Baseline Market Evaluation Metrics for Energy Storage

Final Report

Prepared for:

New York State Energy Research and Development Authority

Albany, New York

Jennifer Phelps
Dana Nilsson
Project Managers

Jason Doling
Energy Storage Program Manager

Prepared by:

Research Into Action, Inc.

Portland, Oregon

Jane S. Peters
Jun Suzuki

NYSERDA Report 17-## NYSERDA Contract 26276 November 2017

NYSERDA Record of Revision

Document Title
Baseline Market Evaluation Metrics for Energy Storage November 2017

Revision Date	Description of Changes	Revision on Page(s)
Add Date	Original Issue	Original Issue
12/20/17	Changed "Green Tech Media" to GTM Research per citing requirements	1-3, 4-5, 4-6

Notice

Table of Contents

List of Tables

List of Figures

1 Introduction

1.1 Program Description

Energy storage will play a critical role in achieving the State's renewable generation and greenhouse gas reduction objectives. Energy storage is a multi-faceted technology that cuts across many sectors, including clean energy production, energy efficiency, diverse types of customers and buildings, and established technologies as well as those still in development. The New York State Energy Research and Development Authority's (NYSERDA's) energy storage team's strategy is to target key barriers limiting distributed energy storage adoption.[1] Distributed energy storage refers to systems in the kW to multi-MW range located behind and in-front-of a customer's meter within the distribution and sub-transmission system, excluding bulk storage.

This report documents the first annual survey of conditions of the major cost components of deployed distributed energy storage systems in New York State (NYS), with an emphasis on soft costs. Contacts provided responses based on their 2016 activities in the energy storage market.

1.2 Summary of Evaluation Objectives, Method, and Findings

The primary purpose of this survey is to establish a baseline on granular soft cost data for distributed energy storage systems designed for managing load in New York State and how this varies based on use case, location, customer, or technology. While hardware costs are declining globally, soft costs are largely driven by local factors and are therefore well positioned for meaningful intervention by NYSERDA. NYSERDA is implementing this annual survey to track progress and to prioritize interventions. Table 1 and Table 2 below summarize the evaluation objectives, methodology, and key findings.

1 Clean Energy Fund (CEF) Investment Plan: Energy Storage Chapter and Renewable Optimization Chapter, August 1, 2016.

Table 1. Evaluation Objectives, Research Questions, and Summary Findings of Survey Data

Objective	Evaluation Question(s)	Data Source(s) & Analytic Method(s)	Findings from Survey of 2016 activity. The data is a high-level summary of the reported responses of 7 valid respondent electrochemical and thermal system vendors. Not all vendors were willing and/or able to provide data for each row.
Clean Energy Fund Investment Plan: Energy Storage Chapter			
Develop a reliable, detailed, NYS based estimate of current soft costs of distributed energy storage systems as a component of the total installed cost	What is the current cycle time for the permitting process?	Telephone-based survey of NYS energy storage vendors	6.5 – 12 months. Lower end for lead acid, and higher end for lithium ion. Permitting cycle time for thermal systems not reported.
Develop a reliable, detailed, NYS based estimate of current soft costs of distributed energy storage systems as a component of the total installed cost	Are there challenges with siting and permitting requirements?		A lack of shared understanding of the battery technology (lithium ion) and codes among the permitting staff.
Develop a reliable, detailed, NYS based estimate of current soft costs of distributed energy storage systems as a component of the total installed cost	How many alternative ownership models are being used?		85% of respondents offer third party ownership, and 70% offer options such as shared savings, performance contracts for site owned projects. No specific details of third party ownership agreements were obtained.
Develop a reliable, detailed, NYS based estimate of current soft costs of distributed energy storage systems as a component of the total installed cost	What is the percent conversion rate of prospective installations from proposal to installed projects?		Electrochemical: Min. 1%; 50% Max; 5% Median. Thermal: 66% based on vendor response.
Develop a reliable, detailed, NYS based estimate of current soft costs of distributed energy storage systems as a component of the total installed cost	What is the cycle time of projects from customer proposal to commissioning?		Electrochemical: 8.75 – 38 months. Median of 19.5 months. Thermal projects cycle time not provided.
Develop a reliable, detailed, NYS based estimate of current soft costs of distributed energy storage systems as a component of the total installed cost	What is the current estimate of soft costs of distributed energy storage systems?		Electrochemical: Min. $50/kWh; Max. $100/kWh (Median of 20% of average soft cost of installed lead acid systems). Thermal system costs not provided (Median of 16% of average soft cost of installed thermal systems).
Develop a reliable, detailed, NYS based estimate of current soft costs of distributed energy storage systems as a component of the total installed cost	What is the average total installed cost per kWh (4-hour duration) for energy storage systems?		$1,000/kWh for lead acid system. Other types of electrochemical systems were not installed by respondent vendors in NYS in 2016 and thermal system total installed cost data was not provided
Develop a reliable, detailed estimate of current hardware and hardware balance of system costs of energy storage systems	What is the current hardware cost for energy storage devices for NYS energy storage system vendors?		Lead acid system: $600-$650/kWh; 40-65% of the total cost. Thermal system 35-42% of the total cost (actual costs not provided).

Note: For detail cost boundaries, see Section 2.1.

Table 2. Evaluation Objectives, Research Questions, and Summary Findings of Secondary Data

Objective	Evaluation Question(s)	Data Source(s)	Cost Boundaries[a]	Findings of Secondary Data
Clean Energy Fund Investment Plan: Energy Storage Chapter				
Develop a reliable, detailed estimate of current hardware and hardware balance of system costs of energy storage systems	What is the current hardware cost for energy storage devices from Secondary Data?	GTM Research, Utility Dive, National Renewable Energy Laboratory (NREL) (National data from 2015-2016)	Supervisory control and data acquisition, (SCADA) controller, containerization, inverter	Lithium ion system[b] Hardware (excluding battery): $369-$380/kW Battery only: $350-$500/kWh
		PacifiCorp/DNV GL (National data from 2016)	SCADA controller, containerization, inverter, power control system, wiring, interconnecting transformer, additional ancillary equipment	Lithium ion system Hardware (excluding battery): $615/kW Battery only: $388-$675/kWh
				Other battery systems Hardware (excluding battery): $635-$858/kW Battery only: $300-$900/kWh
	What is the current hardware balance of system cost for energy storage systems including power electronics and hardware installation cost?	GTM Research, Utility Dive, NREL (National data from 2015-2016)	SCADA controller, containerization, inverter, EPC, soft costs	Lithium ion system $667-$670/kW
		PacifiCorp/DNV GL (National data from 2016)	Wiring, interconnecting transformer, additional ancillary equipment	Lithium ion system $100/kW
				Other battery systems $100-$120/kW
Clean Energy Fund Investment Plan: Renewable Optimization Chapter				
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.?	2015-2016 data unavailable. Most recent data available is from 2010-2011 and likely does accurately describe current battery performance.		

[a] For detail cost boundaries across data sources, see Table 11, Figure 1, and Figure 2 in Section 4.3.4.

[b] Secondary data sources report hardware, engineering, procurement and construction (EPC), and soft costs in kW and costs for the battery itself in kWh.

NYSERDA provided a draft survey instrument and list of contacts to interview based on its insights into current market activity in New York State. The evaluation team worked with NYSERDA and Sustainable City University of New York (CUNY) to modify the survey for implementation and finalize the list of contacts. The evaluation team programmed the final instrument for implementation as an interview/survey and conducted the interviews between March 3 and April 18, 2017. Table 3 displays the final survey disposition. The methods used to implement the survey are in Section 4. Appendix A contains the final instrument.

Table 3. Energy Storage Survey Disposition

Category	Number
Vendor companies identified	29
Vendor companies with completed interviews	26
Interviewed vendor companies with New York State installations	12
Interviewed vendors with valid responses about New York State installations*	7

(*) Valid responses are those that have completed projects in New York State and those that could report valid responses ("don't know," "confidential information," or "not applicable" responses were deemed invalid). The evaluation team considered these respondents have sufficient experience to provide reliable cost estimates.

2 Survey Results

This section summarizes the distributed energy storage system installation costs, cycle time, and value propositions for installed systems in New York State that were reported by the seven companies with valid responses. It is important to note that the data presented here represent perspectives of a small number of vendor companies and are not representative. However, all vendors included in this study have experience in distributed energy storage system installation in New York State. The selection criteria the evaluation team used was vendors that either installed or executed a contract to install a distributed energy storage system in 2016, and are selling systems primarily for load management (rather than primarily for backup/resiliency). Section 4.3 details company profiles and installation activities by these seven vendors.

To accurately summarize this small number of responses, while ensuring anonymity of the respondent companies, this report uses descriptive statistics such as minimum, maximum, and median (the middle value of the reported range of values). A valid response count is also included for each summary statistics to indicate the number of respondent companies that could provide a valid response.

2.1 Cost of Respondent Installed Systems

Table 4. Summary of Installed System Costs summarizes reported costs for installed distributed energy storage systems as reported by the seven respondents. For electrochemical systems, all the reported installed systems were lead acid technology, therefore, all the installed costs refer to installed cost for lead acid systems. At the same time, all the respondent companies with electrochemical systems reported they anticipate their primary system by 2020 will be lithium ion technology, therefore, the costs of anticipated primary system refer to lithium ion technology. The evaluation team asked about three types of installation costs – hardware, engineering and construction, and soft costs. They were defined as follows:

- Hardware costs: Costs of the battery modules, inverter, and balance of systems (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: Costs of design, site preparation, transportation, siting, Professional Engineer (PE) approval, testing and commissioning, electrician and installation labor, wiring, fencing, other overhead, etc.
- Soft costs: Costs of customer acquisition, permitting and interconnection, and financing.

Only two respondent companies that installed lead acid systems provided known installation costs. Both companies estimated the total average installation cost of their lead acid systems to be $1,000 per kWh, and their median average hardware, engineering and construction, and soft cost to be $625, $300, and $75 per kWh respectively. All of the electrochemical technology-focused companies estimated distributions of hardware, engineering and construction, and soft costs that were close in range – medians of 60%, 30%, and 20% respectively. Two thermal technology-focused companies estimated the distribution of these costs – medians of 39%, 46%, and 16% respectively.

The evaluation team further asked the distributions of various elements related to the soft costs. For the installed lead acid systems, four respondent companies estimated costs associated with customer acquisition and permitting to have the largest distribution of soft costs (medians of 38% and 28% respectively). Respondents recognize the cost of preparing documents for permitting, but they typically do not have a sense of having incurred costs while waiting for their permit to be approved. For example, one respondent said “the extra time to get approved permits is not increasing the soft costs because we are using the time to organize our plans, refine our bids and develop other projects. We have a large pipeline as a result and are ready to go once the permits start to be approved.” The long cycle time to obtain approved permit from submission, however, often causes operational challenges to most respondents.

Table 4. Summary of Installed System Costs

The table below reflects the responses received from the seven vendors during the survey. The "valid count" column identifies the number of the five electrochemical system vendors, and two thermal system vendors, that were willing and able to provide data for each row.

The minimum and maximum are the absolute minimum and maximum for the entire pool of valid responses for each question. The median is the middle of the sorted list of responses for each question.

Example: Pool of responses for % of average hardware cost of installed system = (65, 60, 60, 50, 40). Min = 40%, Max = 65%, and the median is 60%.

Cost is $/kWh	Electrochemical				Thermal			
	Valid count	Min	Max	Median	Valid count	Min	Max	Median
Total average cost of installed system	2	$1,000	$1,000	$1,000	0	-	-	-
Average hardware cost of installed system	2	$600	$650	$625	0	-	-	-
Current average hardware cost of anticipated primary system in 2020	2	$450	$520	$485	-	-	-	-
Average engineering and construction cost of installed system	2	$300	$300	$300	0	-	-	-
Average soft cost of installed system	2	$50	$100	$75	0	-	-	-
% of average hardware cost of installed system	5	40%	65%	60%	2	35%	42%	39%
% of average engineering and construction cost of installed system	5	20%	40%	30%	2	42%	50%	46%
% of average soft cost of installed system	5	5%	25%	20%	2	15%	16%	16%
% for customer acquisition	4	20%	50%	38%	1	100%	100%	100%
% for permitting	4	20%	50%	28%	1	0%	0%	0%
% for interconnection	4	0%	25%	10%	1	0%	0%	0%
% for financing	4	0%	40%	13%	1	0%	0%	0%
% for other	4	0%	20%	0%	1	0%	0%	0%

2.2 Cycle Time

The role of cycle time for different stages of the process helps define the source of soft costs. Respondent companies estimated cycle times for various stages of distributed energy storage system installation as shown in Table 5. While these stages were intended to be mutually exclusive, the responses suggest that the vendors did not always treat them as mutually exclusive, however, the median responses are the most meaningful statistics as a baseline.

Table 5. Summary of Cycle Time for Various Project Elements

The table below reflects the responses received from the seven vendors during the survey. The "valid count" column identifies the number of the five electrochemical system vendors, and two thermal system vendors, that were willing and able to provide data for each row.

The minimum and maximum are the absolute minimum and maximum for the entire pool of valid responses for each question. The median is the middle of the sorted list of responses for each question.

Length of time in months	Electrochemical				Thermal			
	Valid count	Min	Max	Median	Valid count	Min	Max	Median
Length of time for customer acquisition – initial engagement to proposal to contract execution	5	3	15	6	1	12	12	12
Length of time to prepare building/fire permit	4	0.25	14	2	0	-	-	-
Length of time to obtain approved permit from submission	3	6.5	14	12	0	-	-	-
Number of resubmission before gaining final approval (Number of times)	3	0	3.5	2	0	-	-	-
Length of time to obtain interconnection approval from application	3	1	3	1.5	0	-	-	-
Length of time from site contract execution to system commissioning	3	1	7	4	0	-	-	-

The longest cycle time across all soft cost elements is the time to obtain applicable fire and construction/electrical permits – a median of 12 months (particularly longer in New York City). Thermal system vendors did not report valid responses. Vendors reported a median of two months to prepare permits and a median of two resubmissions being requested. Interconnection permits took less than two months and the median time for construction from site contract to commissioning was four months.

In regards to the permit approval process, a few electrochemical-focused company respondents implied there is a lack of shared understanding of the storage technology among the staff involved in permitting, which is resulting in longer cycle times to obtain permits. One respondent mentioned the need to enhance jurisdictions' knowledge of the battery technology and code training – especially about lithium ion systems – in order to develop more distributed energy storage systems in the state.

2.3 Value Propositions

Table 6 summarizes monetary benefits offered to their prospective customers and how these values are proposed to them. All of the electrochemical technology-focused companies reported typically offering third-party ownership, demand charge management, and Demand Response (DR) payments as benefits. Distributed Generation (DG) integration and performance contracts were also commonly included benefits. A similar set of benefits are anticipated being included in 2020. When asked which were the most effective benefits for converting leads to sales, demand charge management received the highest count though vendors were largely unsure about the effectiveness of benefits for customer conversion.

Table 6. Monetary Benefits That Are Typically Included in Projects Designed by Responses, Anticipate Offering in 2020, and Most Effective for Conversion

	Electrochemical			Thermal		
	Typically included	Anticipated in 2020	Most effective	Typically included	Anticipated in 2020	Most effective
Valid count	N=5			N=2		
Investment tax credit	50%	25%	20%	50%	50%	0%
Third party ownership	100%	75%	0%	50%	50%	50%
Demand charge management	100%	75%	40%	100%	100%	50%
DR payments	100%	75%	20%	50%	50%	0%
DG integration	75%	75%	0%	50%	50%	0%
Non-wires alternative services	50%	50%	20%	50%	50%	50%
Shared savings, benefits, performance contract	75%	50%	0%	0%	0%	0%
Other benefits	25%	50%	0%	0%	0%	50%

Additionally, 80% of the electrochemical technology-focused companies (4 of 5) reported they offer financing as shown in Table 7. When asked to estimate the percent of New York State customers that use financing for distributed energy storage projects, the respondents reported a median of 43% of their customers use financing but the range of responses from 10% to 100%

suggest that there are a variety of factors affecting decisions to use financing. Respondents agreed that financing would typically reduce upfront costs for the customer, but its effect on the time required for customer acquisition varied (40% increased, 20% the same, and 40% decreased).

Table 7. Financing Offers

The table below reflects the responses received from the seven vendors during the survey. The "valid count" column identifies the number of the five electrochemical system vendors, and two thermal system vendors, that were willing and able to provide data for each row.

The minimum and maximum are the absolute minimum and maximum for the entire pool of valid responses for each question. The median is the middle of the sorted list of responses for each question.

	Electrochemical				Thermal			
	Valid count	Min	Max	Median	Valid count	Min	Max	Median
Does your company offer financing?	5	Yes (80%) No (20%)			0			
% of New York State customers using financing	4	10%	100%	43%	0	-	-	-

3 Findings and Recommendations

3.1 Finding 1

This baseline survey conducted between March-May 2017 identified many more distributed energy storage projects in the pipeline for New York State than have been installed. The cycle time for distributed energy storage approvals exceeds two years and it is therefore difficult to predict the number of pipeline projects that will be installed. These data support the assumption that there are delays in distributed energy storage installation in New York State.

3.1.1 Recommendation 1

The survey should be conducted at intervals to track progress of the initiative in overcoming the barriers to installation of distributed energy storage systems.

3.2 Finding 2

The baseline survey sought to identify costs for three factors: 1) hardware, 2) engineering, design, and construction, and 3) soft costs. Respondents reported that they typically did not have a sense of having incurred 'costs' for permitting of their projects beyond those associated with preparing construction and design documents. Rather, they indicated that the 'cycle time' of the permit process was causing them difficulties and potentially driving them to pursue business outside of New York State. Others noted that the delay did not add cost as they continued to generate projects for their pipeline, in anticipation that the permitting process would improve. Thus, the effect on project costs was low, though the cycle time for the permits was unacceptably high to many of them.

3.2.1 Recommendation 2

Use cycle time as the metric for the effect of permitting on soft costs, rather than a dollar value.

4 Methods

This section describes the development of the survey and list of vendors, the methods used for data collection, and the analysis methods used to provide the estimates of distributed energy storage project activities.

4.1 Survey and List Development

- NYSERDA and CUNY developed a draft survey instrument and provided the draft survey and list of distributed energy storage vendors to Research Into Action. Research Into Action provided comments on the instruments and requested clarification on the intention behind some questions. These were resolved during discussions with initiative staff and the evaluation lead for NYSERDA. The final instrument is provided in Appendix A.
- The list of vendors included contact names, email addresses and phone numbers for most vendors. Research Into Action requested assistance from NYSERDA and CUNY to complete missing contact names, emails, and phone numbers, and did internet research where possible. The list of vendors, without contact information, is provided in Appendix B.

4.2 Data Collection

The research team sent at least two email invitations to each vendor contact with up to five follow-up phone calls to attempt to reach the contact and schedule an appointment. Three senior staff at Research Into Action conducted the interviews between March 3 and April 18, 2017.

Among the 29 vendors, one refused to participate due to inactivity in New York State, one vendor had a specialty energy storage product that did not qualify, and one vendor was unreachable after multiple attempts. The team obtained 26 completed interviews, with seven interviews determined to be valid responses with experiences of installed distributed energy storage projects in New York State.

4.3 Analysis

The team implemented the survey using Qualtrics, and downloaded the data for analysis in Excel. The team used open-ended responses to capture estimates and situations where respondents noted a range of sizes and types of equipment, which were coded to be a single response.

The team reviewed the responses, without identifying the respondent, with the NYSERDA initiative staff. NYSERDA reviewed the responses and aided in identifying valid and invalid responses. This review resulted in the determination that seven responses were valid. The data for these respondents was totaled, and minimum and maximum limits as well the median values were calculated for the variables.

4.3.1 About the Seven Respondent Companies

This section (4.3.1 to 4.3.3) summarizes the seven respondent companies that provided valid responses and their installation activities. As Table 8 shows, among the seven respondent companies that provided valid responses, five companies focus on electrochemical technologies and two focus on thermal technologies. These seven companies appear to have relatively small operations in New York State as suggested by the number of employees engaged in distributed energy storage projects – median of four employees among companies with electrochemical technologies and median of one employee among the companies dealing with thermal technologies. These companies report energy storage activities in the U.S. (except for the Midwest) and internationally, however, electrochemical companies in particular report highly concentrated portfolios in New York State (median of 80%), especially in New York City (NYC) (95% of the NYS portfolio).

Table 8. Respondent Companies Profiles

Technology type		Electrochemical	Thermal
Respondent count		**N=5**	**N=2**
Number of employees (Total in NYS | NYS employees doing distributed energy storage)	Minimum	32 | 0	20 | 1
	Maximum	130 | 8	45 | 1
	Median	55 | 4	33 | 1
	Sum	337 | 19	65 | 1
Count of companies, active in distributed energy storage in each regional market	West	3	1
	Southwest	1	1
	Midwest	0	0
	Southeast	0	1
	Northeast	5	2
	Outside U.S.	2	2
% of companies distributed energy storage portfolio (NYS of all | NYC in NYS)	Minimum	1% | 10%	1% | 80%
	Maximum	100% | 100%	1% | 100%
	Median	80% | 95%	1% | 90%

4.3.2 Installed Systems in New York State in 2016 by the Seven Respondent Companies

Table 9 summarizes the installed systems in New York State in 2016 among the seven respondent companies. All the electrochemical systems installed in New York State in 2016 used lead acid technology. Companies reported a total of 17 electrochemical installed systems with a median capacity of 54 kW or 207 kWh. Ten of these systems were paired with DG or solar components. Most of the respondents pairing with DG said the DG system was already in place and that is why they targeted their sales to those customers. Two companies that reported installing two thermal systems in New York State in 2016, with a median capacity of 1,000 kW or 6,000 kWh. There was no valid response regarding thermal projects paired with DG or solar. The companies that installed electrochemical systems reported a median of 25% of their New York State projects (50% of their projects in North America) were partially or fully funded by utility, state, or municipal incentive programs.

Table 9. Summary of Installed Systems in New York State in 2016 by the Seven Respondent Companies

Technology Type	Electrochemical					Thermal				
	Valid Count	Min	Max	Median	Sum	Valid Count	Min	Max	Median	Sum
Total number of projects	5	0	10	1	17	2	0	2	1	2
Total project size (kW)	3	100	1000	500	1600	0	-	-	-	-
Total project size (kWh)	1	2000	2000	2000	2000	0	-	-	-	-
Average project size (kW)	2	7	100	54	107	1	1000	1000	1000	1000
Average project size (kWh)	2	14	400	207	414	1	6000	6000	6000	6000
Lead acid project count	3	1	10	5	16	1	0	0	0	0
Lithium ion project count	3	0	0	0	0	1	0	0	0	0
Thermal project count	3	0	0	0	0	1	2	2	2	2
Project count that included DG/solar	3	0	10	0	10	0	-	-	-	-

4.3.3 New York State Projects in Pipeline since January 2016 by the Seven Respondent Companies

Table 10 summarizes the reported projects in the pipeline for New York State since 2016 by technology type. The respondent companies reported a large volume of projects in the pipeline since 2016 that are yet to be installed. The five electrochemical-focused companies reported a total of 252 projects in pipeline with average project size ranging from 7 kW to 250 kW, and the two thermal technology-focused companies reported a total of six projects in pipeline. Though all the projects the electrochemical-focused companies installed in 2016 were lead acid systems, the majority of their pipeline projects (approximately 75%) are lithium ion systems. About half of these pipeline projects (46%) are DG- or solar-integrated systems. Among the electrochemical-focused companies, the median conversion rate (percent of New York State customers that have received proposals since January 2016 and have executed contracts) was 5%.

Table 10. Summary of New York State Projects in Pipeline since January 2016 by the Seven Respondent Companies

	Electrochemical					Thermal				
	Valid count	Min	Max	Median	Sum	Valid count	Min	Max	Median	Sum
Total number of projects	5	2	200	20	252	2	1	5	3	6
Total project size (kW)	4	200	25000	950	27100	1	15	15	15	15
Total project size (kWh)	1	1450	1450	1450	1450	1	21000	21000	21000	21000
Average project size (kW)	3	7	250	200	457	1	15	15	15	15
Average project size (kWh)	3	14	1000	60	1074	0	-	-	-	-
Lead acid project count	4	0	50	10	70	1	0	0	0	0
Lithium ion project count	4	10	150	13.5	187	1	0	0	0	0
Thermal project count	4	0	0	0	0	1	1	1	1	1
Project count with DG/solar	4	1	75	20	116	1	0	0	0	0
Conversion rate	4	1%	50%	5%	-	1	66%	66%	66%	-

4.3.4 Secondary Data Analysis

The evaluation team used the following sources for secondary data on installation costs and current performance levels of variety of distributed energy storage technologies. Secondary data represents cost information of energy storage projects completed nationally, unless noted otherwise:

- Utility Dive (2016). *Bigger than batteries: Why the cost of other components matters to storage deployment*. *http://www.utilitydive.com/news/bigger-than-batteries-why-the-cost-of-other-components-matters-to-storage/411827/*
- GTM Research (2016). Grid-scale Energy Storage Balance of Systems 2015-2020.
- NREL (2016). NREL Battery Commercial System Cost Model Excel Workbook.
- PacifiCorp (2016). *Battery Energy Storage Study for the 2017 IRP*. *http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Integrated_Resource_Plan/2017_IRP/10018304_R-01-D_PacifiCorp_Battery_Energy_Storage_Study.pdf*.

Table 11 summarizes the cost breakdown of distributed energy storage systems found in several secondary sources. It should be noted that different sources use different cost boundaries to report costs as illustrated in Figure 1. For instance, GTM Research/Utility Dive/NREL report costs of inverter, containerization, and controller independently as hardware costs, while PacifiCorp/DNV GL report costs of these three components as a whole as well as including costs of power control, wiring transformer, and other ancillary equipment as hardware. Secondary sources also categorize cost related to permitting in EPC cost, while the survey included this as a part of soft cost. Additionally, Figure 2 illustrates how each data source conceives BOS cost differently – for example PacifiCorp/DNV GL includes costs of wiring, transformer, and other ancillary equipment in BOS cost, while GTM Research/Utility Dive/NREL considers all cost components except the cost of battery itself to be the BOS cost. All secondary sources report all cost components in kW except the cost of battery itself. They report costs of battery in kWh.

Table 11. Cost Breakdown of Distributed Energy Storage Systems, by Secondary Data Source

Data Source[a]	Battery Technology	Battery Costs ($/kWh)	Hardware Costs ($/kW)						Soft Costs ($/kW)[c]	EPC Costs ($/kW)[d]	System cost ($/kW; excluding battery)
			SCADA Controller	Container-ization	Inverter	Power Control System	Other[b]	Total			
GTM Research and Utility Dive[g]	Li-Ion	$350	$40	$160	$180	--	--	$380	$170	$120	**$670**
NREL[f]	Li-Ion	$500	$36	$53	$280	--	--	$369	$176	$122	**$667**
PacifiCorp/ DNV GL[e]	Li-Ion NCM	$388	$425			$90	$100	$615	--	$141	**$756**
	Li-Ion LiFePo	$438	$425			$90	$100	$615	--	$141	**$756**
	Li-Ion LTO	$675	$425			$90	$100	$615	--	$141	**$756**
	NaS	$900	$625			$113	$100	$838	--	$170	**$1,008**
	VRB	$600	$625			$113	$120	$858	--	$170	**$1,028**
	ZnBr	$625	$625			$113	$120	$858	--	$170	**$1,028**
	Zinc-air	$300	$425			$90	$120	$635	--	$141	**$776**

[a] Sources: (1) Utility Drive (2016). Bigger than batteries: Why the cost of other components matters to storage deployment. http://www.utilitydive.com/news/bigger-than-batteries-why-the-cost-of-other-components-matters-to-storage/411827/ (2) GTM Research (2016). Grid-scale Energy Storage Balance of Systems 2015-2020. (3) NREL (2016). NREL Battery Commercial System Cost Model Excel Workbook. (4) PacifiCorp (2016). Battery Energy Storage Study for the 2017 IRP. *http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Integrated_Resource_Plan/2017_IRP/10018304_R-01-D_PacifiCorp_Battery_Energy_Storage_Study.pdf*

[b] Includes wiring, interconnecting transformer, and additional ancillary equipment.

[c] Includes interconnection, overhead, and customer acquisition.

[d] Includes design, site preparation, transportation, permitting, electrician and installation labor, testing and commissioning, fencing, other overhead.

[e] Reported values for grid-scale, front-of-the-meter systems available down to 1 MW. Maximum of 50 MW, Page 15. Geographic location unspecified.

[f] California Commercial behind-the-meter systems modeled: 500 kW, 2 hr. duration, Columns C-E, Battery Storage worksheet.

[g] Grid-scale, front-of-the-meter (100 kW or larger) that require similar balance-of-system infrastructure. Page 9. Geographic location unspecified.

Figure 1. Cost Boundaries for Distributed Energy Storage by Data Source

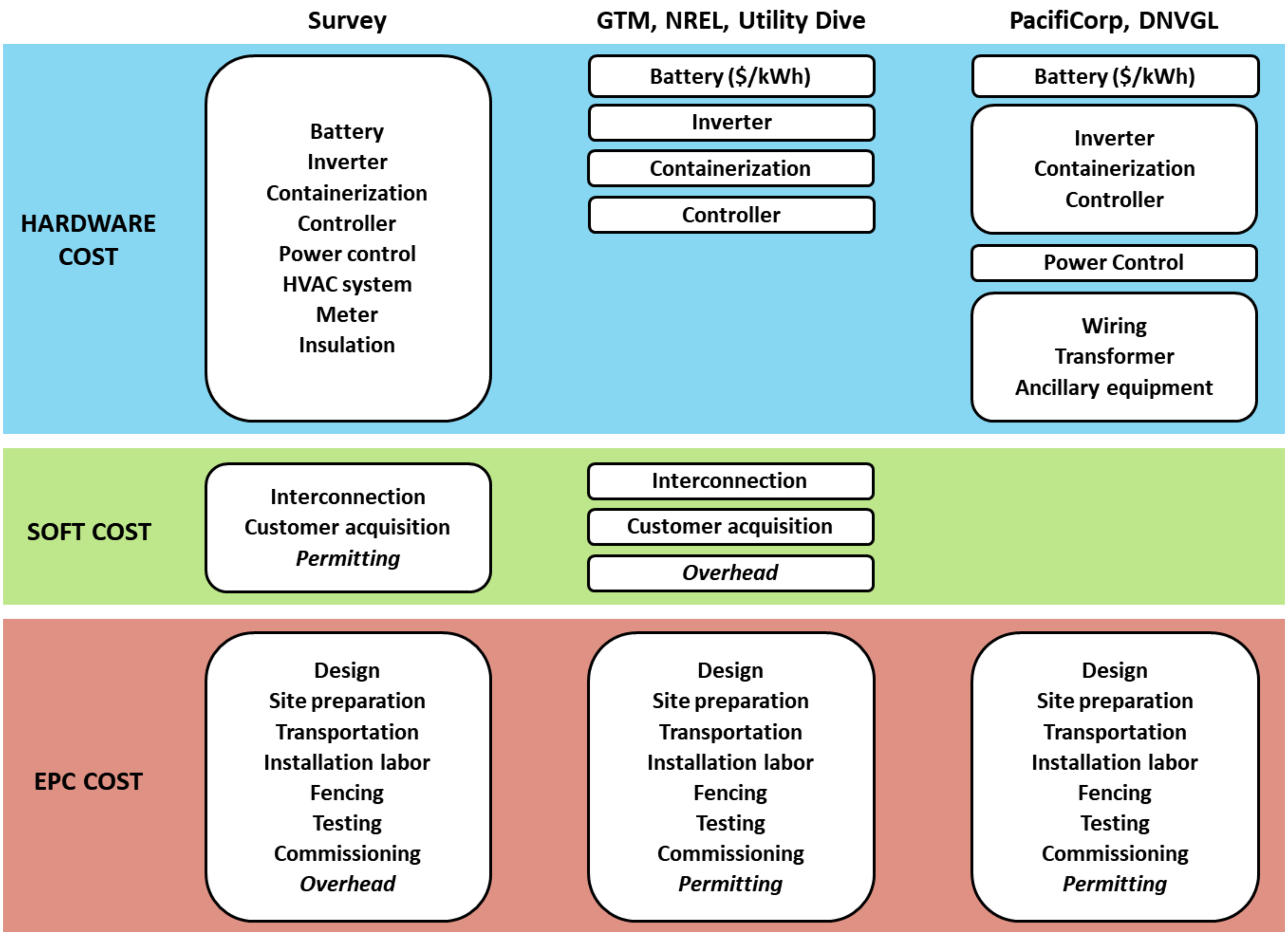
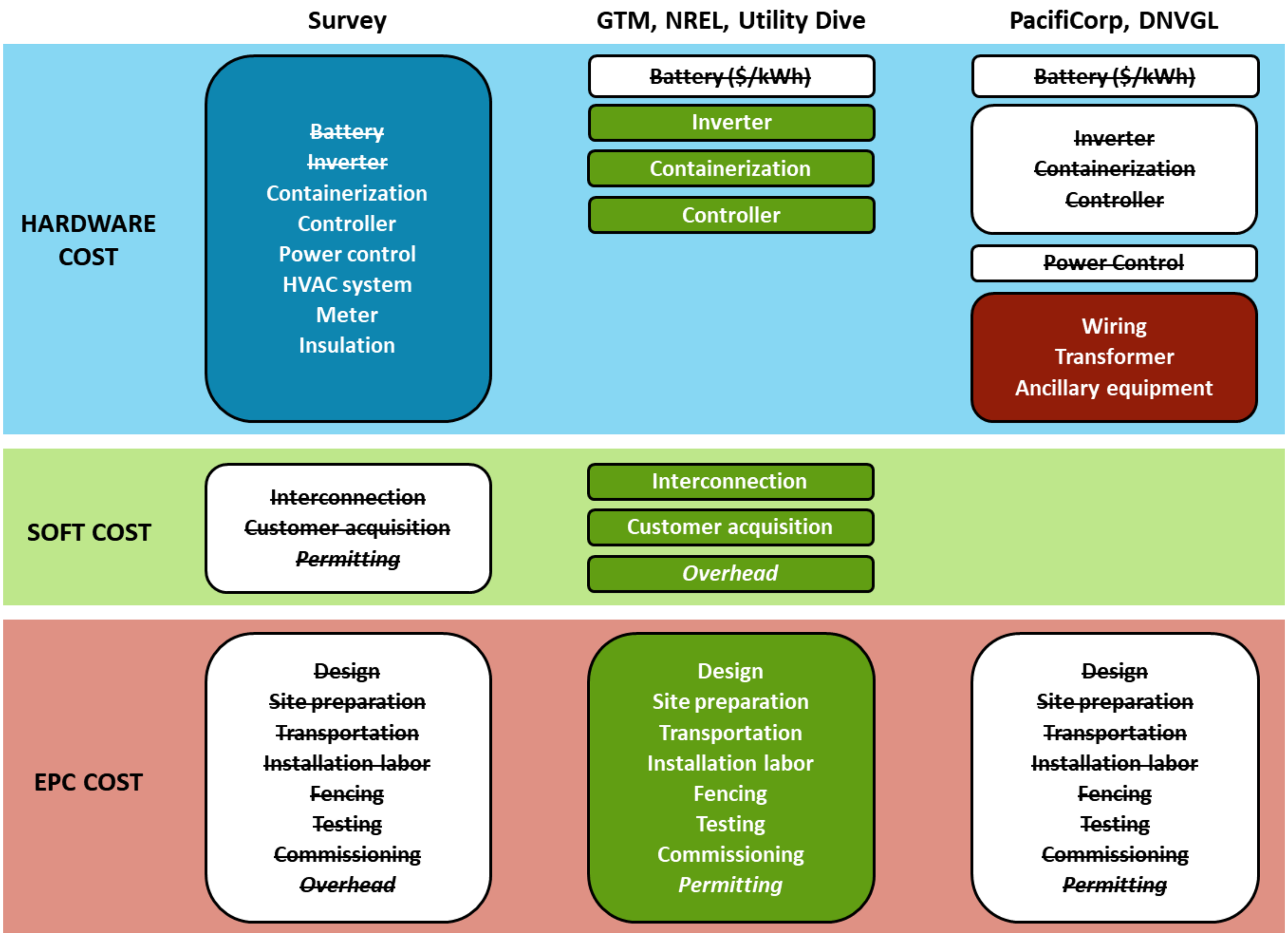


Figure 2. Defining the Balance of Systems (BOS) Cost



Note: The colored components are included in the BOS cost in each source.