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Battery Energy Storage System Technology Market Scan

Prepared for:

Liberty Utilities (Granite State Electric) Corp.

New Hampshire Battery Storage Aggregation Program Pilot

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Background

Liberty Utilities engaged Alectra Energy Solutions to undertake an environmental market scan of available prominent residential storage technologies that can be located behind the meter and that can be, as grid assets, effectively aggregated and controlled for the purpose of providing a variety of functions. Alectra analyzed integrated battery energy storage systems ("BESS") that integrated components from one or several manufacturers, as well as stand-alone components from different manufacturers that could be combined to make a complete system.

This report provides a general overview of the residential energy storage market through tightly defined product comparison criteria, and provides comparison tables for products/features from various vendors. It also provides pricing information. Tesla's pricing information was provided directly to Liberty Utility by Tesla and is very favorable when compared with other companies providing similar solutions. However, we would expect that if a formal RFP process is pursued, pricing for other companies would improve.

Executive Summary

This report provides a general overview of the residential energy storage market through tightly defined product comparison criteria, and includes comparison tables for products/features from different vendors. Two types of storage systems were explored: integrated systems with components from one or several manufacturers, and stand-alone components from different manufacturers that could be combined to make a complete system.

A combination of public resource desk research and manufacturer outreach was used in order to substantiate the findings. The criteria specific pros and cons of each system/component are summarized, price and energy capacity of products, as available, are noted, and conclusions of the market scan are presented.

Taking into consideration technical merits and warranty conditions, as well as cost and software capabilities, Tesla's Powerwall 2 appears to have the most appropriate solution to meet Liberty Utilities' needs. It is extremely important to note, however, that many of the product's software control capabilities were impossible to evaluate directly, as the aggregation platform (marketed as GridLogic) has yet to become publicly available and is still under development. Also, due to the small volume of deployments, it is uncertain whether or not Tesla has an accurate view of the actual installation costs that are involved with a deployment of this scale. As a result, it is difficult to ascertain the level of confidence with which the initial cost estimates can be interpreted.

Aside from Tesla, [redacted] and [redacted] appear to have the most appropriate complete and evolved battery systems for North American needs, as well as a more proven track record of deployments. Their software platforms have also been in production for several years and are currently used to manage a significant asset base.

A more detailed study is required to assess the flexibility level of control features associated with the different products/systems surveyed in order to enable aggregation of resources for utility and/or energy market application needs.

Introduction

Liberty Utilities currently has approximately 43,000 electric customers in New Hampshire, including in areas that are progressive in renewables such as the southern part of the state and in areas close to and including Dartmouth College in Hanover and Lebanon.

Liberty Utilities (Granite State Electric) Corp. is desirous to deploy and implement a Battery Storage Aggregation Program ("BSAP") pilot which will benefit the customers of Liberty Utilities by being able to act as a local backup power supply, while Liberty Utilities is able to deploy energy stored in customers' batteries for use cases that are beneficial to the customer base.

Liberty Utilities has held informal discussions with the NH Public Utilities Commission ("NH PUC") and intends on November 30th, 2017 to submit a rate filing for approval of a pilot program for installation of 5MW of battery storage in 1,000 customer's homes.

Pilot Objective

The BSAP pilot will help Liberty Utilities address rising ISO-New England transmission costs by allowing the utility to discharge their fleet of batteries during peak periods. Customers will receive the benefit of Liberty Utilities discharging the batteries during peak periods as to reduce the utility's share of transmission costs at the peak, which are passed on to all customers. It is envisioned that as the market and regulations evolve, the total aggregate capacity and capability may be expanded.

As part of the pilot, Liberty Utilities will market to customers the opportunity to have these batteries in their homes to be used as needed up to a predetermined portion of capacity (perhaps 30%), and as backup generation during power outages. Liberty Utilities will provide the customer with the option to pay a portion of the battery upfront, or a monthly charge on their bill for a period of years, but the Utility will maintain ownership of the battery. Liberty will draw on the batteries as needed, and as compensation to the customer, Liberty will credit the customer the net metering credit applicable for every kilowatt-hour exported when the Liberty has taken control; customers who pay an upfront contribution will receive the same credit). Liberty Utilities wants the batteries to be accessible to customers up to their predetermined capacity allowance at all times, unless there is a predicted peak. Prior to the peak day, the Company wants to temporarily block the customer's control access to the battery at a designated time (such as midnight the prior day). The battery would then be charged be in preparation for a dispatch command sent at the peak period the following day. Once the peak has occurred, the Company wants to allow the customer control access for the battery again. Customers will always have visibility into the batteries during power outages. Customers in NH will want access to their batteries as often as possible, as will the NH PUC.

System Topologies

There are different topologies for battery energy storage systems (BESS) which can be implemented based on customer and/or grid needs and conditions.

Integrated Model

BESS' come in a variety of designs, chemistries and form factors. The focus here is on Li-Ion systems. The key pieces are the

1. Battery Modules: this houses the Li-Ion cells together with the battery management system (BMS)
2. Power Conversion System (PCS): This converts AC power to DC power in order to charge the battery and converts DC power from the batteries to AC power to feed the grid/on-site loads.
3. Local controller/edge device: A system (usually a hardened computer) that controls all the components on site and is responsible for both the optimization of local operation, responding to external commands as well as ensuring that the BESS operates within its operational envelope
4. Enclosure and Balance of System (BOS): The enclosure both protects the system from external damage as well as insulated the home from the BESS. It also houses thermal management equipment and serves to anchor the BESS to the floor or wall. In addition, other equipment like disconnect switches and protection devices may also be required.

Optional equipment such as a DC charge controller may be added. This device allows direct connection of DC solar panels to the BESS. In a DC-coupled solar battery system the solar PV and the battery energy storage are coupled on the DC side. The PCS can use this energy to charge the batteries or the inverter inside the PCS can convert this to AC power that can be used to off-set onside loads or can be sold to the utility grid for a bill credit. A hybrid inverter equipped PCS has the ability to isolate from the main grid and still power up house loads.

Figure 1 shows the block diagram of a hybrid inverter/charger. The PV or/and the battery energy storage can feed the DC input. Critical loads are connected to the output of this hybrid inverter/charger and will be continuously supplied in either the grid-connected mode or stand- alone mode. The nonessential loads are only connected to the main electrical panel in the house and will not be supplied when the grid is disconnected. In addition, there are two inputs which come from the grid and an auxiliary AC generator. Some hybrid inverter/charger products do not have the second AC input for the auxiliary AC generator. This auxiliary AC input can charge the battery and supply the critical loads when the grid is disconnected and the PV cannot generate the rated power (due to cloudy weather). Figure 2 illustrates the single line diagram of a DC-coupled solar/battery system. The hybrid inverter/charger block in this figure is the same as Figure 1. The controls of the hybrid inverter/charger system allow operation in two modes explained below:

Utility Grid Connected Mode or PQ Mode

This is the active and reactive power (PQ) operation mode of the system with the utility grid connected. In this mode, the utility grid is operational while the critical loads can be supplied by both the grid and the PV/battery based on the EMS program.

Islanded Mode or Vf Mode

In this mode, both the voltage and frequency are regulated by the hybrid inverter/charger. When the utility grid is disconnected, the internal transfer controls sense the outage and the transfer switch will operate. In this condition, the switch for utility grid input will open and critical loads are supported just by PV/battery.

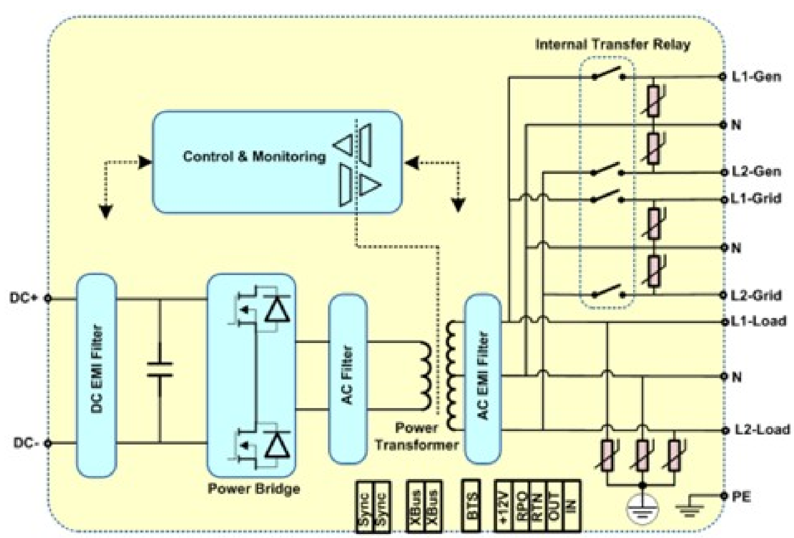

Figure 1 : Block diagram of a typical hybrid inverter/charger (Conext XW+ hybrid inverter / charger Owners' Guide)

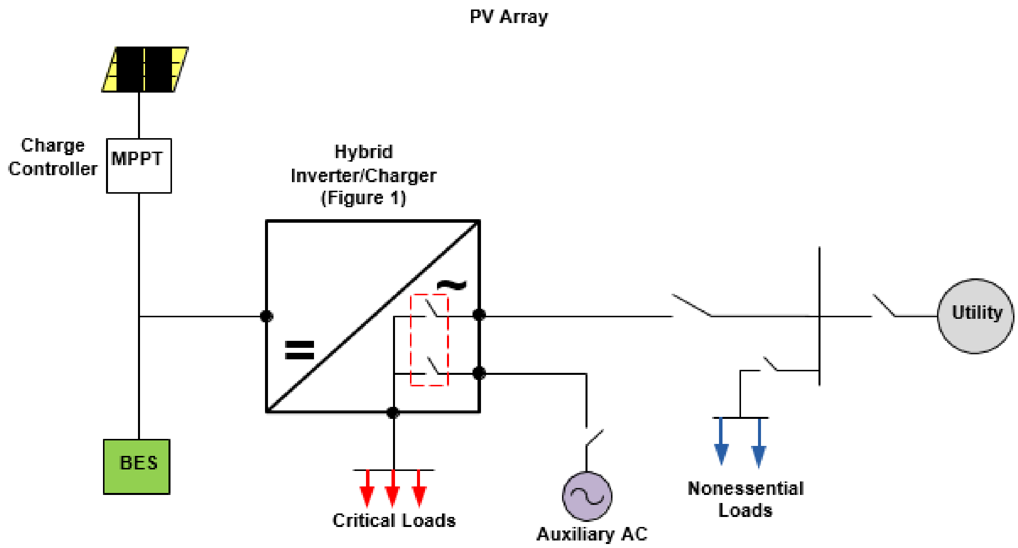

Figure 2 : Single line diagram of a DC-coupled solar/battery system

Separate Connection

In the topology shown in Figure 3, the solar PV and the energy storage are connected to separate inverters and then are coupled to feed the residential loads or, in case of surplus power, to sell the power to the utility. This topology is more suited for existing applications of PV roof-top installations and, in addition, has the potential to provide higher reliability by decoupling energy storage from solar PV. The operation of this topology is as follows:

- In the utility grid connected mode, switch S1 is connected to switch S2, switch S3 is connected to the hybrid inverter/charger bus corresponding to the islanded mode.
- When the utility grid supply is lost, S2 disconnects from S1 and establishes connection with S3. The critical loads are supplied by the solar PV and battery energy storage system. The hybrid inverter/charger of the BESS also senses the loss of the utility grid supply, its controller switches from the utility grid connected mode to the islanded mode regulating both the voltage and frequency.

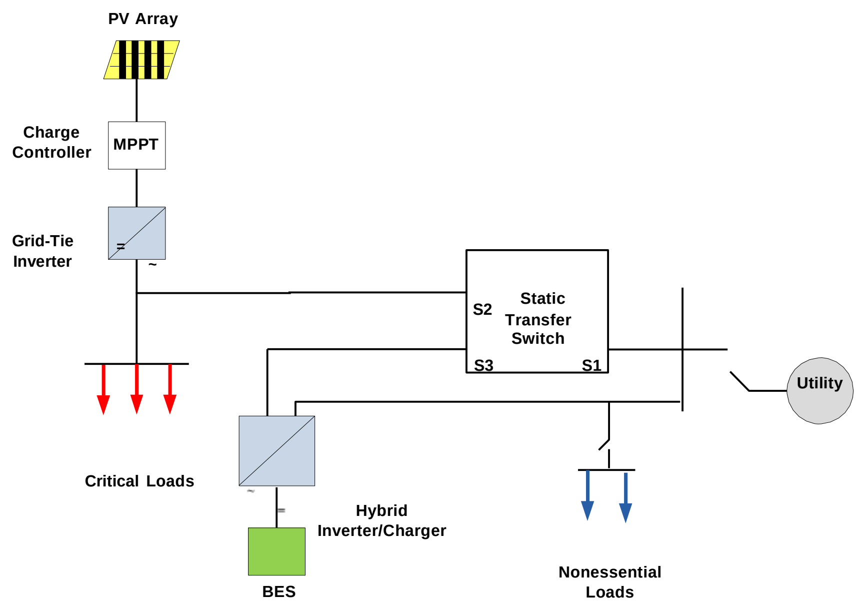

Figure 3: Topology of a typical AC-coupled system

Many developments in inverter technology and control as well as battery energy storage systems have occurred in the past couple of years with respect to their applications in the residential sector. Therefore, it is important to comprehensively study and compare the available technologies in the market.

Criteria for Market Scan

Manufacturers have begun to offer a diverse range of products in the field of residential battery systems. Some of them offer integrated systems as a packaged solution while others produce certain components such as battery energy storage, grid-tied inverters or hybrid inverter/chargers. Products offered by both types of companies are explored and quotes were requested in order to have the information needed for the study. Requests for quotes were sent to [redacted] suppliers around the world and [redacted] suppliers responded to the request.

In order to compare the various options in the market, Alectra jointly defined a set of criteria with Liberty Utilities that represent the most important functionality that such systems would be expected to provide. The following tables present standard definitions for these criteria, which are classified into hardware, software, operational, and standard.

Table 1: Hardware Criteria

Criteria	Definition
Grid Interactivity	The ability of the system in presence of battery storage to feed the essential loads while the main grid is down
Battery Voltage < 600 VDC	Battery storage voltage
Ability to Bypass	Allowing the load to be connected to the main supply without power interruption. It can be performed manually in case of maintenance and service or be automatically due to overload or internal failure.
Seamless Islanding	Avoiding power outages when the operational mode has a transition from grid-connected to islanded (IEEE 1547)
PCS 3KVA+	Power conditioning system (PCS) converts the energy storage medium from DC to AC or vice versa. It also regulates, stabilizes, and controls the power flow and improves the power quality
Energy Capacity	The amount of electric charge that can be delivered at the rated voltage
NEMA 3R Enclosure	A type of NEMA enclosures with specific degrees of protections which is appropriate for housing power distribution and can be used for either indoors or outdoors (https://www.nemaenclosures.com/enclosure-ratings/nema-rated-enclosures/nema-3r-enclosures.html)
Modularity/Scalability	Defined as the ability to modularly increase system size without upgrading the associated power electronics or system topology.
Form Factor	The needed footprint for installation of the system

Table 2: Software Criteria

Criteria	Definition
Communication through Home Internet	The ability of battery management system to communicate and be controlled and monitored through homeowner internet
Built-in Security	Avoiding additional software or tools to protect the data, programs, and performances
Virtual Power Plant (VPP)	The ability to communicate and be connected with other units and also to the central controller which dispatches all of them

Table 3: Operational Criteria

Criteria	Definition
Dynamic P Set-point	Changing the active power set-point dynamically for different reasons such as smoothing of fluctuations
PV Smoothing	Reducing the variability or fluctuations of PV output power by using battery storage which may be caused by changing weather
Peak Shaving	Reducing the amount of purchased energy from the main grid (for the customer) or wholesale markets (for the utility) during the peak demand
Reactive Power/Power Factor Set-point	Determining a set-point for reactive power or power factor

Table 4: Standards Criteria

Criteria	Definition
UL1741/IEEE 1547	UL 1741: Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources IEEE 1547: Standard for Interconnecting Distributed Resources with Electric Power Systems

Market Scan Results

In this section the assessment results from suppliers are presented. As mentioned earlier, two types of systems have been explored, (a) complete systems with components from one or several manufacturers, and (b) components from different manufacturers that could be combined to make complete systems. The results of the two key components, the battery and hybrid inverter/charger, are presented. Finally, some emerging devices in the market are introduced.

Integrated Systems

In integrated storage systems, all of the needed components are factory integrated and can be bought from a single supplier. This greatly simplifies the ease and efficiency of installation. Moreover, it can be ensured that compatible components are selected and connected and reduces integration risk. Tables 5 to 7 compare the criteria among [redacted] available suppliers offering integrated battery systems. The datasheet for each supplier can be found in Appendix A.

Table 5: Hardware Criteria Comparison for Complete Systems

Comparison Criteria	[redacted]	[redacted]	[redacted]	Tesla Powerwall 2
Grid Interactivity	✓	✓	✓	✓
Battery Voltage < 600 VDC	✓	✓	✓	✓
Ability to Bypass	[redacted]	[redacted]	[redacted]	?
Seamless Islanding	✓	✓	✓	✓
PCS > 3kVA	[redacted]	[redacted]	[redacted]	5.8 kVA
Energy Capacity > 6kWh	[redacted]	[redacted]	[redacted]	14 kwh
DC Integrated Solar	[redacted]	[redacted]	[redacted]	AC-coupled
NEMA 3R Enclosure	[redacted]	[redacted]	[redacted]	NEMA 3R – Indoor/outdoor
Battery Modularity	[redacted]	[redacted]	[redacted]	✓
Battery Scalability	[redacted]	[redacted]	[redacted]	14 kwh up to 140
Form Factor (WxHxD)	[redacted]	[redacted]	[redacted]	45.3”x29.7”x6.1”

Table 6: Software Criteria Comparison for Integrated Systems

Comparison Criteria	[redacted]	[redacted]	[redacted]	Tesla Powerwall 2
Communication through Home Internet	✓	✓	✓	✓
Cloud Data Storage	[redacted]	[redacted]	[redacted]	✓
Built-in Security	[redacted]	[redacted]	[redacted]	✓
Real Time EMS	[redacted]	[redacted]	[redacted]	?
Virtual Power Plant (VPP)	[redacted]	[redacted]	[redacted]	Yes, integrated with EMS

Table 7: Cost Comparison

	Tesla Powerwall 2	[redacted]	[redacted]	[redacted]
Battery Capacity (kwh)	13.5	[redacted]	[redacted]	[redacted]
Battery + PCS Cost	[redacted]	[redacted]	[redacted]	[redacted]
Installation (battery system alone)	[redacted]	[redacted]	[redacted]	[redacted]
Software License	[redacted]	[redacted]	[redacted]	[redacted]
Total	$7,400	[redacted]	[redacted]	[redacted]
Storage Cost /kwh (installed)	$548	$1,217	$1,698	$1,945
Total warranted kWh (1 cycle per day)	49,275	36,500	33,872	36,500
Storage Cost per Total warranted kWh (1 cycle per day)	$0.01	$0.03	$0.05	$0.05
# Systems Installed Worldwide	N/A	[redacted]	[redacted]	[redacted]

Table 8: Comparison of Pros and Cons of Available Integrated Systems

Product	Positive Points	Negative Points
[redacted]	• High quality battery • Established market player with very responsive support • Track record of success in [redacted] • Very good value for money • Scalable	• Heavy, difficult to maneuver, making installation difficult and limiting locations • No [redacted] • No proven long term reliability • Pay premium for battery quality
[redacted]	• High quality and [redacted] with long cycle life • Very mature technology and EMS • Volumes of field data make O&M and system support/configuration extremely predictable • Support is very well respected in the industry	• Low output power • Not designed as a utility owned product • Limited track record in [redacted] • Support evaluation based on industry reputation, not firsthand experience • Expensive • Indoor install only
Tesla Powerwall 2	• High marketing value. • Highly scalable and modular • Compact and lightweight, making installation flexible and cost effective • Extremely low cost • Turnkey service – installation, tier 2 support and warranty all provided by certified technicians	• Unproven technology with minimal points of reference for actual grid integration (originally designed as a behind the meter product) • While cost is attractive, it may be understated. Limited install experience may have Tesla underestimating complexity, which may result in overruns by the time commissioning is complete. • Software is largely unproven and SCADA integration unknown.
[redacted]	[redacted] year Warranty on all components • High brand name value • Easy install, modular configuration. • Good track record in [redacted] and established installation practices [redacted] • Strong technical design team [redacted] potential for major cost down	• Low power output compared to other lithium batteries • Warranty only covers [redacted] • Limited thermal tolerance requires indoor install • Battery degradation potential issue

Component Systems

There are many manufacturers producing residential battery energy storage systems across the world. This has resulted in a high level of competition within the market and placed severe pressure on manufacturers to reduce price while improving efficiency, reliability, capacity, and other important features. In this analysis, 8 batteries were investigated and their relative advantages and disadvantages were identified. Table 9 indicates a summary of these points. The detailed information related to these products is presented in Appendix B. Moreover, the price of each battery and price per kWh are tabulated in Table 10. All costs are presented in US dollars.

Table 9: Comparison of Pros and Cons of Available Energy Storage Systems

Product	Positive Points	Negative Points
[redacted]	• High quality [redacted] made • Complete off-grid management • Grid-tied battery backup • Peak shaving configuration • Time of use management • Grid export • Peak demand response • high [redacted] continuous discharge power	• Supported by a limited number of inverter manufacturers • Must be installed indoors
[redacted]	• High cycle life • High power output • The safest lithium chemistry • Integrated BMS	• Must be installed indoors • Requirement for a separate charge controller • High power output is limited by [redacted] • Large physical footprint
[redacted]	• [redacted] • Simple installation process • [redacted]	• No backup power capability • Additional component required for setup and monitoring • Low power output per module [redacted] • Must be installed indoors • High price per kWh of storage
[redacted]	• Integrated charger • [redacted]	• Low cycle life [redacted] • Supported by a limited number of inverter manufacturers
[redacted]	• [redacted] made high quality • Fast charging within 1 hour	• Supported by a limited number of inverter manufacturers • Must be installed indoor • [redacted]

Product	Positive Points	Negative Points
[redacted]	• Can be used in both off-grid and hybrid setups • Compact size • [redacted] • It can be mounted inside or outside • [redacted]	• [redacted] complicates the installation procedure increasing both component and installation costs.
[redacted]	• Safest Lithium Chemistry • Integrated BMS • Good cost-per-kWh	• Only [redacted] year warranty • Supported by a limited number of inverter manufacturers • No off-grid capability • Must be installed indoor
[redacted]	• Very high cycle life [redacted] • Safe, stable battery chemistry • Can be used in both off-grid and hybrid setups • [redacted] year warranty • Very high efficiency and cycle life • BMS integrated into each battery • Peak shaving	• Must be installed indoors • Relatively expensive

Table 10: Price Comparison of Available Battery Energy Storage Solutions

	Usable Capacity (kWh)	Price (USD)	Price/kWh (USD)	Available in North America
[redacted]	[redacted]	[redacted]	928	Yes
[redacted]	[redacted]	[redacted]	738	No
[redacted]	[redacted]	[redacted]	1,250	No
[redacted]	[redacted]	[redacted]	473	No
[redacted]	[redacted]	[redacted]	1,296	No
[redacted]	[redacted]	[redacted]	716	Yes
[redacted]	[redacted]	[redacted]	594	No
[redacted]	[redacted]	[redacted]	1,305	Yes

Conclusion

Based on the analysis performed and the requirements set forth by Liberty Utilities, Alectra Energy Solutions has reached the following conclusions:

- Integrated systems or all-in-one unit systems are the preferred technology options due to ease of installation and ongoing support compared to stand alone or component systems.

- Due to its nascent nature, understanding the capabilities of individual suppliers is difficult in this market, and requires a certain level of confidence in the integrity of the manufacturer as well as their experience level in practical deployments. As such our recommendations are predicated on the ability of Liberty Utilities to independently verify the costing and software functionality of any vendor that is ultimately selected for the pilot project.

- Based on reported pricing and software capabilities, it would appear that Tesla's Powerwall 2 product is the ideal technology for the BSAP program. It is advisable that Liberty Utilities ensure the following conditions are met prior to final vendor selection:

  1. A detailed bill of materials is provided for all installation components.
  2. A thorough review of the GridLogic software control platform is performed to ensure it meets the required functional capabilities necessary for Liberty Utilities to derive expected benefits.
  3. IT/OT integration analysis is performed to ensure the operations team at Liberty Utilities will have the tools and visibility required to adequately control and monitor the systems, and that adequate automation is built into the software such that dispatching assets is not overly burdensome.
  4. Installation criteria must be explicitly defined in advance in order to ensure installation volumes are met. This will prevent selective exclusion of residents by Tesla in order to meet their aggressive installation pricing targets.

- Both [redacted] and [redacted] offer comparable alternatives to Tesla, and should be carefully considered should any of the above conditions not be met.

Appendices

This part presents the datasheets of the systems and components that are investigated in the report.

Appendix A

In this section, the datasheet of the complete solar battery systems can be found.

Table 11: Datasheet of [redacted]

AC Input Output	
Nominal Frequency	[redacted]
Continuous Output Power	[redacted]
Max. Output Power	[redacted]
AC Input Voltage	[redacted]
Operating Output Voltage Range	[redacted]
Recommended AC Breaker Size	[redacted]
Total Harmonic Distortion	[redacted]
Automatic Transfer Relay Rating/Typical Transfer Time	[redacted]
Max. Efficiency	[redacted]
CEC Efficiency	[redacted]
DC Input (PV with MPPT 80 600)	
SCC Operating Range	[redacted]
Maximum PV Open Circuit Voltage	[redacted]
Maximum PV Short Circuit	[redacted]
Battery	
Type	[redacted]
Nominal Voltage	[redacted]
Energy Capacity	[redacted]
Feature/Function	
Certifications	[redacted]
Enclosure Protection Rating	[redacted]
Communication	[redacted]
Cooling	[redacted]
General Data	
Operating Temperature Range	[redacted]
Dimension (W/H/D)	[redacted]
Weight	[redacted]

Table 12: Datasheet of [redacted]

AC Input / Output	
AC Grid Voltage	[redacted]
Nominal Power at 25°C	[redacted]
Max. Grid Current	[redacted]
Nominal AC output Current	[redacted]
Nominal Frequency	[redacted]
Operating Frequency range	[redacted]
Battery	
Type	[redacted]
Input Voltage	[redacted]
Usable Energy Capacity	[redacted]
Max. Charge Current	[redacted]
Nominal Charge Current	[redacted]
Depth of Discharge	[redacted]
Full Cycle	[redacted]
Off-Grid	
Continuous AC Output Current	[redacted]
Max. Output Power (100 ms)	[redacted]
Max. Output Power (5 s)	[redacted]
Max. Output Power (30 m)	[redacted]
Feature/Function	
Grid Integration	[redacted]
Certifications	[redacted]
Warranty	[redacted]
Max. Efficiency	[redacted]
Cooling	[redacted]
Communication	[redacted]
Enclosure Protection Rating	[redacted]
General Data	
Dimension (W/H/D)	[redacted]
Weight	[redacted]
Operating Temperature	[redacted]

Table 13: Datasheet of [redacted]

DC Input (PV)	
Max. Open Circuit Voltage	[redacted]
Max. Input Power	[redacted]
MPPT Operating Voltage Range	[redacted]
Number of Independent MPPT	[redacted]
Battery	
Type	[redacted]
Usable Energy Capacity	[redacted]
AC Output (Grid-Tied)	
Nominal Power	[redacted]
Nominal Voltage	[redacted]
Operating Voltage Range	[redacted]
Operating frequency Range	[redacted]
Power Factor	[redacted]
Feature/Function	
Max. Efficiency	[redacted]
CEC Efficiency	[redacted]
Cooling	[redacted]
Enclosure Protection Rating	[redacted]
Certification	[redacted]
General Data	
Dimension (W/H/D)	[redacted]
Weight	[redacted]
Operating Temperature	[redacted]

Appendix B

The detail information of the battery energy storages are given here.

Table 14: Datasheet of [redacted]

Type	[redacted]
Energy Capacity	[redacted]
Usable Energy Capacity	[redacted]
Nominal Voltage	[redacted]
Voltage Range	[redacted]
Max. Charge Current	[redacted]
Max. Discharge Current	[redacted]
Max. Discharge Power	[redacted]
Efficiency	[redacted]
Depth of Discharge	[redacted]
Full Cycles	[redacted]
Built-in Inverter	[redacted]
Off-Grid Capability	[redacted]
Operating Temperature	[redacted]
Self-Discharge	[redacted]
Enclosure Protection Rating	[redacted]
Warranty	[redacted]
Communication	[redacted]
Scalability	[redacted]
Dimension (W/H/D)	[redacted]
Weight	[redacted]

***Table 15: Datasheet of* [redacted]**

Type	[redacted]
Energy Capacity	[redacted]
Nominal Energy Capacity	[redacted]
Nominal Voltage	[redacted]
Operating Voltage Range	[redacted]
Continuous Output Power	[redacted]
Max. Output Power	[redacted]
Depth of Discharge	[redacted]
Round-Trip Efficiency	[redacted]
Built-in Inverter	[redacted]
Communication	[redacted]
Enclosure Protection Rating	[redacted]
Warranty	[redacted]
Operating Temperature Rating	[redacted]
Scalability	[redacted]
Compatible Inverters	[redacted]
Dimension (W/H/D)	[redacted]
Weight	[redacted]

Table 16: Datasheet of [redacted]

Type	[redacted]
AC Output	
Nominal Voltage	[redacted]
Max. Output Voltage	[redacted]
Voltage Range	[redacted]
Continuous Output Power	[redacted]
Duration of Discharge at Rated Power	[redacted]
Nominal Frequency	[redacted]
Frequency Range	[redacted]
Power Factor	[redacted]
Max. Efficiency	[redacted]
CEC Efficiency	[redacted]
Battery	
Energy Capacity	[redacted]
Usable Energy Capacity	[redacted]
Nominal Voltage	[redacted]
Depth of Discharge	[redacted]
Round-Trip Efficiency	[redacted]
Full Cycle	[redacted]
Built-in Inverter	[redacted]
Off-Grid Capability	[redacted]
Operating Temperature Range	[redacted]
General Data	
Enclosure Protection rating	[redacted]
Scalability	[redacted]
Communication	[redacted]
Certification	[redacted]
Warranty	[redacted]
Dimension (W/H/D)	[redacted]
Weight	[redacted]

Table 17: Datasheet of [redacted]

Type	[redacted]
Energy Capacity	[redacted]
Usable Energy Capacity	[redacted]
Nominal Voltage	[redacted]
Voltage Range	[redacted]
Maximum Charging Voltage	[redacted]
Depth of Discharge	[redacted]
Continuous DC Current at 25° C	[redacted]
Peak Pulse DC Current at 10 s	[redacted]
Peak pulse DC Current at 100 ms	[redacted]
Efficiency	[redacted]
Built-in Inverter	[redacted]
Off-Grid Capability	[redacted]
Operating Temperature	[redacted]
Enclosure Protection rating	[redacted]
Scalability	[redacted]
Warranty	[redacted]
Expected Life Time	[redacted]
Communication	[redacted]
Compatible Inverters	[redacted]
Certification	[redacted]
Dimension (W/H/D)	[redacted]
Weight	[redacted]

Table 18: Datasheet of [redacted]

Type	[redacted]
Energy Capacity	[redacted]
Usable Energy Capacity	[redacted]
Nominal Voltage	[redacted]
Voltage Range	[redacted]
Depth of Discharge	[redacted]
Full Cycle	[redacted]
Round-Trip Efficiency	[redacted]
Nominal Charge Current	[redacted]
Max. Charge Current	[redacted]
Max. Discharge Current	[redacted]
Expected Life time	[redacted]
Built-in Inverter	[redacted]
Off-Grid Capability	[redacted]
Communication	[redacted]
Scalability	[redacted]
Warranty	[redacted]
Enclosure Protection Rating	[redacted]
Operating Temperature Range	[redacted]
Certifications	[redacted]
Dimension (W/H/D)	[redacted]
Weight	[redacted]

Table 19: Datasheet of [redacted]

Type	[redacted]
Energy Capacity	[redacted]
Usable Energy Capacity	[redacted]
Nominal Voltage	[redacted]
Voltage Range	[redacted]
Continuous Output Power	[redacted]
Max. Output Power	[redacted]
Depth of Discharge	[redacted]
Round-Trip Efficiency	[redacted]
Off-grid Capability	[redacted]
Operating Temperature Range	[redacted]
Warranty	[redacted]
Built-in Inverter	[redacted]
Off-Grid Capability	[redacted]
Scalability	[redacted]
Enclosure Protection Rating	[redacted]
Communication	[redacted]
Compatible Inverters	[redacted]
Certification	[redacted]
Dimension (W/H/D)	[redacted]
Weight	[redacted]

Table 20: Datasheet of [redacted]

Type	[redacted]
Energy Capacity	[redacted]
Usable Energy Capacity	[redacted]
Nominal Voltage	[redacted]
Voltage Range	[redacted]
Continuous Output Power	[redacted]
Peak Charge Power	[redacted]
Peak Discharge Power	[redacted]
Expected Life Time	[redacted]
Communication	[redacted]
Depth of Discharge	[redacted]
Full Cycles	[redacted]
Enclosure Protection Rating	[redacted]
Warranty	[redacted]
Built-in Inverter	[redacted]
Off-Grid Capability	[redacted]
Communication	[redacted]
Operating Temperature Range	[redacted]
Certification	[redacted]
Dimension (W/H/D)	[redacted]
Weight	[redacted]

Table 21: Datasheet of [redacted]

Type	[redacted]
Energy Capacity	[redacted]
Usable Energy Capacity	[redacted]
Nominal Voltage	[redacted]
DC Voltage Range	[redacted]
Max. Charge Current	[redacted]
Depth of Discharge	[redacted]
Full Cycles	[redacted]
Max. Efficiency	[redacted]
Self-Discharge Rate	[redacted]
Operating Temperature Range	[redacted]
Warranty	[redacted]
Scalability	[redacted]
Compatible Inverter	[redacted]
Built-in Inverter	[redacted]
Off-Grid Capability	[redacted]
Dimension (W/H/D)	[redacted]
Weight	[redacted]

Table 22: Datasheet of Tesla Powerwall 2

Type	Lithium-ion
Battery	
Energy Capacity	14 kWh
Usable Energy Capacity	13.5 kWh
Nominal Voltage	50 V
Continuous Output Power	5 kW
Max. Output Power	7 kW, 10 sec
Round-Trip Efficiency	90%
AC Output	
Nominal Voltage	120/240 V
Nominal Frequency	60 Hz
Continuous Output Power	5.8 kVA
Max. Output Power	7.2 kVA, 10 sec
General Data	
Warranty	10 years
Scalability	Up to 10 units
Certification	UL 1642, UL 1741, UL 1973
Operating Temperature Range	-20°C to 50°C
Enclosure Protection Rating	IP 67/ NEMA 3R
Built-in Inverter	Yes
Off-Grid Capability	Yes
Dimension (W/H/D)	755 / 1150 / 155
Weight	125 kg