Home Energy Storage Game.” *SmartGridNews.com*. http://www.smartgridnews.com/node/101926/print.

Maloney, Peter. 2017. “Massachusetts State Report Recommends 600 MW Energy Storage Target | Utility Dive.” *Utility Dive*. Accessed January 4. http://www.utilitydive.com/news/massachusetts-state-report-recommends-600-mw-energy-storage-target/426483/.

Manghani, Ravi. 2015. “Behind-the-meter Energy Storage Market Poised for Explosive Growth.” *Greentech Media*. https://www.greentechmedia.com/articles/read/behind-the-meter-energy-storage-market-poised-for-exponential-growth.

Massachusetts Department of Energy Resources. 2016. “STATE OF CHARGE.” http://energystorage.org/system/files/attachments/ma_storage_study.final_w5768299x7ac2e.pdf.

Mearian, Lucas. 2016. “Researchers Move Closer to Charging an EV as Fast as Filling a Tank of Gas | Computerworld.” *ComputerWorld*. http://www.computerworld.com/article/3025341/car-tech/researchers-move-closer-to-charging-an-ev-as-fast-as-filling-a-tank-of-gas.html.

MESA. 2016. “Eaton, Samsung SDI, and Siemens Join the MESA Standards Alliance.” http://mesastandards.org/eaton-samsung-sdi-and-siemens-join-the-mesa-standards-alliance/.

Morley, Michael. 2015. "How Will NY REV Impact Energy Storage?" *ScottMadden Insights Library*. http://www.scottmadden.com/insight/how-will-ny-rev-impact-energy-storage/.

Morris, Jackon. 2015. "REV-Ing It up in New York : A Look Under the Hood of the Reforming the Energy Vision Track I Order." *NRDC Expert Blog*. https://www.nrdc.org/experts/jackson-morris/rev-ing-it-new-york-look-under-hood-reforming-energy-vision-track-i-order.

Munsell, Mike. 2016. "German Energy Storage Market to Reach $1B by 2021 | Greentech Media." *GTM Research*. http://www.greentechmedia.com/articles/read/german-energy-storage-market-to-reach-1b-by-2021.

National Fuel Cell Research Center. n.d. "Fuel Cells Explained." http://www.nfcrc.uci.edu/3/FUEL_CELL_INFORMATION/FCexplained/.

Navigant Research. 2015a. "Advanced Battery Tracker 4Q15."

———. 2015b. "Advanced Energy Storage for Automotive Applications."

———. 2016. "Market Data: Advanced Batteries for Utility-Scale Energy Storage."

Neubauer, Jeremy, and Michael Simpson. 2015. "Deployment of Behind-the-meter Energy Storage for Demand Charge Reduction." doi:NREL/TP-5400-63162.

New York State. 2015. "New York State Energy Plan Overview." http://energyplan.ny.gov/.

New York State Energy Research and Development Authority. 2016. "Clean Energy Fund Investment Plan: Energy Storage Chapter." https://www.nyserda.ny.gov/-/media/Files/About/Clean-Energy-Fund/CEF-Energy-Storage.pdf.

New York State Governor's Press Office. 2016. "Governor Cuomo Announces Establishment of Clean Energy Standard That Mandates 50 Percent Renewables by 2030 | Governor Andrew M. Cuomo." https://www.governor.ny.gov/news/governor-cuomo-announces-establishment-clean-energy-standard-mandates-50-percent-renewables.

NY BEST. 2015. "Summary of High Level Meetings and Activities with Policy Makers."

Opalka, William, and Rich Heidorn. 2015. "New York PSC Bars Utility Ownership of Distributed Energy Resources: RTO Insider." *RTO Insider*. https://www.rtoinsider.com/new-york-rev-der-13376/.

Parkinson, Giles. 2015. "Solar and Battery Storage Already Cheaper than Grid Power in Australia." *Reneweconomy.com.au*.

Pentland, William. 2016. "As Energy Storage Enters Mainstream Markets, System Size Becomes Key Differentiator." *Forbes*.

Popper, Kevin, Anders Hove, and Dongliang Zhang. 2012. "China Grid-Scale Energy Storage: Technologies & Markets, 2012-2016."

Research and Markets. 2016. “Lithium-Ion Batteries for Electric Buses 2016-2026.” http://www.researchandmarkets.com/research/qthvbf/lithiumion.

Romm, Joe. 2016. “To Beat Tesla, China Plans To Boost Electric Vehicle Sales 10-Fold.” *ThinkProgress*. https://thinkprogress.org/china-to-boost-electric-vehicle-sales-10-fold-211053eb032b#.exnrhqs69.

Shahan, Zachary. 2016. “Tesla Drastically Underestimated Model S & X Demand (Financials Flashback) | CleanTechnica.” *CleanTechnica*. https://cleantechnica.com/2016/05/05/tesla-drastically-underestimated-model-s-demand-flashback/.

Stanforth, Lauren. 2016. “GE Proclaims Success, despite Battery Plant Closure.” *Times Union*, January 16. http://www.timesunion.com/tuplus?local/article/GE?proclaims?success?despite?battery?plant?6748205.php.

Trabish, Herman. 2015. “Why Community Solar Is Exploding in Minnesota.” *UtilityDive*. http://www.utilitydive.com/news/why-community-solar-is-exploding-in-minnesota/360241/.

Trabish, Herman K. 2016. “How Rate Reform Can Help Turn Energy Efficiency into a ‘Profit Center’ for Utilities.” *UtilityDive*. http://www.utilitydive.com/news/how-rate-reform-can-help-turn-energy-efficiency-into-a-profit-center-for/417549/.

U.S. Department of Energy. n.d. “Alternative Fuels Data Center.” http://www.afdc.energy.gov/vehicles/electric.html.

Vlasic, Bill. 2016. “Tesla’s New Model 3 Jump-Starts Demand for Electric Cars.” *The New York Times*.

Voelcker, John. 2016a. “Ford CEO Mark Fields Confirms 200-Mile Electric Car Coming (Updated).” *Green Car Reports*. http://www.greencarreports.com/news/1103673_ford-ceo-mark-fields-confirms-200-mile-electric-car-coming.

———. 2016b. “Smaller, Cheaper Toyota Mirai Fuel-Cell Car Coming in 2019, Company Says.” *Green Car Reports*. http://www.greencarreports.com/news/1103847_smaller-cheaper-toyota-mirai-fuel-cell-car-coming-in-2019-company-says.

Walton, Robert. 2016. “First Battery Storage Project Begins Operating in MISO | Utility Dive.” *Utility Dive*. http://www.utilitydive.com/news/first-battery-storage-project-begins-operating-in-miso/422505/.

Wesoff, Eric. 2016. “New York’s Con Ed Is Building a Virtual Power Plant From Sunverge Energy Storage and SunPower PV | Greentech Media.” http://www.greentechmedia.com/articles/read/New-Yorks-ConEd-Is-Building-a-Virtual-Power-Plant-From-Sunverge-Energy-Sto.