2019 Energy Storage Market Evaluation

Annual Report

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1 Introduction

1.1 Program Description

This report presents results from primary and secondary data collection efforts including a market actor survey and literature review completed by the market evaluation team for the following two NYSERDA energy storage initiatives:

1. Reducing Barriers to Deploying Distributed Energy Storage (DES) Investment Plan:[1]
Energy storage is a multifaceted 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 targets key barriers limiting energy storage adoption in three areas: customer-sited (behind-the-meter [BTM] systems), transmission and distribution (T&D) system needs, and the transportation system. This initiative originally sought to reduce soft costs related to permitting, customer acquisition, and interconnection for customer-sited energy storage systems by 25% per kilowatt-hour (kWh) in 3 years and 33% or more in 5 years based on a 2015-16 baseline of $200/kWh. This goal has been recalibrated to the broader objectives described in the Public Service Commission (PSC)[2] Energy Storage Order, which references estimates in the New York State Energy Storage Roadmap[3]. The Roadmap states that New York can reduce total soft costs by up to $50 per kWh for a distribution/bulk storage system and up to $150 per kWh for a customer-sited system by 2025 compared to 2017-18 costs. The initiative's soft cost reductions now include all use cases; permitting, interconnection, customer acquisition, and engineering and construction costs; and tools to support market replication. This initiative works in conjunction with NYSERDA's market acceleration storage incentives.[4]

[1] NYSERDA. 2020. *Clean Energy Fund: Energy Storage Chapter.* Portfolio: Market Development. Matter Number 16-00681, In the Matter of the Clean Energy Fund Investment Plan. Revised June 15, 2020. https://www.nyserda.ny.gov/-/media/Files/About/Clean-Energy-Fund/CEF-Energy-Storage.pdf

[2] Case 18-E-0130, In the Matter of Energy Storage Deployment Program, Order Establishing Energy Storage Goal and Deployment Policy, issued December 13, 2018.

[3] Case 18-E-0130, In the Matter of Energy Storage Deployment Program, New York State Energy Storage Roadmap, issued June 21, 2018.

[4] NYSERDA. 2020. "Developers Contractors and Vendors." Energy Storage, Developers & Contractors. https://www.nyserda.ny.gov/All-Programs/Programs/Energy-Storage/Developers-Contractors-and-Vendors

2. Energy Storage Technology and Product Development Investment Plan:[5] There are many grid and consumer benefits from the increased use of renewable energy assets and energy storage. 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 use 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, EV charging, solar PV, and large-scale wind.
    - Load-side and generation-side energy storage applications to reduce peak load, store and reuse solar PV and wind energy to help firm up these resources, and provide ancillary services.
- Facilitate strategic corporate partnerships among small- and medium-sized companies and large 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.

1.2 Summary of Evaluation Objectives and Methods

The evaluation design is longitudinal in nature and is structured to capture data over multiple years. This design allows program stakeholders to compare current market conditions to the baseline market conditions established in 2017 and to observe market trends over time. The time-series data developed over the course of the evaluation will help NYSERDA and other program

[5] NYSERDA. 2020. *Clean Energy Fund: Renewables Optimization Chapter*. Portfolio: Innovation & Research. Matter Number 16-00681, In the Matter of the Clean Energy Fund Investment Plan. Revised June 15, 2020. https://www.nyserda.ny.gov/-/media/Files/About/Clean-Energy-Fund/CEF-Renewables-Optimization-chapter.pdf

stakeholders better understand the factors that drive the energy storage market in New York State as the market grows.

The primary data collection and literature review collect data for front-of-the-meter (FTM) and BTM systems. For FTM systems, the primary data collection differentiates between bulk and retail use cases:

- **Bulk:** systems larger than 5 MW, provide wholesale market energy, ancillary services, and capacity services
- **Retail:** capped at 5 MW, grid-connected energy storage systems located either with load or connected directly into the distribution system.

The literature review refers to all utility-scale storage as FTM systems. For BTM systems, the primary data collection includes systems located at commercial and industrial (C&I) customer sites, while the literature review includes data for C&I and residential systems.

The evaluation objectives and select results from the 2019 primary data collection and literature review efforts completed by the market evaluation team are shown in Table 1 and Table 2.

Table 1: Evaluation questions mapped with 2019 primary data collection results

The objective of primary data collection is to develop a reliable, detailed, New York-based estimate of current soft costs ($/kWh) of DES systems as a component of the total installed cost ($/kWh, duration).

Source: Market evaluation team analysis

Evaluation Questions	2019 Findings[a]
What is the current estimate of soft costs ($/kWh capacity) of DES systems?[b]	**BTM**: Average = $325/kWh Median = $250/kWh n=5 **FTM (Retail)**: Average = $77/kWh Median = $73/kWh n=11
What is the installed cost per kWh capacity for energy storage systems by duration?[c]	**BTM**: Average = $1,279/kWh Median = $833/kWh n=7 **FTM (Retail)**: Average = $434/kWh Median = $405/kWh n=61 **Bulk**: Average = $416/kWh Median = $463/kWh n=8
How many ownership models (e.g., third-party ownership, end-user ownership, performance contracting) are being used?	Most FTM energy storage systems are exclusively third party-owned (9 of 11), with only two FTM systems using site or end-user ownership. Most BTM systems are third party-owned, though other ownership models were reported.
What is the percent conversion rate (%) of prospective installations from proposal to installed projects?	The average conversion rate for FTM energy storage projects was 47% (n=3). The BTM project conversion rate was 25% (n=5).
What is the cycle time (months) of projects from customer proposal to commissioning?	BTM: 20 months n=4 FTM: 22 months n=10
What is the current cycle time (months) for the permitting process?	BTM: 6 months n=5 FTM: 5 months n=10

Evaluation Questions	2019 Findings[a]
Are there challenges with siting and permitting requirements?	One survey respondent mentioned known challenges with Authorities Having Jurisdiction (AHJ) permitting requirements, which have been the subject of significant NYSERDA engagement.

a The cost data presented in this table reflects a blend of estimated installed costs and invoiced costs.

b Includes a combination of 2- to 4 -hour systems.

c Duration is defined as the ratio of the storage system's energy capacity to power capacity, which indicates the length of the system's full discharge.

Table 2: Evaluation questions mapped with literature review results

The objective of the literature review is to develop a reliable, detailed estimate of current hardware and hardware balance of system (BOS) costs ($/kWh) of energy storage systems.

Source: Market evaluation team analysis

Evaluation Questions	2019 Findings
What is the current hardware cost ($/kWh) for energy storage devices?	Typical utility-scale lithium ion (Li-ion) battery cost = $195/kWh. Battery costs are ~33% higher for C&I systems and ~40% higher for residential systems. Unit cost may be significantly higher for high-performing batteries.
What is the current hardware BOS cost for energy storage systems including power electronics and hardware installation cost ($/kWh)?	Typical utility-scale power conversion system (PCS) hardware cost = $81/kW. PCS cost is ~81% higher than utility-scale systems for C&I systems and ~161% higher for residential systems. Typical utility-scale BOS hardware cost = $21/kW + $33/kWh. BOS costs are ~314% higher than utility-scale systems for C&I and ~390% higher for residential.
What is the current performance of energy storage systems in terms of efficiency, life, energy/power density, etc.?	Performance metrics were not evaluated as part of the 2019 market evaluation, as they were evaluated in 2017 and 2018 and do not change significantly year to year.

2 Market Characterization and Assessment

2.1 Primary Data Collection Results

This section summarizes 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 combines information from 40 responses to the evaluation survey and 60 customers that provided NYSERDA with energy storage incentive program application data in 2019. The survey targeted all companies that contracted or completed DES projects in New York State in 2019. Not all companies answered all survey questions. Incentive program application data provided only total average cost. All data represented in this analysis is for real projects, but it includes a mix of projects installed in 2019 and projects contracted in 2019 with anticipated commissioning dates in 2020-2022. The data from the contracted projects not yet installed necessitated estimates. Section 5.1.4 provides additional detail regarding the companies that responded to the evaluation survey.

2.1.1 System Costs

The survey asked responding companies to provide information on average installed costs for their primary use case DES systems and secondary use case DES systems, if applicable.[6] The market evaluation team collected information from 10 C&I BTM use cases, 11 utility FTM (retail) use cases, and one bulk use case. The market evaluation team excluded two retail use cases. Of the 40 respondents who took the survey, 17 provided cost data.

While the survey sample includes a small number of respondents, the storage market in New York is relatively nascent with few players. NYSERDA tracks operational projects in New York State and has confirmed the survey responses collected by the primary research activities represent the market and capture the companies implementing the most projects in the state.[7]

[6] Two respondents provided primary and secondary use case information as defined in the survey document (see Appendix B).

[7] A database of all distributed energy resource projects installed throughout New York is available on NYSERDA's website: https://der.nyserda.ny.gov/

The NYSERDA incentive program application data provided an additional two BTM systems, 50 utility FTM systems, and eight bulk systems.

Survey respondents reported that 21 use cases were lithium ion (Li-ion) installations, two of which were secondary use cases. Respondents reported no other battery technologies. Respondents and applicants provided geographic data for 59 DES systems, presented in Table 3.

Table 3: Geographic locations of installed or planned DES systems, 2019

Source: Market evaluation team analysis of survey data

Geography	Bulk	BTM	FTM (Retail)	Total
New York City	0	0	0	**0**
Long Island	0	0	0	**0**
Westchester	0	0	5	**5**
Other New York State	7	2	45	**54**

Reported retail system size ranged from 36 kWh to 20,000 kWh, with an average size of 9,487 kWh and a median size of 10,000 kWh. Reported bulk retail system size ranged from 16,500 kWh to 800,000 kWh, with an average size of 153,500 kWh and a median size of 80,000 kWh.

The market evaluation team asked companies to estimate what percentage of total system cost constituted 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, and outdoor containerization (when necessary).
- **Engineering and construction costs:** Cost of design, site preparation, transportation, siting, Professional Engineer approval, testing and commissioning, electrician and installation labor, wiring, fencing, and other overhead.
- **Soft costs:** Cost of customer acquisition, permitting, interconnection, and financing.

Survey respondents provided soft cost information for 16 use cases, including five BTM and 11 FTM retail use cases. The incentive program application data provided average cost information in addition to data collected via the survey. Table 4 (BTM), Table 5 (FTM Retail), and Table 6 (bulk) present all cost data available to the market evaluation team, with n counts to designate the number of use cases and systems that informed each calculation.[8] The 2019 survey collected average system duration for the first time, and the market evaluation team analyzed average system cost data by system duration where possible.

Table 4 presents cost data for BTM retail storage projects collected over the past 3 years.[9] The final or anticipated commissioning dates for the 2019 projects represented are from 2019 to 2022. The table presents average installed system costs in aggregate, not broken out by duration, due to limited number of responses received.

Table 4: Average costs of BTM DES projects by component,[a] 2017-2019

Source: Market evaluation team analysis of survey and incentive program data

Cost	Unit	2017 n	2017 Average	2017 Median	2018 n	2018 Average	2018 Median	2019 n	2019 Average	2019 Median
Average installed system cost	$/ kWh	3	$883	$850	5	$1,000	$1,000	7	$1,279	$833
Hardware costs	%	3	62	60	5	55	50	5	45	40
Engineering and construction costs	%	3	22	20	5	24	20	5	30	25
Soft costs	**%**	**3**	**17**	**15**	**5**	**21**	**20**	**5**	**25**	**30**
Customer acquisition	*%*	*3*	*3*	*3*	*5*	*2*	*2*	*5*	*5*	*3*
Permitting	*%*	*3*	*8*	*10*	*5*	*6*	*8*	*5*	*12*	*10*
Interconnection	*%*	*3*	*5*	*5*	*5*	*10*	*10*	*5*	*7*	*10*
Financing	*%*	*3*	*1*	*0*	*5*	*3*	*0*	*5*	*1*	*0*

[a] The percent sum of average hardware costs, engineering and construction costs, and soft costs should sum to 100; any variance is due to rounding. The median values do not necessarily sum to 100 because of the variance within data points. Soft costs are a sum of the average customer acquisition costs, permitting, interconnection, and financing costs. These also sum to 100 for average columns but not the median columns.

The market evaluation team considered correlations between geographic location and costs and found that 2019 BTM storage projects in New York City, Long Island, and Westchester counties

[8] One survey respondent provided bulk use case data, including hardware, engineering and construction, and soft costs; however, the market evaluation team elected not to report this data to protect anonymity and avoid bias created by a sample size of one.

[9] 2017 and 2018 data does not include incentive program application data, only the 2019 average installed system cost does.

are more than twice as expensive as those projects in the rest of the state. This finding does not take into account differences in project size or duration.

Installed system costs for BTM projects in 2019 averaged $1,279. This value is higher than both the 2017 average ($883) and 2018 average ($1,000). Notably, the median installed system costs for BTM projects in 2019 were $833, which is slightly lower than both the 2017 median ($850) and 2018 median ($1,000), indicating that fewer, more expensive projects may be driving up the average installed system cost for 2019.

The percentage of costs attributable to soft costs for BTM projects, 25% on average in 2019, increased from the percentage observed in 2017 (17%) and 2018 (21%). While trends in installed system costs and soft costs appear to have increased over time, the limited number of respondents and variability between specific projects could skew these generalized results from one year to the next. The market evaluation team will continue to collect time-series data regarding these metrics in the coming years so that NYSERDA and other program stakeholders can monitor these trends as the market matures and more DES projects are installed in New York State.

Table 5 and Table 6 present 2019 FTM and bulk DES project average installed system costs in aggregate, not broken out by duration, due to the limited number of responses received. The 2017 and 2018 reports were unable to provide cost estimates beyond average installed costs for FTM projects because of the limited number of survey responses.

Table 5: Average costs of FTM Retail DES projects by component,[a] 2019

Source: Market evaluation team analysis of survey and incentive program data

Cost	Unit	2019 n	2019 Average	2019 Median
Average installed system cost	**$/kWh**	**61**	**$434**	**$405**
Average system costs; <3-hour duration	$/kWh	15	$489	$503
Average system costs; ≥3-hour duration	$/kWh	46	$416	$392
Hardware costs	%	11	72	70
Engineering and construction costs	%	11	11	13
Soft costs	**%**	**11**	**18**	**18**
Customer/site acquisition	*%*	*11*	*2*	*1*
Permitting	*%*	*11*	*5*	*3*
Interconnection	*%*	*11*	*8*	*8*
Financing	*%*	*11*	*3*	*2*

[a] The percent sum of average hardware costs, engineering and construction costs, and soft costs should sum to 100; any variance is due to rounding. The median values do not necessarily sum to 100 because of the variance within data points. Soft costs are a sum of the average customer acquisition costs, permitting, interconnection, and financing costs. These also sum to 100 for average columns but not the median columns.

Table 5 presents retail storage projects installed in front of the meter, sized up to 5 MW. The final or anticipated commissioning dates for the projects represented are from 2019 to 2022.

On average, systems with durations shorter than 3 hours are roughly 15% more expensive than systems with durations longer than 3 hours. Again, the market evaluation team considered correlations between geographic location and costs and found that FTM retail storage projects in New York City, Long Island, and Westchester counties are roughly 20% more expensive than those projects in the rest of the state. This finding does not take into account differences in project size or duration.

The percentage of costs attributable to soft costs for FTM retail projects were 18% in 2019, also lower than that of BTM projects in 2019 (25%).

Table 6: Average costs of bulk DES projects, 2019

Source: Market evaluation team analysis of survey and incentive program data

Cost	Unit	2019 n	Average	Median
Average installed system cost	$/kWh	8	$416	$463

Table 6 presents bulk storage projects installed in front of the meter, sized greater than 5 MW. The anticipated commissioning dates for the projects represented are 2020-2021.

All bulk project cost data, except for one data point, represents data collected in the NYSERDA incentive program application process. The application collected only total project costs, not component costs.

Average installed system costs for FTM retail projects and bulk projects in 2019 were $434 and $416, respectively, both significantly lower than the average installed system costs for BTM projects ($1,279).

2.1.2 Value Proposition and Alternative Ownership Models

Survey respondents cited several benefits of DES systems that were important in closing the deal for potential customers. As shown in Table 7, the most frequently cited benefit in 2019 remained the same as in 2018, with 80% of responding companies citing distributed generation integration most frequently. Slightly fewer companies, 73%, cited investment tax credit as important for deal closure. Non-wires alternative services decreased in importance from 2018, with only 33% of companies citing this benefit as important for deal closure in 2019. Demand charge management, demand response payments, and resilience or backup power continued to decrease in importance since 2017.

Table 7: DES system benefits important for deal closure by percentage of respondent companies,[a] 2017-2019

Source: Market evaluation team analysis of survey data

Benefit	2017	2018	2019
Investment tax credit	63%	50%	73%
Distributed generation integration	38%	75%	80%
Non-wires alternative services	38%	75%	33%
Demand charge management	63%	50%	13%
Demand response payments	63%	50%	20%
Resilience/backup power	38%	25%	7%
Other	25%	0%	47%

[a] Survey respondents could select more than one answer to this question. 2017 n=9, 2018 n=4 , 2019 n=19

One of NYSERDA's objectives is to increase the number of alternative ownership models (e.g., third-party ownership, end-user ownership, performance contracting) for DES projects, shown in Table 8. For 2019, most FTM use cases are exclusively third party-owned, with only two FTM use cases reported using site or end-user ownership and one using performance contracting. Most BTM use cases are third party-owned, though other ownership models were reported.

Table 8: Ownership models for FTM and BTM projects, 2019

Source: Market evaluation team analysis of survey data

Ownership Model	FTM (n=9)	BTM (n=5)
Third party	8	4
Site or end user	2	2
Performance contracting or shared savings	1	1

Responses in 2018 mentioned third-party performance contracting models and end-use ownership for both BTM and FTM projects.

2.1.3 Barriers in the New York State Market

The NYSERDA incentive program launched in early 2019, and NYSERDA expected the program to positively influence the number of DES installations in New York State in 2019 and beyond. The market evaluation team received an increase in survey responses in 2019 (n=40), supporting this expectation.

NYSERDA aims to increase the percent conversion rate for DES projects receiving a proposal to projects receiving a contract. As shown in Table 9, the average conversion rate for 2019 BTM retail projects was 25%, an increase from 2018 (18%), though lower than 2017 (45%). The average conversion rate for 2019 FTM projects was 47%.

Table 9: Conversion rate, proposal to contract,[a] 2017-2019

Source: Market evaluation team analysis of survey data

System Type	2017 n	2017 Average	2018 n	2018 Average	2019 n	2019 Average
BTM	6	45%	5	18%	5	25%
FTM (Retail)	N/A	N/A	N/A	N/A	3	47%

[a] The 2017 and 2018 data is reported in aggregate and did not distinguish between FTM and BTM.

Table 10 presents the average percentage of projects awaiting permit approval. BTM retail projects awaiting permit approval increased in 2019 to 47%, higher than in 2018 (25%) but similar to 2017 (42%). Respondents reported a higher percentage of FTM projects awaiting permit approval in 2019 at 60%.

Table 10: Percentage of projects awaiting permit approval,[a] 2017-2019

Source: Market evaluation team analysis of survey data

System Type	2017 n	2017 Average	2018 n	2018 Average	2019 n	2019 Average
BTM	9	42%	5	25%	7	47%
FTM (Retail)	N/A	N/A	N/A	N/A	11	60%

[a] The 2017 and 2018 data is reported in aggregate and did not distinguish between FTM and BTM.

Five companies reported an average of 25% of 2019 BTM projects that received a proposal went on to receive a contract compared to an average of 18% in 2018 (n=5). Conversely, companies reported an average of 47% of BTM projects (n=7) waiting for permits to be approved in 2019, compared to an average of 25% of DES projects (n=9) in 2018. FTM projects showed a higher conversion rate of 47% (n=3) and a higher percentage of projects awaiting permit approval at 60% (n=11).

Respondents reported similar average cycle time from customer proposal to system commissioning for BTM projects (20 months) and FTM retail projects (22 months). Respondents likewise reported similar average length of time to obtain electrical, building or fire department permits for BTM projects (6 months) and FTM retail projects (5 months). Table 11 and Table 12 present these results. Interestingly, respondents reported that New York City use cases did not have the longest cycle times for either FTM or BTM.

Table 11: Average cycle time from customer proposal to system commissioning, 2019

Source: Market evaluation team analysis of survey data

System Type	n	Cycle Time (months)
BTM	4	20
FTM (Retail)	10	22

Table 12: Average length of time to obtain electrical, building, or fire department permits, 2019

Source: Market evaluation team analysis of survey data

System Type	n	Cycle Time (months)
BTM	5	6
FTM (Retail)	10	5

2.2 Literature Review Results

The primary objective of the 2019 literature review was to provide a reference for energy storage costs based on new data collected by the market evaluation team since the 2018 report. The additional data sources are listed in Appendix C. The approach the market evaluation team used to analyze the data is described in Section 0.

The market evaluation team quantified typical costs of hardware and non-hardware components in addition to total installed cost:

- **Battery:** Battery rack with battery management system
- **PCS:** Inverter
- **BOS:** Enclosure, HVAC, transformer, switchgear, wiring, etc. (excludes interconnection and software costs)
- **Energy Management System (EMS):** Software and controls
- **Engineering, procurement, and construction (EPC):** May include development and other soft costs
- **Total installed cost:** Includes all components

Hardware (abbreviated as HW in charts) is based on the sum of the battery, PCS, and BOS components, while total cost is based on the assessment of reported total system costs (not a sum of the values found for individual components).

Consistent with the 2018 report, the market evaluation team analyzed these costs for their dependence on a variety of parameters:

- **Duration:** Dependence on energy to power ratio (hours)
- **Size:** Dependence on system size and grid location
- **Time:** Historical and forecast cost reductions

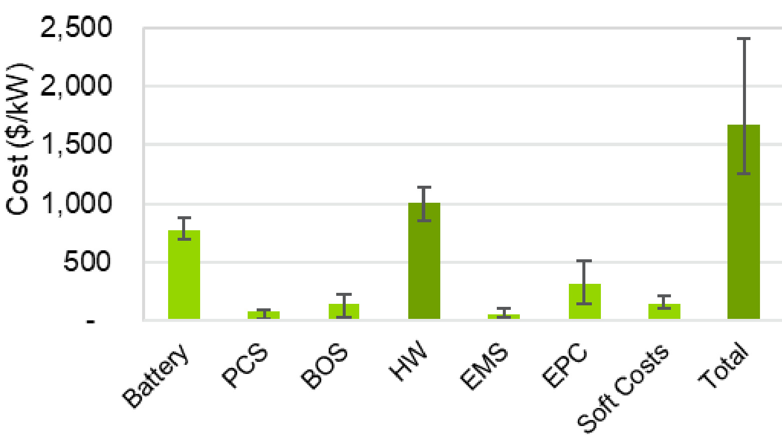
The results of this analysis indicate that updated 2019 costs are generally in line with costs projected in the 2018 report.

2.2.1 Variability in Costs

As Figure 1 shows, the variability in costs can be significant and is driven by a combination of EPC and hardware costs, with EPC costs showing the most variability. Variability for BOS is higher relative to 2018, which appears to be because of additional data sources in the 2019 analysis.

Figure 1: Variability in costs (2019, Li-Ion, utility-scale, 4-hour)[a]

Source: Market evaluation team analysis



[a] Range in variability represents the highest and lowest cost data points for each hardware component, EMS, EPC, and total costs. Range in variability for hardware costs were based upon the sum of the highest and lowest cost data points for battery, BOS, and PCS components, while range in variability for soft costs was based upon same relative range for total costs.

Several uncertainties drive variability in costs:

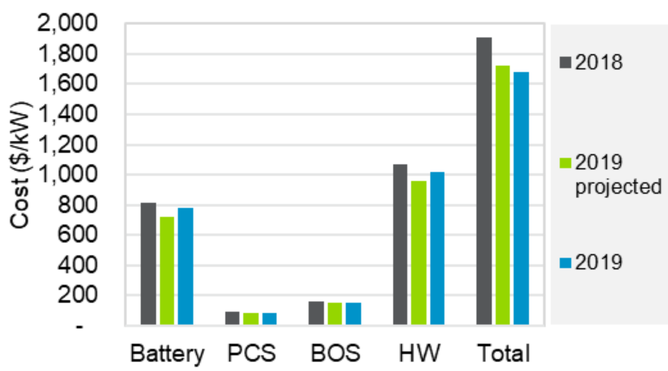
- Data sources do not always indicate whether the data includes profit margins.
- Data sources do not always specify whether theoretical maximum energy or actual usable energy is the basis for battery costs.
- There is a limited number of sources for costs by component for C&I and residential systems.
- Cost forecasts may not account for unexpected circumstances (e.g., coronavirus outbreak effects on supply chains).
- Components may be defined differently across supports; non-hardware costs are reported differently across sources, making direct comparisons challenging.
- Assumptions of size or grid location are not always clearly specified.

2.2.2 Comparison of Costs Between 2019 and 2018 Analysis

Total cost reductions from 2018 to 2019 were somewhat greater than expected as seen in Figure 2. Cost reductions for hardware components were generally in line with projections, except for relatively modest reductions in battery costs. Modest battery cost reductions are likely due to supply constraints because of EV market growth (see Section 2.2.5).

Figure 2: Cost by component (2018 vs. 2019, Li-Ion, 4-hour)

Source: Market evaluation team analysis

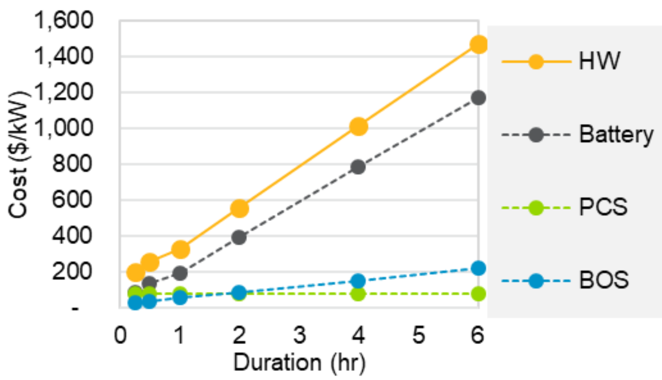


2.2.3 Dependence on Duration

The cost of an energy storage system varies depending on the duration (hour), which is equivalent to the ratio between the usable energy (kWh) and the maximum power (kW). Consistent with the 2018 report, the battery component most significantly depends on duration. As Figure 3 shows, the dependence of each component's cost ($/kW) on duration is approximately linear.[10] While battery costs scale primarily with energy, other hardware components (shown in Figure 4) scale primarily with power (PCS) or with a mix of power and energy (BOS).

Figure 3: Cost by duration (2019, Li-Ion, utility-scale, hardware components)[a]

Source: Market evaluation team analysis



[a] Dashed lines represent costs at the component level; the solid line represents cost for hardware components.

Figure 4: Cost by duration (2019, Li-Ion, utility-scale, PCS and BOS)

Source: Market evaluation team analysis

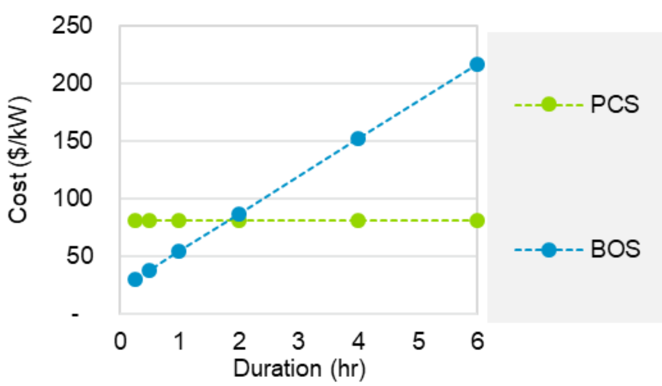


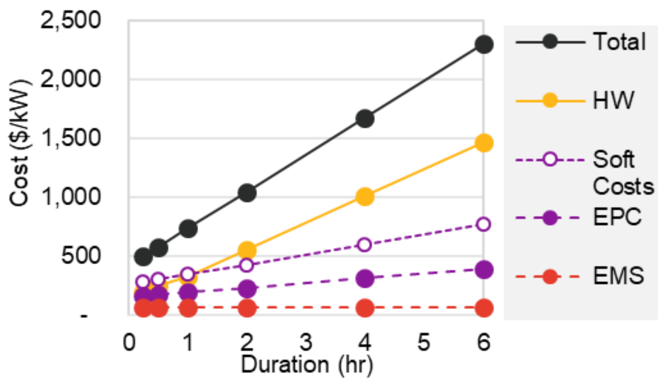
Figure 5 shows cost by duration for all components. EMS cost, like PCS, scales almost exclusively with power, while EPC and total installed costs are driven by power and energy.

[10] The relationship for batteries is not entirely linear. At shorter durations, more expensive batteries or a narrower depth of discharge to limit degradation from rapid cycling is required.

However, power costs are the greater contributor at shorter durations, while energy costs are the greater contributor at longer durations.

Figure 5: Cost by duration (2019, Li-Ion, utility-scale) [a]

Source: Market evaluation team analysis



[a] Dashed lines represent costs at the component level; the solid line represents cost for hardware components and total cost.

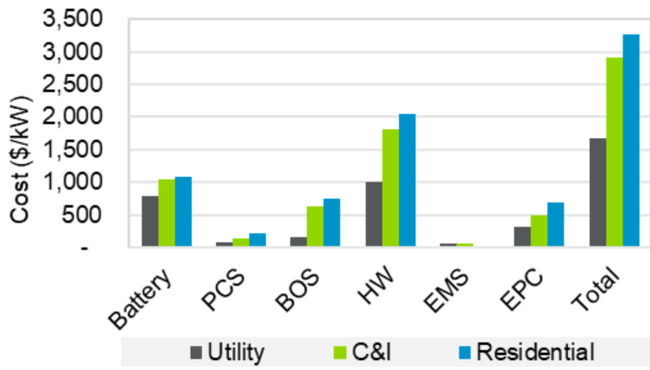
2.2.4 Dependence on Size

Observed 2019 costs indicate similar trends to those found in the 2018 analysis. As Figure 6 shows, hardware and non-hardware costs tend to increase as system size decreases. Similar trends as in 2018 are observed for the following components:

- **Battery:** Continuous reductions with scale
- **PCS:** Affected by economies of scale and functionality enhancements
- **EMS:** No clear variability with size
- **EPC:** Continuous reductions with scale

Figure 6: Cost by scale (2019, Li-ion, 4-hour)[a]

Source: Market evaluation team analysis



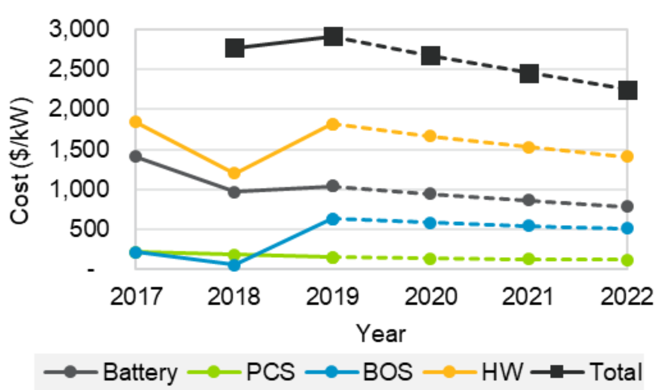
[a] Residential and C&I systems are BTM systems, while utility-scale systems are FTM systems.

Notable exceptions include BOS and total installed costs for C&I systems, which appeared to increase from 2018 to 2019 (shown in Figure 7).

- **BOS:** The market evaluation team found BOS costs show continuous reductions with scale, similar to trends seen with other hardware components. In the 2018 analysis, BOS costs were lower for C&I systems than utility-scale systems. The increase in C&I costs in 2018-2019 is likely due more to refined estimates from additional data than actual increases in costs.
- **Total cost:** The market evaluation team found total costs show continuous reductions with scale, driven primarily by battery, BOS, and EPC costs. Similar to BOS costs, increases in C&I costs are likely due more to the additional data collected for C&I systems rather than actual increases in costs.

Figure 7: Cost by year (C&I, Li-ion, 4-hour)[a]

Source: Market evaluation team analysis



[a] Dashed lines represent cost forecasts and solid lines represent actual costs.

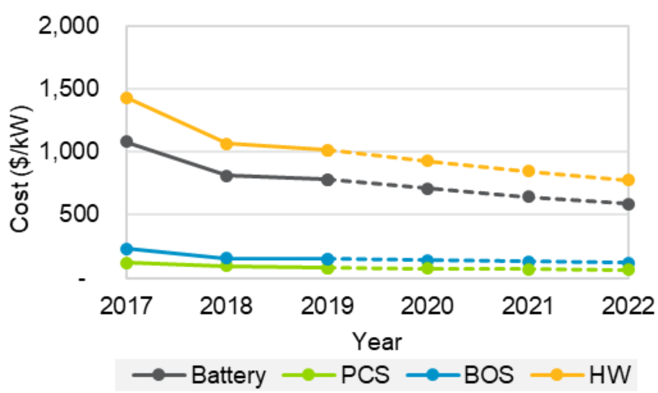
Notably, while grid location is a reasonable approximation for system size (which typically increases from residential to C&I to utility-scale), system sizes—and, therefore, associated costs—can vary significantly within a given grid location. Across different literature sources, there is no consistent standard size basis at a given grid location, which may contribute to variability in reported costs between different sources.

2.2.5 Cost Reductions Over Time

As Figure 8 shows, a modest decline in hardware costs is observed between 2018 and 2019. The same rate of decline is not expected to continue in the future. Instead, costs are expected to decline more rapidly, at a rate between what was observed for 2017-2018 and 2018-2019. For non-hardware components, what appear to be significant cost reductions are more likely due to refined cost estimates from additional data than actual cost reductions (Figure 9).

Figure 8: Cost by year (Li-ion, utility-scale, 4-hour, hardware components)[a]

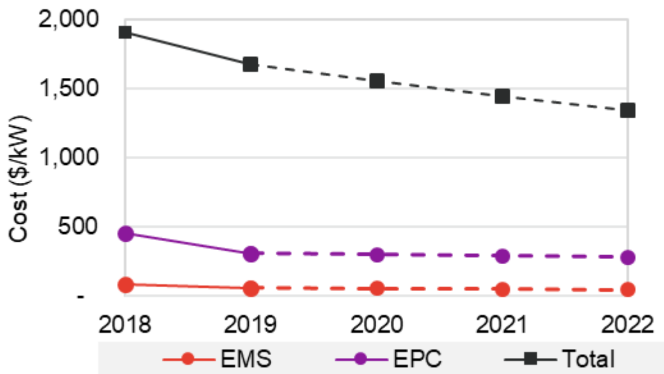
Source: Market evaluation team analysis



[a] Dashed lines represent cost forecasts and solid lines represent actual costs.

Figure 9: Cost by year (Li-ion, utility-scale, 4-hour, total and non-hardware) [a]

Source: Market evaluation team analysis



[a] Dashed lines represent cost forecasts and solid lines represent actual costs.

Battery cost reductions, in particular, were modest in 2018-2019. This modesty is likely because of supply constraints due to the growth of the EV market, which kept battery prices from declining significantly for stationary projects.[11] As noted previously for hardware costs, battery costs are expected to decline more rapidly in the future. Table 13 shows the calculated compound annual growth rate (CAGR) values for costs by component. The market evaluation team calculated pre-2019 and post-2019 CAGR values relative to the 2019 prices from the duration analysis using sources with data across multiple years. Notably, future cost projections from 2019 to 2022 are expected to be similar for hardware and non-hardware components.

Table 13: Annual cost reductions by component (CAGR)

Source: Market evaluation team analysis

Timeframe	Battery	PCS	BOS	Hardware	EMS	EPC	Total Cost
2017-2018	-25%	-22%	-32%	-26%	-	-	-
2018-2019	-4%	-14%	-4%	-5%	-28%	-32%	-12%
2020-2022	-9%	-8%	-6%	-9%	-7%	-3%	-7%

[11] Maloney, Peter. 2018. "Electric vehicle and stationary storage batteries begin to diverge as performance priorities evolve." *Utility Dive.* August 1. https://www.utilitydive.com/news/batteries-for-electric-vehicles-and-stationary-storage-are-showing-signs-of/528848/

The coronavirus outbreak may affect supply chains and influence storage costs. While the effect on supply chains, demand, and prices is unclear, there are a few potential scenarios:

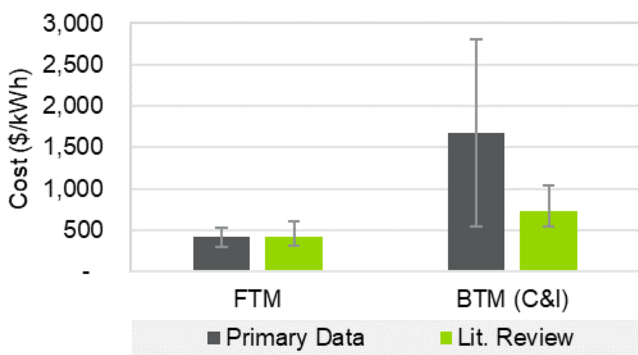
- Supply and demand remain relatively in balance, resulting in steady cost reductions.
- Demand remains high while supply chain issues cause shortages that either keep prices flat or drive them up.
- Demand decreases and causes storage costs to decline more rapidly.[12]

2.2.6 Comparison of Primary Data and Literature Review Results

Figure 10 compares the total installed costs from the primary data and literature review. The literature review finds lower average costs than the primary data, though costs from the primary data are generally within the range of error from the literature review. Total installed costs for FTM systems from the survey are consistent with literature review findings. BTM system costs from primary data, however, are higher than literature review findings for all components (see Figure 11). The discrepancy may be because of the high variability in BTM costs due to the small number of New York projects reflected in the primary data.

Figure 10: Comparison of literature review and primary data (2019, Li-ion, total installed cost) [a, b]

Source: Market evaluation team analysis



[a] Primary refers to 2019 New York-reported primary data; Lit. Review refers to the 2019 literature review.

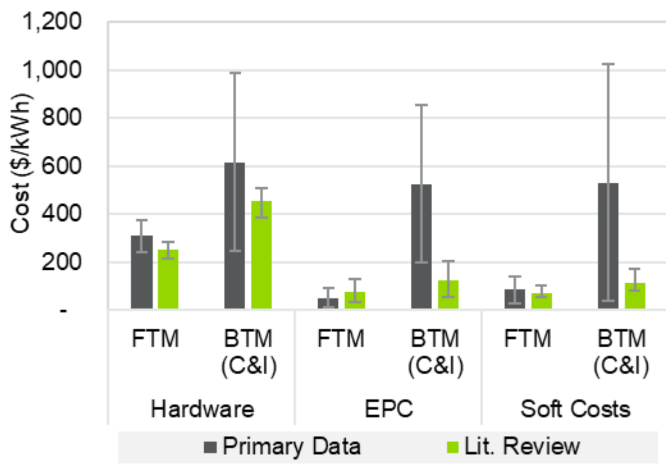
[b] Primary costs are based on 2+ hour for BTM and 3+ hour for FTM. Literature review costs are based on 4-hour systems.

[12] Cox, Molly and Mitalee Gupta. 2020. "WoodMac: Solar and Storage Prices Falling Faster Than Expected Due to COVID-19." *Green Tech Media*. June 30. https://www.greentechmedia.com/articles/read/covid-19-is-pushing-down-front-of-the-meter-solar-and-storage-pricing.

Figure 11 compares hardware, EPC, and soft costs from the primary data and literature review. Similar to total installed costs, soft costs for FTM systems from the primary data appear to be similar to calculated soft costs from the literature review. Conversely, soft costs for BTM systems from primary data appear to be significantly higher than calculated soft costs.

Figure 11: Comparison of literature review and primary data (2019, Li-ion, hardware, EPC, and soft costs)[a]

Source: Market evaluation team analysis



[a] Primary data is based on 2+ hour for BTM and 3+ hour for FTM. Literature review costs are based on 4-hour systems.

Several factors contribute to the discrepancy in BTM costs:

- A low number of primary data points with a few high cost outliers drive up average costs.
- Labor costs in New York are higher relative to nationwide averages.
- The BTM storage market in New York is immature, resulting in inefficiencies that drive up labor and soft costs.

3 Findings

Finding 1

Average installed system costs and the proportional percentage of soft costs for BTM projects in New York continues to increase since 2017. However, the median installed system costs have decreased since 2017, indicating that fewer, more costly projects may be driving up the average installed system cost for 2019. While NYSERDA tracks operational projects in New York State and has confirmed the survey responses collected by the primary research activities are representative of the market, the market evaluation team acknowledges that all data collected to date is based on a limited number of respondents and may not reflect larger market trends. Nationally, total cost reductions from 2018 to 2019 were somewhat greater than expected. Although a modest decline in hardware costs was observed between 2018 and 2019, the market evaluation team does not expect the same rate of decline to continue in the future. Future annual cost declines are expected to decline more rapidly in the future.

Finding 2

The 2019 survey collected data on system size, which was not collected in prior evaluations. On average, survey responses indicated that FTM systems with durations shorter than 3 hours cost roughly 15% more than FTM systems with durations longer than 3 hours.

Finding 3

While total installed costs for FTM systems were consistent across the primary data collection and literature review findings, BTM system costs from the survey were higher than the literature review findings, particularly for labor and soft costs. Specifically, the costs associated with permitting and interconnection were the two largest contributors to soft costs according to survey data.

4 Recommendations

Recommendation 1

Consider revisions to the survey to capture responses on external forces that may be affecting the energy storage market in New York, such as market changes due to technology (e.g., EV or other competing energy storage markets), legislative mandates (e.g., Climate Leadership and Community Protection Act), or other factors (e.g., coronavirus outbreak).

Recommendation 2

For projects NYSERDA is funding, the market evaluation team recommends defining data collection requirements and establishing terminology standards to address gaps and inconsistencies in data for costs and performance metrics. The terminology standards would enable more consistent evaluation and data comparison (e.g., nameplate vs. actual data).

Recommendation 3

The market evaluation team recommends that programs focused on energy storage technologies concentrate on driving labor (i.e., EPC) and soft costs down. The greatest difference between New York State-reported primary data and secondary literature review results was observed for these cost components. Furthermore, New York State agencies likely have greater ability to impact these cost components, which can be affected by local markets and policies, whereas hardware costs are largely driven by factors associated with global supply and demand. Programs that focus on reducing permitting and interconnection costs will be the most effective in driving down total soft costs.

5 Methods

5.1 Primary Data Collection Methods

This section describes the methods the market evaluation team used to complete the primary data collection activities.

5.1.1 Survey Design and Data Collection

NYSERDA fielded a survey to 82 energy storage companies in January and February 2020. Due to a low initial response rate, the market evaluation team collaborated with NYSERDA to target key respondents for enhanced communication including outbound phone calls and email follow-up. The market evaluation team closed the survey in the third week of February. The market evaluation team also received incentive program application data from NYSERDA, which included estimations of average total costs. All data represented in this analysis is for real projects, but it does include projects installed in 2019 and projects contracted in 2019 with anticipated commissioning dates in 2020-2022. The data from the projects not yet installed necessitate estimates.

The survey gathered data on the following items:

- Percentage of DES project costs spent on hardware, engineering and construction, and soft costs for primary use case and secondary use case, if applicable
- Characteristics of DES projects in New York State
- Characteristics of each company's primary DES use case and secondary use case, if applicable
- Length of DES project sales and implementation cycles
- Key selling points for DES projects
- Differences between the DES market in New York State and other markets
- Company characteristics

Forty companies responded to the survey (49% response rate) with 26 answering all questions in the survey. Fifteen respondents provided cost information for BTM, FTM retail, or bulk projects. Two companies installed residential projects, which the market evaluation team excluded from analysis. Nine companies did not install, commission, or have any projects in the pipeline with an executed contract in New York State in 2019, so they were not asked many questions, such as those relating to cost, cycle time, or conversion rate.

5.1.2 NYSERDA Energy Storage Incentive Program Application Data Collection

In 2019, NYSERDA launched an energy storage incentive program that provides funding to accelerate energy storage deployment in New York State. To apply for NYSERDA energy storage incentives, applicants must provide an estimated cost of their proposed project. NYSERDA provided this cost data to the market evaluation team to include in the analysis. The market evaluation team appended total cost data from these applications to the survey data prior to analysis.

5.1.3 Analysis

The market evaluation team fielded the survey using Qualtrics and downloaded the data to analyze in Excel. The market evaluation team conducted all data analysis, excluding instances where missing information could not be resolved.

The market evaluation team excluded responses from companies that indicated they installed residential projects. The market evaluation team also excluded responses from companies that indicated they did not install, commission, or have any projects in the pipeline with executed contracts in New York State in 2019, except those related to respondent characteristics and system benefits. The market evaluation team did not weight results due to a concern that weighting would add bias.

5.1.4 Respondent Characteristics

Surveyed companies reported what roles they filled in the energy storage market. Mirroring 2017 and 2018, respondents most frequently indicated they fulfilled the role of developer (n=29) in 2019. Differing from 2018, however, respondents reported the second most commonly fulfilled role in 2019 as installer (n=16), followed by integrator (n=10). The number of companies reporting roles as manufacturer continued to decrease (n=3) from prior years. Results are shown in Table 14.

Table 14: Company roles in energy storage market (multiple responses)

Source: Market evaluation team analysis of survey data

Company Type	Number of Companies (2017, n=20)	Number of Companies (2018, n=23)	Number of Companies (2019, n=36)
Developer	13	14	29
Integrator	8	5	10
Installer	8	4	16
Manufacturer	6	5	3
Sales	4	3	8
Financier	4	1	6
Distributor	3	2	0
Operator	1	0	3
Other	2	2	0

5.1.5 Statewide DES Projects

In addition to providing metrics on their primary and secondary use cases, if applicable, energy storage companies reported on all projects installed, commissioned, or in the pipeline with an executed contract in New York State in 2019.

Survey respondents (n=40) reported 64 projects installed, commissioned, or contracted in New York State in 2019. This total included 44 FTM projects and 20 BTM projects. Respondents indicated all reported use cases used Li-ion technology (n=21). Two respondents reported on residential projects, so the market evaluation team removed their responses from this calculation. Nine companies indicated they did not implement any projects in New York State in 2019.

Eighteen companies provided information on the sectors they most frequently served, shown in Table 15. Half of respondents indicated their companies serve the utility sector.

Table 15: Sectors served in New York, 2019

Source: Market evaluation team analysis of survey data

Sectors Served	Number of Companies (n=18)
Single family to fourplex residential	3
Multifamily	2
Commercial (not utility)	5
Industrial (not utility)	4
Utility	9
Municipal, University, Schools, or Healthcare (MUSH)	0
Other	2

5.2 Literature Review Methods

The literature review was based on data gathered for the 2017 and 2018 reports and new data gathered this year. 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.

5.2.1 Sources

See Appendix C for a list of all sources used in the literature review.

5.2.2 Data Cleaning

The market evaluation team cleaned the data by excluding individual data points with unclear assumptions, limited relevance, or questionable accuracy. Reasons for exclusion include the following: lack of specified system duration (for cost data), 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.

5.2.3 Data Selection and Trend Evaluation

The market evaluation team tagged and extrapolated data points 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). If the grid location was not specified, it was assumed, as appropriate, to be based on utility-scale data. In some cases, calculated values were based on a limited number of data points when applying multiple filter criteria (e.g., duration, technology, component, year, and grid location).

The market evaluation team calculated costs by duration based on the costs of individual components as a function of duration. Where insufficient 2019 data was available, costs for 2018 and 2020 were considered as well. PCS costs were assumed to be independent of duration. Li-ion battery costs were assumed to scale only with energy for systems at least 1 hour in duration, which excluded the cost of lithium titanate oxide (LTO) batteries. For battery costs of 15-minute and 30-minute systems, LTO cost and average costs for LTO and standard Li-ion chemistry were assumed, respectively. Hardware costs were calculated as the sum of calculated costs across different hardware components (battery, BOS, and PCS). Soft costs were calculated based on the difference between total installed costs and the sum of all component costs based on the premise that EPC component costs may not include all soft costs. The range for soft costs provided in Figure 1 and Figure 11 is based on the same relative range as for total costs (Figure 1), given that total costs demonstrated more significant variability than any component and soft costs are expected to have a relatively high range of variability compared to other components.