2017 Energy Storage Market Evaluation

Final Report

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1 Introduction

1.1 Program Description

This report presents the evaluation results from two of NYSERDA's energy storage initiatives:

1. Energy Storage Technology and Product Development Investment Plan:[1] Increased use of renewable energy assets and energy storage has many grid and consumer benefits. Optimizing the energy output and uptime of renewable resources will provide near-term economic benefits and decrease the total cost to deploy renewable technologies in the future. Energy storage can reduce the intermittency of solar and wind energy, helping these resources to be flexible assets deployed when needed. Energy storage can also avoid the need for new electric system infrastructure, increase system efficiency and resiliency, and reduce the need for fossil fuel plants to meet periods of peak electric demand. To meet these goals, NYSERDA is undertaking the following activities:

- Provide competitive funding opportunities in support of technology companies to leverage existing capabilities, validate technologies, create innovative products and applications, and otherwise facilitate energy storage development in New York. NYSERDA will issue broad competitive solicitations for project proposals to identify teams and approaches to address innovations focusing on:
    - Reduced hardware cost for energy storage components and devices, including reduced power electronics cost for energy storage systems.
    - Improved performance (efficiency, safety, energy density) of storage devices, especially for New York-specific applications and duty cycles—e.g., building demand response, electric vehicle charging, solar photovoltaics (PV), and large-scale wind.
    - Load-side and generation-side applications of energy storage to reduce peak load, store and reuse solar PV and wind energy to help firm up these resources, and provide ancillary services.

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[1] Clean Energy Fund Investment Plan: Renewables Optimization Chapter. Portfolio: Innovation & Research. Matter Number 16-00681, In the Matter of the Clean Energy Fund Investment Plan. September 7, 2018. https://www.nyserda.ny.gov/-/media/Files/About/Clean-Energy-Fund/CEF-Renewables-Optimization-chapter.pdf

- Facilitate strategic corporate partnerships among small/medium sized companies and large original equipment manufacturers (OEMs) to speed up the path to commercialization.
- Explore viability of establishing technical performance specifications that can serve as a market-relevant stretch goal to drive innovation. If appropriate, use the stretch goal as a technology challenge in one or more competitive solicitations.

2. Reducing Barriers to Deploying Distributed Energy Storage Investment Plan:[2] Energy storage is a multi-faceted technology that cuts across many sectors, including clean energy production, energy efficiency, various types of customers and buildings, and both established technologies and those still in development. NYSERDA's energy storage strategy will target key barriers limiting energy storage adoption in three sectors: customer-sited (behind-the-meter systems), transmission and distribution system needs, and the transportation system. The initial initiative described in this section addresses barriers in the customer-sited (behind-the-meter) sector and the ability to use these systems to meet transmission and distribution system needs. Five activities that contribute toward reducing soft costs by 33% and enable half of all distributed energy storage installations to provide value to two or more parties within five years are included in this initiative: safety validation and permitting for electrochemical systems, best fit customer acquisition, quality assurance (performance confidence), value stacking pilots, and tools to support market replication.

1.2 Summary of Evaluation Objectives and Methods

The evaluation objective and methods are shown in Table 1 and Table 2 below for this report and future evaluations.

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[2] Clean Energy Fund Investment Plan: Energy Storage Chapter. Portfolio: Market Development. Matter Number 16-00681, In the Matter of the Clean Energy Fund Investment Plan. September 6, 2018. https://www.nyserda.ny.gov/-/media/Files/About/Clean-Energy-Fund/CEF-Energy-Storage.pdf

Table 1. Evaluation objectives mapped against evaluation questions, primary data collection

Objective	Evaluation Question(s)	2017 Findings
Develop a reliable, detailed, New York-based estimate of current soft costs ($/kWh) of distributed energy storage systems as a component of the total installed cost ($/kWh, duration).	What is the current estimate of soft costs ($/kWh capacity) of distributed energy storage systems?	Average = $146/kWh Median = $150/kWh *n=3*
	What is the cost per kWh capacity for energy storage systems by duration?	Average = $883/kWh Median = $850/kWh Duration not specified *n=3*
	How many alternative ownership models are being used?	The majority of the six relevant behind-the-meter projects survey respondents reported using site-based ownership, although a few use third-party ownership models. Limited data is available for front-of-the-meter projects, but third-party ownership and performance contracting models were reported in the survey responses. Given the that this an emerging market, this may not be indicative of larger trends over time.
	What is the percent conversion rate (%) of prospective installations from proposal to installed projects?	Median = 38% Average = 45% *n=6*
	What is the current cycle time (months) for the permitting process?	Insufficient data collected[3].
	Are there challenges with siting and permitting requirements?	Insufficient data collected[3].
	What is the cycle time (months) of projects from customer proposal to commissioning?	Insufficient data collected[3].

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[3] Too few survey responses to accurately draw quantitative conclusions. Qualitative observations presented in Section 2.1.3.

Table 2. Evaluation objectives mapped against evaluation questions, secondary data collection

Objective	Evaluation Question(s)	2017 Findings
Develop a reliable, detailed estimate of current hardware and hardware balance of system (BOS) costs ($/kWh) of energy storage systems.	What is the current hardware cost ($/kWh) for energy storage devices?	Typical utility-scale lithium ion (Li-ion) battery cost = $270/kWh. Battery costs are ~30% higher for commercial and industrial (C&I) and ~50% higher for residential. Unit cost may be significantly higher for high-performance batteries.
	What is the current hardware BOS cost for energy storage systems including power electronics and hardware installation cost ($/kWh)?	Typical utility-scale power conversion system (PCS) hardware cost = $121/kW. PCS cost is ~75% higher for C&I and ~110% higher for residential. Typical utility-scale BOS hardware cost = $75/kW + $40/kWh.[4] BOS costs are ~10% lower for C&I and ~120% higher for residential. Installation cost not included.
Develop a reliable, detailed estimate of the current performance of energy storage systems.	What is the current performance of energy storage systems in terms of efficiency, life, energy/power density, etc.	Nameplate efficiency varies significantly by technology. Real efficiency varies widely and is significantly driven by use. Density varies widely and depends significantly on system design. Warranty life typically varies between 5 and 20 years. Limited field data exists on actual degradation rates.

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[4] For example, BOS costs for a 1 MW, 4 MWh system would cost approximately $235,000 ($75/kW x 1,000 kWh + $40/kWh x 4,000 kWh).

2 Market Characterization and Assessment

2.1 Primary Data Collection Results

This section summarizes distributed energy storage (DES) system installation costs, project cycle times, characteristics of projects statewide, value propositions, ownership models, and barriers in the New York market. The data included in this analysis is compiled from 22 companies that responded to NYSERDA's evaluation survey and were later reviewed by Navigant. Not all companies answered all survey questions. Therefore, much of the information provided is drawn from a smaller pool of respondents that answered a given question. The analysis included all respondents that completed projects or contracted for projects in 2017. Seven respondents did not complete projects in New York State in 2017, so they were excluded from the analysis. They are included in the Respondent Characteristics section (4.1.3) to provide a more complete picture of companies operating in the New York State DES market.

2.1.1 System Costs

The survey asked vendors to provide information on average installed costs for their primary use case DES systems. Evaluators collected information from two respondents serving residential behind-the-meter customers, four respondents serving C&I behind-the-meter customers, two respondents serving utility front-of-the-meter customers, and one respondent serving utility bulk scale customers. While the survey sample includes a small number of respondents, the storage market in New York is relatively new, with few players. Companies providing cost information represent 15% of all known storage companies in New York State, even those that have not installed projects yet or in the most recent year. Furthermore, this analysis captured the companies implementing the majority of projects in New York. Therefore, while the 2017 sample is small, it is considered representative and can serve as a baseline for future program years.

All primary use cases reported were electrochemical systems, with eight Li-ion installations and one lead-acid installation. Five DES systems were installed in New York City; the remaining four were installed in other parts of the state. Average reported system size ranged from 9.8 kWh to 13,000 kWh, with a median size of 500 kWh and an average size of 2,884 kWh.

The evaluators also asked vendors to estimate what percentage of costs were spent on hardware, engineering and construction, and soft costs. These categories are defined as follows:

- **Hardware costs:** Battery module, inverter, and BOS costs such as fire controls, power electronics, communication system, containerization, insulation, HVAC system, meter, control system, outdoor containerization (when necessary), etc.
- **Engineering and construction costs:** Cost of design, site preparation, transportation, siting, Professional Engineer (PE) approval, testing and commissioning, electrician and installation labor, wiring, fencing, other overhead, etc.
- **Soft costs:** Cost of customer acquisition, permitting and interconnection, and financing.

Of the nine respondents who provided complete use case information, five provided soft cost information. Four of these respondents provided information related to behind-the-meter C&I projects and one respondent provided information related to front-of-the-meter projects. The evaluators analyzed these use cases separately. The results presented in Table 3 are for three behind-the-meter C&I respondents who provided complete soft cost data. The evaluators excluded one respondent who provided incomplete soft cost data.

Table 3. Average costs NY State C&I behind-the-meter DES projects in 2017, by component (n=3)

Name	Unit	Average	Median
Total average installed system	$/kWh	$883	$850
Hardware costs	%	62	60
Engineering and construction	%	22	20
Soft costs	**%**	**17**	**15**
Customer acquisition costs	*%*	*3*	*3*
Permitting	*%*	*8*	*10*
Interconnection	*%*	*5*	*5*
Financing costs	*%*	*1*	*0*

The evaluators found that average system costs are $883/kWh based on survey responses. This value differs slightly from the value reported in the *New York State Energy Storage Roadmap*,[5] which is $840/kWh. The value in the roadmap is based on data from the NYSERDA/DPS Energy

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[5] New York State Energy Storage Roadmap and Department of Public Service / New York State Energy Research and Development Authority Staff Recommendations. June 21, 2018. https://www.nyserda.ny.gov/All-Programs/Programs/Energy-Storage/Achieving-NY-Energy-Goals/The-New-York-State-Energy-Storage-Roadmap

Storage Study, completed by Acelerex.[6] The roadmap value was based on an independent review of market information and a separate vendor survey undertaken for the specific purpose of gathering cost data as well as other required market data that was needed to write the energy storage roadmap. This survey had a different format, set of criteria, and some differences in survey respondents. The evaluators' soft costs values (average of 17%) align with those in the roadmap.

Data from 2017 for front-of-the-meter electrochemical projects in early stages of development has also begun to emerge. These projects constituted a limited sample size (only 2 was captured in the survey responses), were outside of Con Edison's territory or Long Island, were Li-ion chemistries, and indicated approximately 70% for hardware costs and 30% for all non-hardware costs.

Table 4 contains average system costs and soft costs for 2016 projects.[7] Note that there are several key differences between the 2016 and 2017 data, which should be kept in mind if attempting to compare these two datasets. An apples-to-apples comparison is not possible for the following reasons:

- **The majority of projects in 2016 were lead acid and the majority of projects in 2017 were lithium-ion.** Soft costs are not comparable between these technologies.

- **Survey questions were formatted differently.** In 2016, respondents were asked what percentage of their costs were soft costs and then to identify what percentage of soft costs were customer acquisition, permitting, interconnection, and financing. In 2017, participants were asked what percentage of the overall costs were spent on customer acquisition, permitting, interconnection, and financing. These numbers were used to calculate what percentage of the project could be attributed to soft costs.

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[6] Appendix K of New York State Energy Storage Roadmap. The 2018 average installed cost of 4-hour duration, front-of-the-meter storage systems ($450) is multiplied by 1.25, the multiplier for installations in New York City, and by 1.5, the multiplier for behind-the-meter storage, to get an approximate average installed cost of $840.

[7] Research Into Action. (2017). *Baseline Market Evaluation Metrics for Energy Storage*. Prepared for New York State Energy Research and Development Authority. This study provided a baseline of energy storage soft costs for 2016.

Table 4. Median costs for DES projects New York State in 2016[8], by component

Name	Valid Count	Unit	Median
Total average installed system	2	$/kWh	$1,000
Hardware costs	5	%	60
Engineering and construction	5	%	30
Soft costs	**5**	**%**	**20**
Customer acquisition costs	*4*	*%*	*38*
Permitting	*4*	*%*	*28*
Interconnection	*4*	*%*	*10*
Financing costs	*4*	*%*	*13*

2.1.2 Value Proposition and Alternative Ownership Models

When asked what benefits were important in closing the deal for customers, respondent companies cited several benefits. As shown in Table 5, the investment tax credit (n=5), distributed generation integration (n=5), and non-wires alternative service (n=5) were the most frequently mentioned benefits.

Table 5. DES benefits important for deal closure

Company Type	Number of Respondent Companies
Investment tax credit	5
Distributed generation integration	5
Non-wires alternative services	5
Demand charge management	3
Demand response payments	3
Resilience/backup power	3
Other	2

Multiple response question, n=9

One of NYSERDA's objectives is to increase the number of alternative ownership models for DES projects. While there are a variety of ownership models being used in New York State, there is room to increase the number of projects using those models, particularly for behind-the-meter storage. Most respondents used one type of ownership model, with only one company using more

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[8] Research Into Action. *Baseline Market Evaluation Metrics for Energy Storage*.

than one. For behind-the-meter projects, site or end-use ownership was the most common model, with four companies reporting this as their most common contractual arrangement. Two companies said that third-party ownership was their most common contractual arrangement for behind-the-meter projects. This finding may be due to the small number of projects completed in 2017, and thus the small eligible population to survey for this data, rather than describing a rapid change in the market as compared to 2016. For front-of-the-meter projects, one company reported that third-party ownership was the most common contractual arrangement, and another primarily used performance contracting. Seven companies reported using financing in 2017.

2.1.3 Barriers in the New York Market

NYSERDA aims to increase the percent conversion rate from projects receiving a proposal to projects receiving a contract. Companies (n=6) reported a median of 38% of projects that receive a proposal receive contracts (average=45%).[9] In addition, companies (n=9) reported a median of 33% of DES projects with executed contracts were still waiting for permits to be approved (average = 42%).

When asked how long they spent on New York State-specific projects relative to other jurisdictions only one company said the staff time was in line with other jurisdictions. The other companies (n=2) indicated the process took two to three times longer. Respondents were also given the opportunity to provide general feedback about their experience completing DES projects in New York State. One company said that long-term revenue uncertainty has hampered its ability to complete projects in New York.

2.2 Secondary Data Collection Results

The objective of the secondary data collection was to provide a 2017 benchmark for energy storage hardware costs and performance metrics. This will provide a basis to evaluate future cost reductions and inform efforts to reduce costs and improve performance. The evaluators evaluated hardware costs for three components: the battery, PCS, and BOS. Performance analysis was

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[9] Some zero values were excluded because all companies included in the analysis reported at least one 2017 project installed, commissioned, or in the pipeline with an executed contract.

based on three metrics: efficiency,[10] energy density,[11] and lifetime (cycle and calendar).[12] The evaluation also considered key parameters that impact cost and/or performance: duration, size, and use case. The secondary data analysis was based on data taken from a variety of sources, which are listed in the Appendix. The figures in the section that follows were constructed from these sources using the approach described in Section 4.2.

2.2.1 Cost

This analysis quantified typical costs of hardware components:

- **Battery:** Battery rack with battery management system (BMS)
- **PCS:** Inverter
- **BOS:** Enclosure, HVAC, transformer, switchgear, wiring, etc. (excludes interconnection and software costs)

This analysis did not include other costs such as software and controls, development, installation, and interconnection.

The evaluators analyzed these costs for their dependence on a variety of parameters:

- **Duration:** Dependence on energy to power ratio (hours)
- **Size:** Dependence on system size/grid location
- **Use case:** How the energy storage system is used (indirectly evaluated based on duration and grid location)
- **Time:** Historical and forecast cost reductions

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[10] Efficiency = ratio between power output (discharge) and power input (charging and auxiliary power)

[11] Energy density = Energy stored (MWh) on volumetric (per unit volume), gravimetric (per unit weight), or areal (per unit area) basis

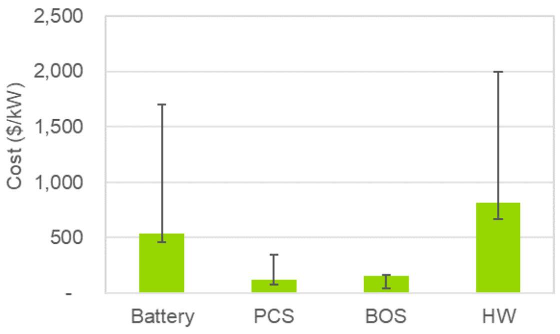
[12] Lifetime is typically expressed based upon the battery warranty or the point at which batteries reach 80% of their original energy capacity. Cycle life is expressed as the number of full charge-discharge cycles. Calendar life is expressed in years.

The results of this analysis indicate that battery costs constitute the majority of hardware costs for systems with a duration greater than or equal to two hours. Hardware costs primarily vary based on duration and size. No direct trends were identified based on use case (e.g., frequency regulation), but the duration and grid location together inform expected costs based on use case. Recent cost reductions have exceeded 10% per year since 2014, and annual reductions are expected to remain around 10% over the next 2-3 years.

2.2.1.1 Variability in Costs

As shown in Figure 1, the variability in costs can be significant and is driven largely by battery costs. A major driver of variability in battery costs is the technology. Even within Li-ion, the costs can differ substantially depending on the chemistry. More durable and high performing chemistries tend to come at a premium. Technology assumptions are also a considerable factor for PCS costs, which can vary depending on assumed functionalities such as islanding.

Figure 1. Cost variability (2017, Li-ion, utility-scale, 2-hour)



Many other uncertainties drive variability in reported costs. Reported data does not always specify to whom the cost applies and to what extent profit margins are included in the cost (e.g., cost of production or cost to buyer). In addition, cost data often does not specify whether the costs are based on a battery’s theoretical maximum energy or the actual usable energy in an energy storage system. Further, components across sources may be defined differently (e.g., including transformer and switchgear in PCS vs. BOS). Further, the assumed size and/or grid location (e.g., residential, C&I, utility) is not always clearly specified.

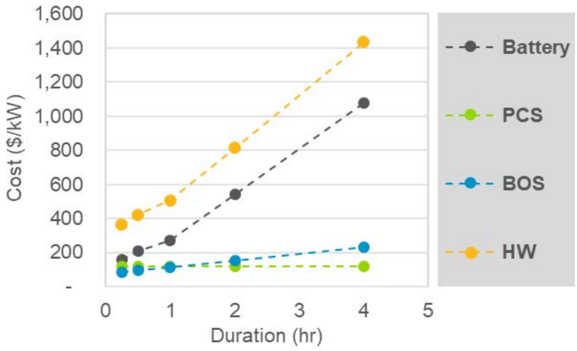
2.2.1.2 Dependence on Duration

The cost of an energy storage system varies significantly depending on the duration (hour), which is equivalent to the ratio between the usable energy (kWh) and the maximum power (kW). The dependence of each component’s cost on duration is roughly linear, as expressed in Equation 1.

Equation 1. $\mathrm{C}_{Component}\left(\$/_{kW}\right)=\mathrm{C}_{power}\left(\$/_{kW}\right)+\mathrm{C}_{energy}\left(\$/_{kWh}\right)\times t\left(hr\right)$

The battery component has the most significant dependence on duration, as the costs scale primarily with energy (Figure 2). Hardware (HW) is the sum of the other parts presented in the figure. The relationship for batteries is not entirely linear, particularly at short durations—shorter durations typically require more expensive batteries and/or a narrower depth of discharge to limit degradation from rapid cycling.

Figure 2. Cost by duration (2017, Li-ion, utility-scale)

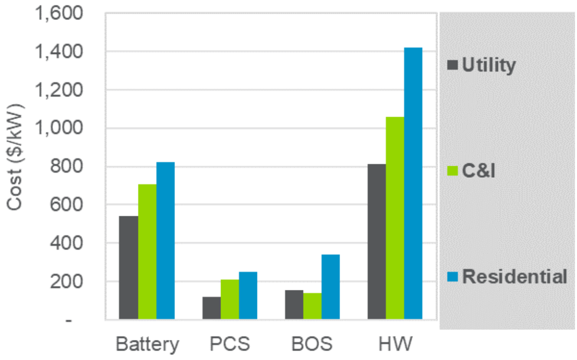


Other components scale primarily with power. The PCS cost scales almost exclusively with power, such that costs are relatively independent of duration. The BOS cost is mostly driven by power at shorter durations, while it is driven more by energy at longer durations.

2.2.1.3 Dependence on Size

Hardware costs tend to decrease as the system size increases, as shown in Figure 3. Battery costs show continuous reductions with scale. PCS costs are affected by economies of scale and to typical enhancements in functionality (e.g., islanding capability). Conversely, the evaluators found BOS costs to be lower for C&I systems than utility-scale systems, which is likely due in part to the ability to leverage existing customer infrastructure (e.g., lack of need for additional containers and HVAC equipment). An alternative representation of hardware costs as a function of size is shown in Figure A-1 in the Appendix.

Figure 3. Cost by scale (2017, Li-ion, 2-hour)



2.2.1.4 Dependence on Use Case

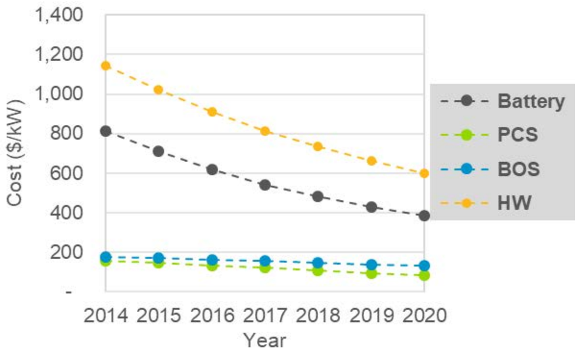
In general, there was limited available data to compare costs directly based on use case. The evaluators instead evaluated cost dependence on use case according to the two previously discussed factors that drive cost: duration and scale. Short duration applications such as frequency regulation are primarily driven by power costs and may require more high performing battery chemistries at a premium price. Long duration applications such as resource adequacy are primarily driven by energy costs and may use less expensive batteries.

As noted above, the dependence on scale is related both to system size and grid location. Notably, while customer-sited systems may come at a higher price, they also open up additional value streams such as demand charge management and backup power.

2.2.1.5 Cost Reductions over Time

The rate of decline in hardware costs is expected to remain high (~10% per year) over the next 2 - 3 years, though slightly less than in previous years (>10% per year). As shown in Figure 4, the battery cost decreased significantly in the years prior to 2017. The calculated compound annual growth rate (CAGR) values are shown in Table A-1 in the appendix.

Figure 4. Cost by year (2017, Li-ion, 2-hour)



2.2.2 Performance

The performance analysis focused on the following metrics:

- **Efficiency:** System efficiency (including auxiliary power)
- **Energy density:** Usable energy (MWh) on a gravimetric, volumetric, and areal basis
- **Lifetime:** Calendar (year) and cycle life basis

The evaluators evaluated the impact of duration, size, and use case, as well as variations over time, but significant dependencies were generally not observed. Two notable exceptions were the dependence of efficiency on the use case and the dependence of energy density on the size of the energy storage system.

2.2.2.1 Variability in Performance

Performance is largely driven by technology, but variability in performance data is also driven by a number of other factors. For example, stated efficiencies do not always indicate whether it is on an alternating current (AC) or direct current (DC) basis. Performance data also does not consistently indicate whether the basis for the data is at the cell, module, rack, or system level. Cycle life data does not consistently report underlying assumptions of whether partial or full cycles are assumed, and both cycle and calendar life data do not consistently report assumptions regarding augmentation (e.g., adding batteries to offset degradation) or sizing (e.g., oversizing initially to maintain rated energy for longer).

2.2.2.2 Efficiency

Energy storage system efficiency primarily depends on technology and use. While uncertainties in the AC versus DC basis for reported efficiency data lead to variability, inverter efficiencies can be quite high (Figure 5). This variability is driven as much or more by variations in battery chemistry and system design.

Technology is the primary driver of differences in nameplate efficiency. For example, as shown in Figure 5, flow batteries tend to have significantly lower efficiencies and a greater range of efficiency than Li-ion batteries.

However, nameplate efficiencies typically do not reflect expected standby and auxiliary losses, which drive down real efficiencies of energy storage systems. Real efficiencies are driven primarily by use. Performance data from energy storage systems funded by California’s Self-Generation Incentive Program (SGIP) shows significant variability/range (Figure 6). The low efficiencies of many of these systems is because they are used primarily for demand charge management, which may require infrequent discharge. Losses from self-discharge and powering of auxiliary components in standby (neither charging nor discharging) result in low system efficiencies.

Figure 5. Efficiency (AC vs. DC, nameplate)

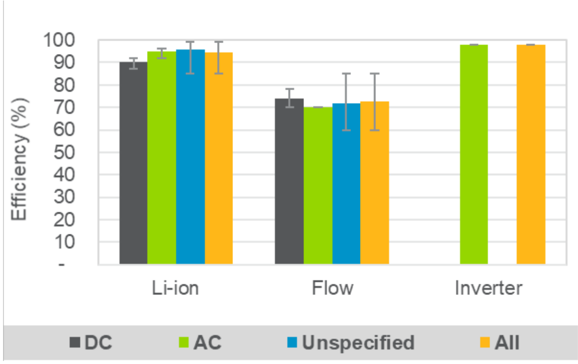
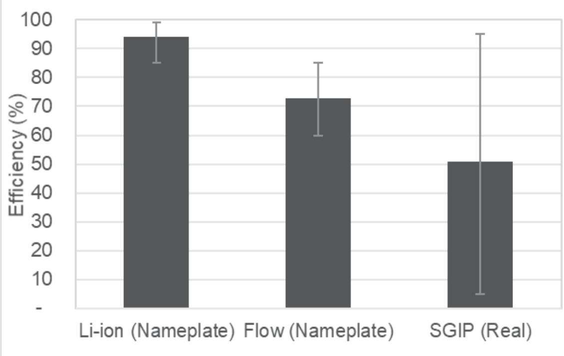


Figure 6. Efficiency ranges by technology



2.2.2.3 Energy Density

This analysis indicates that energy density depends as much on system-level design as it does technology. This leads to significant variability/range within a given technology, as illustrated in Figure 7. While Li-ion battery systems tend to have higher energy density than flow battery systems, they also have a greater range of energy densities, and some flow battery systems may have higher energy density than some Li-ion battery systems.

As shown in Figure 8, energy density varies between cell, module, rack, and container levels. Gravimetric and volumetric density tends to decrease at each step due to reductions in the fraction of weight and volume constituted by cells. Areal density increases from the module to rack level, as racks consist of multiple modules stacked on top of one another, but then decreases going from rack to container.

Figure 7. Density (by technology)

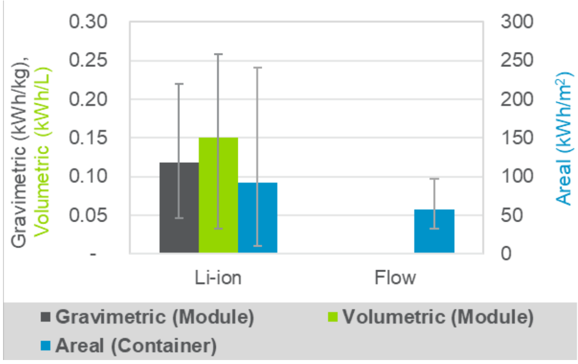
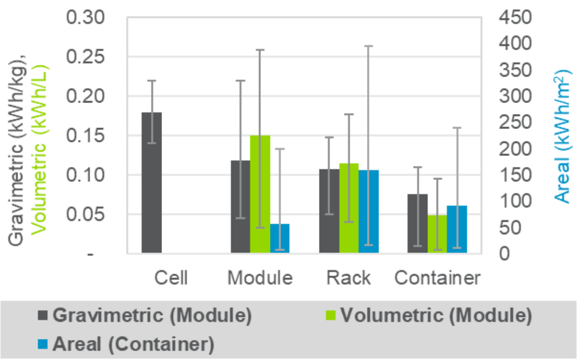
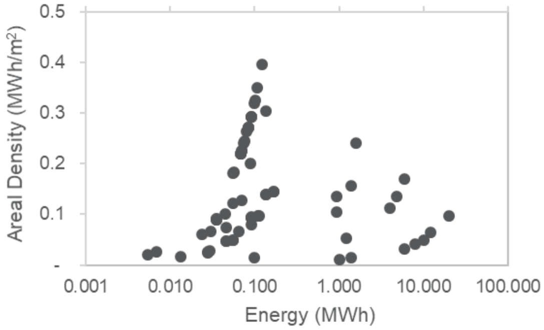


Figure 8. Density (Li-ion by basis)



Thus, while materials innovations at the cell level can drive up density, improvements at the rack/container level may be easier to achieve. Figure 9 shows nameplate energy density for various racks, modules, and containers from various energy storage systems across multiple vendors, further illustrating this point.

Figure 9. Areal density vs. size

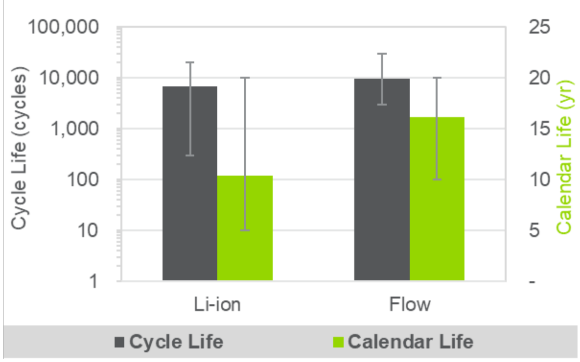


2.2.2.4 Lifetime

The lifetime of an energy storage system is expressed in both cycle life and calendar life. The lifetime is typically based on the number of cycles or years for the usable energy in an energy storage system to degrade to 80% of its initial rated energy. Both cycle and calendar life are used because energy storage systems degrade with the amount of cycling as well as over time independent of the amount of cycling.

As shown in Figure 10, the cycle life for a given type of technology can vary by an order of magnitude, which can be due to the specific chemistry or the cycle rate. For example, batteries tend to degrade faster when discharged in 30 minutes versus 4 hours. The reported calendar life varies within a smaller window, but still may vary by a factor of four.

Figure 10. Lifetime (by technology)



Two key challenges exist in evaluating lifetime. First, lifetimes are typically expressed on a nameplate basis. Limited data exists for evaluating the real lifetime and degradation rates of deployed energy storage systems. Second, lifetimes are often expressed based on the warranty period or financial life of a system. However, the same system may be financed or warrantied over a variable period depending on the agreements' terms.

3 Findings and Recommendations

Finding 1

The evaluators found significant variability and uncertainty in publicly available data on energy storage system cost and performance data. Further, much of the data used was based on nameplate performance, which can vary significantly from actual system performance. With such large variability, the evaluators may not be able to accurately assess the impacts of NYSERDA's efforts in future evaluations.

Recommendation 1

NYSERDA could request project-specific cost and performance data from the projects they are funding through these efforts. This would provide New York State-specific data that the evaluators could use to benchmark against the baseline data collected for this report.

Finding 2

While fielding the survey, evaluators received several questions/concerns from potential survey respondents about data privacy. This resulted in some potential respondents from the already small population not taking the survey, resulting in fewer data points for the evaluation.

Recommendation 2

For the 2019 survey, the evaluators recommend bolstering the written language and verbal description used during outreach on how the data will be used and protected to give respondents more certainty about their privacy.

Finding 3

In talking with NYSERDA and interpreting the survey results, it appears that market actors have varying definitions of what is included in financing costs. The evaluators believe financing costs are a key area where NYSERDA's efforts may have a measurable impact, but the evaluators need to ensure financing costs are reported on a consistent basis.

Recommendation 3

For the 2019 survey, include more detailed description of how financing costs are defined. NYSERDA and the evaluator will need to decide if financing costs include any or all of the following: origination, other fees, cost of equity, and/or cost of debt. The agreed upon definition should then be included in the survey.

4 Methods

The following section describes the methods used in the primary data collection activities.

4.1 Primary Data Collection Methods

4.1.1 Survey Design and Data Collection

NYSERDA fielded a survey targeting 59 energy storage vendors from February 2018 to March 2018. NYSERDA closed the survey at the end of March. The evaluators reopened the survey in July 2018 to solicit responses from a few additional key respondents. The survey instrument gathered data on the following items:

- Key selling points for DES projects
- Project characteristics of DES projects in New York State
- Project characteristics of each vendor’s primary use case
- Percentage of costs spent on hardware, engineering and construction, and soft costs
- Length of the project sales and implementation cycle
- Differences between the New York storage market and other markets
- Vendor characteristics

Twenty-two vendors responded to the survey (37% response rate). However, only nine of those vendors answered all the questions in the survey, including providing cost information (15% response rate). Many companies cited confidentiality concerns as a reason for not answering all questions in the survey. Seven companies did not install, commission, or have any projects in the pipeline with an executed contract in New York State in 2017, so they indicated that many questions were not applicable to their business.

4.1.2 Analysis

Both NYSERDA and the evaluators fielded the survey using Qualtrics and downloaded the data for analysis in Excel. In some instances, missing details about a company’s primary use case were filled in using information from other questions in the survey, a database of energy storage projects, or expertise of NYSERDA or the evaluators. Instances where missing information could not be filled in were excluded from the analysis. Companies that indicated they did not install, commission or have any projects in the pipeline with executed contracts in New York State in 2017 were also excluded from the analysis of all questions, except those related to respondent characteristics.

4.1.3 Respondent Characteristics

Respondents to this survey represented companies of various sizes, roles within the storage industry, and varying levels of engagement in New York State.

Table 6 shows the size characteristics of the companies that responded to this section of the survey (n=20). While a few respondents worked for large companies (n=7), the majority worked for companies with 100 or fewer employees (n=13). Seven companies reported having no staff working on storage projects in New York State, 11 companies reported having between 1 and 10 employees work on storage in New York State, and two companies had over 10 employees working on storage in New York State.

Table 6. Company size characteristics

Company Size Metrics	Min	Max	Median	Average	Total
Total Employees in New York State	0	20,000	10	1,041	**20,814**
Total Employees involved in Storage in New York State	0	50	1	6	**125**
Total Employees Outside New York in US and Canada	0	80,000	19	4,485	**89,701**
Total Employees	4	100,000	32	5,526	**110,515**

Companies were also asked what roles they filled in the energy storage market. The most common role fulfilled by companies was developer (n=13), followed by integrator (n=8) and installer (n=8). Results are shown in Table 7.

Table 7. Company roles in energy storage market (multiple response, n=20)

Company Type	Number of Companies
Developer	13
Integrator	8
Installer	8
Manufacturer	6
Sales	4
Financier	4
Distributor	3
Other	3

4.1.4 Statewide DES Projects

In addition to providing metrics on their primary use case, companies were also asked to report on all projects installed, commissioned, or in the pipeline with an executed contract in New York State in 2017. On average, companies (n=11) reported that 41% of all their projects were in New York State and 31% of all their projects were in New York City.

Respondents (n=12) reported that 50 total projects were installed, commissioned, or had a contract signed in New York State in 2017. Of the reported projects, the majority (n=35) were behind-the-meter, while 15 were front-of-the-meter. All projects were electrochemical projects, with 13 lead-acid projects and 37 Li-ion projects. Seven companies indicated that they did not implement any projects in New York in 2017.

Of the 12 companies providing information on the sectors they most frequently served, three reported serving the utility sector, three reported serving commercial facilities, two reported serving single-family buildings, one reported serving multifamily buildings, and two reported other project types. One company served a combination of multifamily, commercial, industrial, and MUSH (municipal, university, school, and hospital buildings).

4.2 Secondary Data Collection Methods

The secondary data analysis was based on data taken from a variety of sources. Individual data points were filtered for accuracy and consistency, as described in the following sections. Due to limited data specific to New York State, the numbers are representative of national averages.

4.2.1 Sources

See Table A-2 in the appendix for details regarding the types of data points extracted from each source.

4.2.2 Data Cleaning

The evaluators cleaned the data by excluding individual data points with unclear assumptions, limited relevance, and/or questionable accuracy. Reasons for exclusion of data include: lack of specified system duration (for cost data), not based on batteries for stationary and grid-connected systems, questionable accuracy for significant outliers, and unclear assumptions from which to interpret the scope and applicability of the data.

4.2.3 Data Selection and Trend Evaluation

The evaluators tagged and manipulated data points were to provide a direct comparison between like data points. Individual data points were tagged by parameters including source, size, duration, grid location, use case, technology, component, and year. Cost data was converted to $/kW values for a specified duration. To support evaluation of cost as a function of duration, some data points were extrapolated across multiple durations (e.g., 1-, 2-, and 4-hour durations, assuming constant $/kW cost for PCS and constant $/kWh cost for batteries). For some incomplete data, certain assumptions were made as was reasonable. For example, if the size was not specified, it was assumed based on grid location (utility = 10 MW, C&I = 200 kW, residential = 5 kW). If the grid location was not specified, it was assumed, as appropriate, to be based on utility-scale data. In some cases, calculated values are based on a limited number of data points when applying multiple filter criteria (e.g., duration, technology, component, year, and grid location).

The evaluators calculated costs by duration based on the costs of individual components as a function of duration. Data from 2016 through 2018 was included and adjusted to 2017 values based on calculated annual cost reductions. PCS costs were assumed to be independent of duration. Li-ion battery costs were assumed to scale only with energy for systems less than 1 hour, which excluded the cost of high performing batteries such as lithium iron phosphate (LFP) and lithium titanate oxide (LTO). For battery costs of 30-minute and 15-minute systems, LFP and LTO were assumed, respectively.

Performance data was generally assumed to be nameplate unless otherwise specified. Areal density data includes only the direct footprint and does not include necessary clearances, which can further reduce the effective areal energy density.