2017 Energy Storage Market Evaluation

Appendices to the Final Report

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Appendix A: Additional Secondary Data Collection and Analysis

Figure A-1 is an alternative representation of Figure 4 in Section 2.2.1.3, displaying hardware cost as a function of size for residential (5 kW), commercial and industrial (C&I) (200 kW), and utility (10 MW) levels.

Figure A-1. Cost by size (2017, Li-ion, 2-hour)

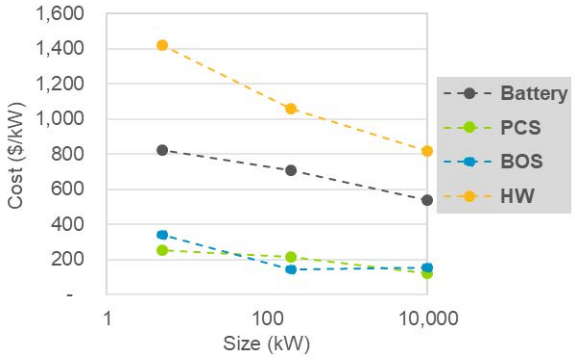

Table A-1 shows the calculated compound annual growth rate (CAGR) values for hardware costs based on component (Section 2.2.1.5). The market evaluation team calculated pre-2017 and post-2017 CAGR values relative to the 2017 prices from the duration analysis (Section 2.2.1.2) using sources with the data across multiple years.

Table A-1. Pre-2017 and post-2017 CAGR values

Component	2014-2017 CAGR	2017-2020 CAGR
Battery	-15%	-11%
Power conversion system (PCS)	-9%	-11%
Balance of system (BOS)	-5%	-6%

As noted in Section 4.2.1, a list of sources and the type of data obtained from each of the sources is shown in Table A-2.

Table A-2. List of sources

Source	Cost	Performance		
		Efficiency	Density	Lifetime
Black & Veatch	✓			
Bloomberg	✓			
BMZ		✓	✓	✓
BYD		✓		
Con Edison			✓	
Deloitte		✓	✓	✓
EIA	✓			
Electrovaya			✓	✓
Eos		✓	✓	✓
EPRI	✓		✓	
GE		✓	✓	✓
GTM	✓		✓	✓
HDR	✓	✓		✓
IRENA	✓	✓	✓	
IVA		✓	✓	
Kokam		✓	✓	✓
Leclanche			✓	✓
LG Chem		✓	✓	
Lockheed Martin		✓	✓	
Navigant	✓	✓	✓	✓
NREL	✓			
NYSERDA	✓			
PacifiCorp	✓	✓		✓
Panasonic		✓		
Primus Power		✓		✓
Samsung SDI			✓	✓
SGIP		✓		
Tesla	✓	✓		
UniEnergy		✓		✓
Vionx Energy		✓	✓	✓

Appendix B: Assessment of Program Achievements

Testable Hypothesis	Goal Prior to Exit	Output/Outcome	Indicators	Question	2017 Finding
If energy storage device capital costs are reduced and their performance is improved, energy storage market penetration by new customers and investors will increase.		Reduced hardware BOS costs ($/kWh) including power electronics for energy storage systems and hardware installation costs.	Hardware BOS cost including power electronics for energy storage systems and hardware installation cost ($/kWh, duration).	What is the current hardware BOS cost for energy storage systems including power electronics and hardware installation costs ($/kWh)?	Typical utility-scale PCS hardware cost = $121/kW. PCS cost are ~75% higher for C&I and ~110% higher for residential. Typical utility-scale BOS hardware cost = $75/kW + $40/kWh. BOS cost are ~10% lower for C&I and ~120% higher for residential. Installation cost not included.
		Reduced hardware costs ($/kWh) for energy storage devices.	Hardware costs for energy storage devices ($/kWh, duration).	What is the current hardware cost ($/kWh) for energy storage devices?	Typical Li-ion battery cost = $270/kWh. Battery costs are ~30% higher for C&I and ~50% higher for residential. Unit cost may increase significantly for high performance batteries.
		Improvements in performance of energy storage systems (efficiency, life, energy/power density, etc.).	Performance of energy storage systems (efficiency, life, energy/power density, etc.).	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

Testable Hypothesis	Goal Prior to Exit	Output/Outcome	Indicators	Question	2017 Finding
					and 20 years. Limited field data exists on actual degradation rates.
If soft costs are reduced by 25% or more from a 2015-16 baseline of approximately $220/kWh while battery costs continue to decline through global manufacturing scale up, then the installed cost for a distributed energy storage system in New York State will become much more attractive for a greater number of customers to manage their peak electric demand and use these systems to meet electric system needs.	Soft costs for distributed energy storage systems have been meaningfully reduced, with a goal of 25% per kWh in 3 years (end of 2019) and 33% in 5 years (end of 2021) compared to a 2015-16 internal baseline.	Quicker permitting process for energy storage systems.	Cycle time for permitting process (months).	What is the current cycle time (months) for the permitting process?	Insufficient data collected.
			N/A	Are there challenges with siting and permitting requirements?	Insufficient data collected.
		Greater number of alternative ownership models.	Number of alternative ownership models.	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.

Testable Hypothesis	Goal Prior to Exit	Output/Outcome	Indicators	Question	2017 Finding
		Soft costs for distributed energy storage systems have been meaningfully reduced, with a goal of 25% per kWh in 3 years (end of 2019) and 33% in 5 years (end of 2021).	Soft cost percentage declines per kWh of battery storage based on Clean Energy Fund strategies.	What is the current estimate of soft costs ($/kWh) of distributed energy storage systems?	Average = $146/kWh Median = $150/kWh n=3
		Reduced installed cost per kWh for a given duration (hours).	Cost per kWh, duration (hours).	What is the cost per kWh for energy storage systems, by duration?	Average = $883/kWh Median = $850/kWh Duration not specified. n=3
	Identifying and attracting best fit customers is readily accomplished by vendors as measured through vendor and customer surveys.	Conversion of prospective installations into installed energy storage projects.	Percent conversion rate from proposal to project (%).	What is the percent conversion rate (%) of prospective installations from proposal to installed projects?	Median = 38% Average = 45% n=6

Testable Hypothesis	Goal Prior to Exit	Output/Outcome	Indicators	Question	2017 Finding
	Ability to use distributed energy storage, including aggregated systems behind customer meters, to meet system needs is understood and readily recognized in utility planning and procurement.	Significant uptake in system approval and accelerated timeline.	Cycle time of projects from customer proposal to commissioning (months).	What is the current cycle time (months) of projects from customer proposal to commissioning?	Insufficient data collected.

Appendix C: Acronyms and Abbreviations

AC	Alternating current
CAGR	Compound annual growth rate
C&I	Commercial and industrial
BMS	Building management system
BOS	Balance of system
DC	Direct current
DES	Distributed energy storage
HVAC	Heating, ventilation, and air conditioning
kW	Kilowatt(s)
kWh	Kilowatt-hour(s)
Li-ion	Lithium ion
LFP	Lithium iron phosphate
LTO	Lithium titanate oxide
MUSH	Municipal, university, school, and hospital buildings
MW	Megawatts
NYSERDA	New York State Energy Research and Development Authority
OEM	Original equipment manufacturer
PCS	Power conversion system
PE	Professional Engineer
PV	Photovoltaics
REV	Reforming the Energy Vision
SGIP	Self-Generation Incentive Program (California)
W	Watt(s)

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Appendix E: Survey Instrument

Start of Block: Respondent Company Profile and Introduction

What is your company's size (employees) in New York State in terms of FTE (Full Time Equivalent)? [Enter number]

☐ Overall in New York State (1)

_____

☐ In New York State doing energy storage projects (2)

_____

☐ Overall outside New York State in North America (U.S. and Canada) (3)

_____

We are collecting data on Distributed Energy Storage (DES) systems that are installed primarily for load management or grid services rather than installed primarily for backup power or resilience. DES refers to systems in the kW to multi-MW range located behind or in-front-of a customer's meter within the distribution and sub-transmission system, excluding bulk storage.

What is your firm's role in the market for Distributed Energy Storage (DES) systems? [Check all that apply]

- ☐ Manufacturer (1)
- ☐ Distributor (2)
- ☐ Sales (3)
- ☐ Integrator (4)
- ☐ Developer (5)
- ☐ Installer (6)
- ☐ Financier (7)
- ☐ Other(specify) (8)

End of Block: Respondent Company Profile and Introduction

Start of Block: Installation Activities

Please respond to the following questions for DES projects primarily for load management or grid services you have installed, commissioned, or those in the pipeline with a contract signed and submitted for permitting and interconnection in New York State in 2017. Please do not include projects your company only contributed to.

	Lead Acid (1)	Lithium Ion (2)	Thermal (3)	Other (4)
Total number of in-front of-the- meter projects (1)				
Total number of behind-the-meter projects (2)				

What percentage of your company's DES portfolio in North America (U.S. and Canada) is in New York State, based on capacity? [Enter percentage]

O % (1) _____

What percentage of your company's New York State DES portfolio is in New York City, based on capacity? [Enter percentage]

O % (1) _____

Approximately what percent of your New York State customers that have received DES proposals since January 2017 have received contracts? [Enter percentage]

O % (1) _____

Of those 2017 New York State projects with executed contracts, what percent are waiting for permits to be approved? [Enter percentage]

O % (1) _____

End of Block: Installation Activities

Start of Block: Business Strategies

What percent of your DES systems in New York State in 2017 have each of the following types of contractual arrangements? [Enter percentage].

If you don't know, then write NA in the space provided.

	In front of the meter (%) (1)	Behind the meter (%) (2)
Third party ownership (1)		
Site or end user ownership (2)		
Performance contracting or shared savings (3)		

What percent of your DES customers in New York State in 2017 are in each of the following sectors [Sum to 100%]

Single family to four plex residential (%) :_____(1)
Multifamily (five or more units) (%) :_____(2)
Commercial (not utility) (%) :_____(3)
Industrial (not utility) (%) :_____(4)
Utility (%) :_____(5)
Municipal, University, Schools, or Healthcare ("MUSH") (%) :_(6)
Other (specify): :_____(8)
Total : _____

Which of the following benefits are important in closing the deal for your DES customers in New York State in 2017? [Check all that apply]

☐ Investment tax credit (1)

☐ Demand charge management (2)

☐ Demand response payments (3)

☐ Distributed generation integration (4)

☐ Non-wires alternative services (5)

☐ Any other benefits you typically promote? (specify): (6)

_____

☐ Don't know (7)

What percent of your DES customers in New York State in 2017 use financing? [Enter percentage]

O % (1) _____

O Don't know (2)

O Confidential Information (3)

Of those DES customers in New York State in 2017 that use financing, what percent are in the following sectors? [Sum to 100%]

Single family to four plex residential (%) :_____(1) Multifamily (five or more units) (%) :_____(2) Commercial (not utility) (%) :____(3)
Industrial (not utility) (%) :_____(4) Utility (%) :_(5)
Municipal, Universities, Schools, or Healthcare ("MUSH") (%) :_____(6) Other (specify): :_____(7)
Total : _____

End of Block: Business Strategies

Start of Block: Intro and primary use case

Next are some questions about the primary use case (geographic location, customer type, technology, and size) of DES systems your company sells. This primary use case applies to one with the highest number of projects, and only to your DES systems installed, commissioned, or those in the pipeline with a contract signed and submitted for permitting and interconnection in 2017 in New York State.

Please define your primary use case (geographic location, customer type, technology, and size) [Choose one from each drop down list below]

Geographic location

O New York City (1)

O Westchester County (2)

O Long Island (3)

O Other locations in NYS (4)

Customer type

O Utility customers (1)

O Industrial customers

(2)

O Commercial customers

(3)

O Residential customers

(4)

O Municipal, Universities, Schools, or Healthcare ("MUSH") customers (5)

Technology

O Lithium Ion (1)

O Lead Acid (2)

O Thermal (3)

O Other (4)

We'd like to understand the scale of your primary use case. Please provide an estimate of the average system size (kWh) in the space provided below.

O Average kWh (1) _____

End of Block: Intro and primary use case

Start of Block: Total Installed Cost

For your primary use case (geographic location, customer type, technology, and size), what is the average total installed cost $/kWh?

Total includes all costs for hardware, EPC and soft costs.

O $/kWh (1) _____

For your primary use case (geographic location, customer type, and technology) of DES systems in New York State in 2017, which percentage is constituted by the following: [Sum to 100%]

Hardware cost (%) (Battery modules, inverter, containerization, controller, power control, HVAC system, meter, insulation. Excludes upgrades required for permitting or interconnection approval.):_____(1)

Engineering and Construction cost (%) (Design, site preparation/survey, transportation, PE approval, testing, electrician and installation labor, wiring, fencing, testing, commissioning, and enrollment in energy markets. Excludes upgrades required for permitting or interconnection approval.): (2)

Permitting cost (%) (Including application fees, responding to requests for additional information, studies, and unique safety protections required from the AHJ):_____(3)

Interconnection cost (%) (Including application, and required upgrades or studies cost): (4)

Customer acquisition cost (%): (5)

Finance cost (%) (Including cost of capital, potential interest rate increases, due diligence, legal compliance and regulatory costs):_____(6)

Total: _____

End of Block: Total Installed Cost

Start of Block: Cycle Time and Staff Time

Next are some questions about the cycle time for the primary use case (geographic location, customer type, and technology) you listed above for DES systems your company sells in New York State in 2017. This cycle time is incurred up to and including the commissioning period for all of your DES systems installed, commissioned, or those in the pipeline with a contract signed and submitted for permitting and interconnection in 2017 in New York State.

For your primary use case in New York State in 2017, please list the average cycle time for various stages. We understand there are many factors that influence the cycle time, but we'd like you to provide your best estimate. [Fill in blanks in months]

	Number of Months (1)
Length of time for customer acquisition: from initial engagement to proposal being presented to the customer (1)	
Length of time from proposal to agreement to proceed (2)	
Length of time from agreement to proceed to site contract execution (3)	
Length of time to prepare electrical, building and/or fire department permits (before application submission) (4)	
Length of time to obtain approved permits from building and/or fire departments (after application submission) (5)	
Length of time to obtain interconnection approval from utility (6)	
Length of time from site contract execution to system commissioning (7)	
Length of time to commission the system (8)	

For your primary use case (geographic location, customer type, technology, and size) of DES systems in New York State in 2017, do you spend more staff time on New York State specific projects compared to other states where you do business?

If so, please provide an estimate of additional staff time (2 times, 3 times, etc.) you spend on New York projects compared to other states along with a brief explanation. For example, some potential increases in staff time could be due to permitting, interconnection, customer training, financing, and project management.

Within customer acquisition, what comprises the most extensive portion of your staff's time?

- O Customer Identification (1)
- O Closing the deal (2)
- O Contracting (3)
- O Audit/site assessment/data logging (4)
- O Some other activity (5)

- O Don't know (6)
- O Confidential Information (7)

End of Block: Cycle Time and Staff Time

Start of Block: Questions about secondary use cases and factors

Finally, we have some questions about the cost ($/kWh) and cycle time (months) for **other installations** for DES systems your company sells in New York State in 2017. These costs and cycle time are incurred up to and including the commissioning period for all of your DES systems installed, commissioned, or those in the pipeline with a contract signed and submitted for permitting and interconnection in 2017 in New York State.

Please indicate for each of the following factors which significantly decreased or significantly increased the total cycle time (months) and/or the total cost ($/kWh) of the DES projects you installed, commissioned or are in the pipeline in 2017 in New York State. Only choose factors that apply to your **other installations**. For factors that apply to your primary use case, please leave row blank.

	Compared to your primary use case, costs ($/kWh) were significantly			**Compared to your primary use case, cycle times (months) were significantly**		
	Lower by 20% or more (1)	**Higher by 20% or more (2)**	**No effect or Don't know (3)**	**Lower by by 20% or more (1)**	**Higher 20% or more (2)**	**No effect or Don't know (3)**
Project located in NYC (1)	O	O	O	O	O	O
Project located in Westchester County (2)	O	O	O	O	O	O
Project located in Long Island (3)	O	O	O	O	O	O
Project in other locations in NYS (4)	O	O	O	O	O	O
Utility customers (5)	O	O	O	O	O	O
Industrial customers (6)	O	O	O	O	O	O
Commercial customers (7)	O	O	O	O	O	O
Residential customers (8)	O	O	O	O	O	O

Municipal, Universities, Schools, or Healthcare customers (15)	O	O	O	O	O	O
System sizes 20% or more larger than primary use case (9)	O	O	O	O	O	O
When the system is designed to provide backup power (10)	O	O	O	O	O	O
When solar is included in the system (11)	O	O	O	O	O	O
When distributed generation is included in the system (12)	O	O	O	O	O	O
Other factors: (13)	O	O	O	O	O	O
Other factors: (14)	O	O	O	O	O	O

End of Block: Questions about secondary use cases and factors

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Start of Block: Closing

Is there anything about your experience completing DES projects in New York State that we have not discussed today, or that worked well or didn't work well, that you would like to convey to NYSERDA?

End of Block: Closing