McClellanville Battery Energy Storage Study

Central Electric Power Cooperative, Inc.

McClellanville Battery Energy Storage Study
Project No. 119928

Revision A
5/1/2020

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prepared for

Central Electric Power Cooperative, Inc.
McClellanville Battery Energy Storage Study
Columbia, South Carolina

Project No. 119928

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5/1/2020

prepared by

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1.0 INTRODUCTION

Central Electric Power Cooperative (CEPCI) retained Burns & McDonnell Engineering Company, Inc. (BMcD) to study the potential costs of battery energy storage systems (BESS) to support peak shaving and/or islanding use cases for the Awendaw circuit near McClellanville, South Carolina. The CEPCI McClellanville BESS Study (Study) is screening-level in nature and includes an analysis of two use cases and a comparison of BESS technologies that may be used to support those use cases. The BESS evaluation includes a review of technical features, capital cost, and operation and maintenance (O&M) characteristics.

It is the understanding of BMcD that this Study will be used for preliminary information in support of the Owner's long-term power supply planning process for the McClellanville area. Any technologies of interest to the Owner should be followed by additional detailed studies to further investigate each technology and its direct application within the Owner's long-term plans.

1.1 Revision A Update

The draft was report was issued in March 2020. In August 2022, CEPCI requested capital cost updates and applicable technology updates. Minor comments/edits from the draft report are addressed in Revision A, which is dated 5/1/2020 to align with the date of the original comments. Capital cost updates will be provided separately in a letter to CEPCI. The letter may reference this report, but the technology and cost data in Revision A is unchanged from the draft report in 2020.

1.2 Study Understanding and Purpose

The McClellanville area in northern Charleston County is served by Berkeley Electric Cooperative (BEC), a member of CEPCI. The Awendaw / McClellanville system is mostly residential loads, and due to electric heating, it generally peaks in the winter. The primary feed for the area is an overhead distribution line owned by Dominion Energy, Inc. (Dominion) with a metering point and recloser at the Awendaw MP substation. CEPCI has an agreement with Dominion that is limited to 120 A per phase at 24.9 kV.

There is a secondary 24.9 kV feed that may be used during planned or unplanned outages on the Awendaw circuit, or when the peak load is expected to exceed the Dominion contractual current limit. This backfeed is provided by the BEC Commonwealth circuit and the tie point between it and the Awendaw circuit is the Buck Hall DL recloser.

CEPCI is evaluating whether BESS technology could be economically and technically feasible for two use cases. The primary use case is peak shaving when loads approach or exceed the contractual current limits on the Dominion circuit. A secondary use case includes a larger BESS to accommodate the entire circuit in the event of an outage, commonly known as "islanding".

The purpose of this Study was to evaluate the BESS sizing to accommodate each use case and present cost and scope information to inform CEPCI long term planning for its customers. CEPCI identified a preliminary targeted useful life of seven years for a BESS installed by the end of 2020.

1.3 Study Approach and Objectives

To aid CEPCI in their development of technical and economic feasibility studies, this Study focuses on the following objectives:

- BESS sizing for two potential use cases
  - Peak shaving
  - Emergency grid backup (islanding)
- Scope and cost ranges for battery technologies to suit each use case
  - Lithium-ion technology
  - Flow battery technology
- Discussion of the potential interconnection costs and system impacts if battery technology is used for either use case

BMcD relied on load data and system information provided by CEPCI. Assumptions and clarifications were developed through correspondence with CEPCI stakeholders.

1.4 Statement of Limitations

All use case evaluations, BESS sizing information, and capital cost information provided in this Study are preliminary, intended to support technical and/or economic feasibility for the respective alternatives. They are not intended for and are not suitable for design or construction activities.

Estimates and projections prepared by BMcD relating to use case development, system performance, construction costs, operating and maintenance costs, and material compatibility are based on experience, qualifications, and judgment as a professional consultant. BMcD has no control over weather, cost and availability of labor, material and equipment, labor productivity, construction contractor's procedures and methods, unavoidable delays, construction contractor's method of determining prices, economic conditions, government regulations and laws (including interpretation thereof), competitive bidding and market conditions or other factors affecting such estimates or projections. Actual rates, costs, performance ratings, schedules, etc., may vary from the data provided.

2.0 STUDY BASIS

2.1 Study Basis

This section includes overarching assumptions that guided the BMcD Study. Additional assumptions and/or clarifying information related to use case alternatives may be included in the respective sections related to that information.

The scope of the Study focused on the primary objectives and approach outlined in the previous section. BMcD' s baseline understanding of the Awendaw distribution system information provided by CEPCI, including the documents listed below (presented in no particular order).

This Report assumes that the reader has a technical familiarity with the Awendaw and Commonwealth/Buck Hall circuits, as well as a general understanding of battery storage technology uses and limitations.

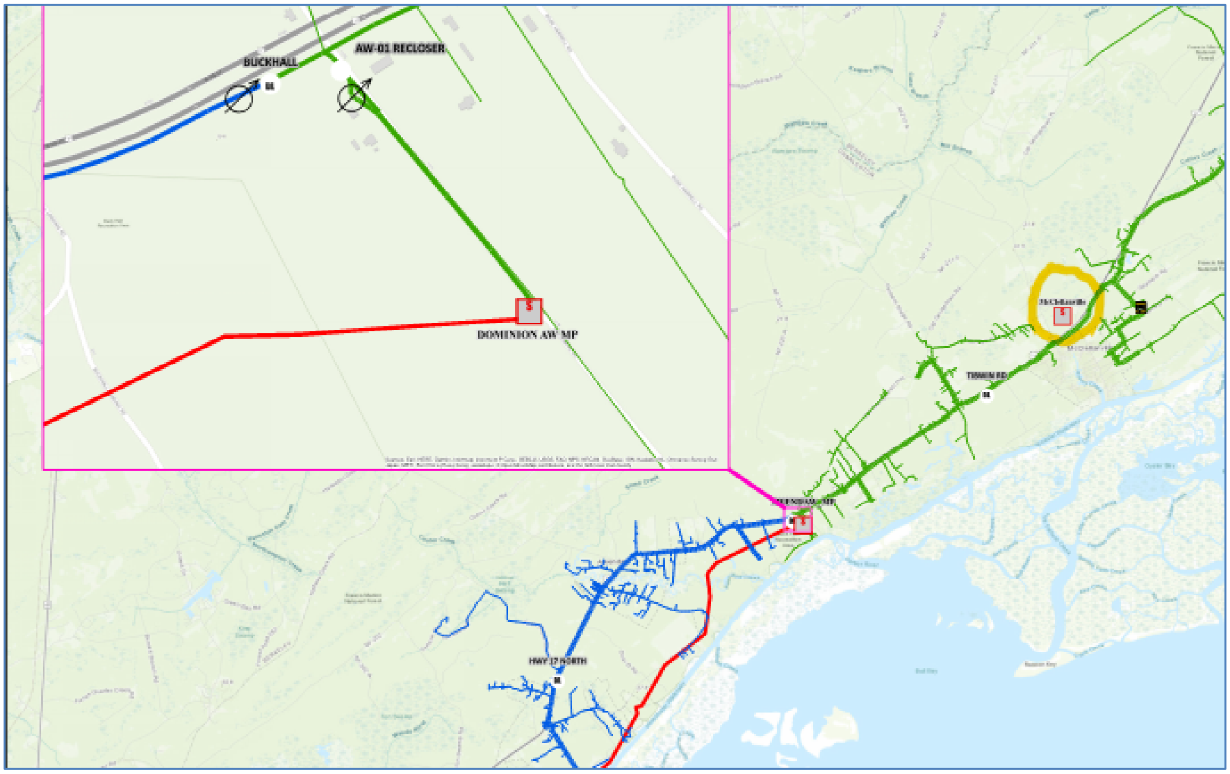
Table 2-1: Files Provided by CEPCI

File Name	Notes
AW_Load 2016-Present.xlsx	Load data at Awendaw Metering Point
ELIPS 2012-2016 Hourly Data	Load data at Awendaw Metering Point
AW01 CW08 Outages.xlsx	Outage data for Awendaw system
Buck Hall Aug 2018-Present.xlsx	Load data at Buck Hall recloser
CW08 Jan 2016 to Present.xlsx	Load data at Commonwealth substation
MV load forecaset_battery_project.xlsx	Peak load projections for McClellanville area through 2029
SeeWee Jan 2016 to Present.xlsx	Load data at SeeWee recloser
Awendaw Area Overall Distribution System.pdf	Color coded map of distribution system
gs43025_ColorbyCircuit_AW.pdf	Color coded map of distribution system
Awendaw MP ONE LINE FEED (2019).pdf	One-line diagram for Awendaw / McClellanville area
Multiple shape files	GIS data for distribution system

2.1.1 System Maps

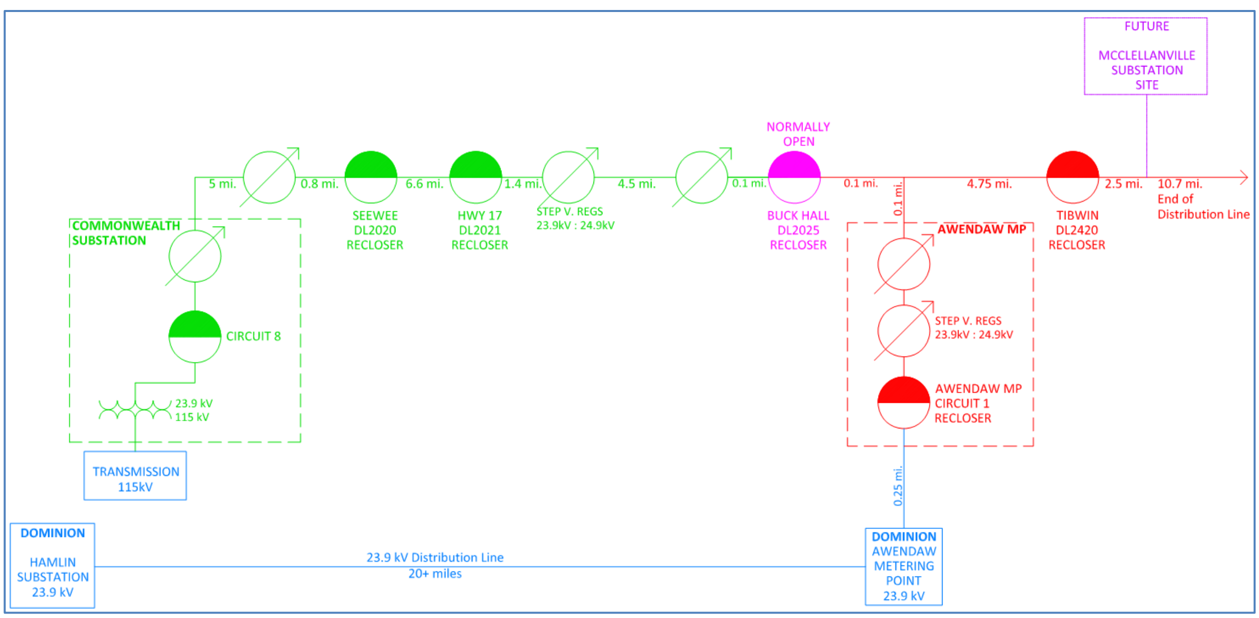
The figures below show a general schematic of the Awendaw distribution system and the related one-line diagram of the feeds from the Commonwealth and Awendaw substations. Both figures are copied from the documents listed in Table 2-1.

Figure 2-1: Awendaw Distribution System Schematic*



*Source: Awendaw Area Overall Distribution System.pdf

Figure 2-2: Awendaw Circuit One-Line*



*Source: AWENDAQ MP ONE LNE FEED (2019).pdf

2.1.2 Assumed BESS Location

Per CEPCI stakeholders, it is assumed that BESS alternatives in this Study would be located on the parcel shown in Figure 2-3. Accessible from US Highway 17 between North Pinckney St. and Leland Creek Road, BEC already has control of this land, which is approximately 2 acres excluding the access road. The figure below also shows a possible interconnection route (< 0.5 miles) to the existing Awendaw circuit. CEPCI indicated that approximately 10 acres may be available, but this plot is already cleared and leveled.

Figure 2-3: Assumed BESS Location and Interconnection Route

2.2 System Use Case Assumptions

For both use cases, it is assumed that the battery would be fully charged when the outage or peaking event occurs. For a peaking system, the need can potentially be anticipated and the battery can be charged accordingly. Still, should CEPCI wish to explore these options further, there are design and sizing issues that may increase the size of the battery or limit its ability to perform multiple functions on the system. Lithium technologies degrade differently depending on the resting state of charge (SOC). If the optimal resting SOC was 50%, for example, then there may be increased risk of degradation or self-discharge if the battery is maintained at an SOC closer to 100%. Therefore, the BESS may need to be larger if the Owner seeks to optimize the longevity or limit the charging costs associated with the system.

This evaluation does not consider the sizing implications of a system that satisfies both use cases simultaneously. For example, the islanding BESS can technically be capable of also serving as the peaking BESS, but there is rarely an ability to plan for a forced outage on the distribution system. If emergency backup for the entire Awendaw circuit is required, the BESS would need to be fully charged and could not be counted on to provide peak shaving without increased capacity.

2.3 Storage Technologies Considered

The Study focuses on technologies that are commercially available and suitable for peak shaving or islanding use cases under 10 MW. CEPCI identified a preliminary targeted useful life of seven years for a BESS installed by the end of 2020.

2.3.1 Lithium-ion Technology

A conventional battery contains a cathodic and an anodic electrode and an electrolyte sealed within a cell container than can be connected in series to increase overall facility storage and output. During charging, the electrolyte is ionized such that when discharged, a reduction-oxidation reaction occurs, which forces electrons to migrate from the anode to the cathode thereby generating electric current. Batteries are designated by the electrochemical materials utilized within the cell. This Study provides capital and maintenance cost information that is indicative of multiple lithium-ion chemistries that are commercially available, including the following:

- Lithium nickel manganese cobalt oxide (NMC)
- Lithium iron phosphate (LFP)
- Lithium nickel cobalt aluminum oxide (NCA)

Lithium-ion batteries contain graphite and metal-oxide electrodes and lithium ions dissolved within an organic electrolyte. The movement of lithium ions during cell charge and discharge generates current. Lithium-ion technology has seen a resurgence of development in recent years due to its high energy density, low self-discharge, and cycling tolerance. Consequently, lithium-ion technology has gained traction in several markets including the utility and automotive industries.

Many lithium-ion manufacturers currently offer 10-20-year warranties or performance guarantees. Longer project lifetimes will likely require capacity augmentation due to performance degradation throughout the life of the project. Roundtrip efficiencies are commonly 80% - 90% when measured on the alternating current (AC) side of the system.

Lithium-ion battery prices are trending downward, and continued development and investment by manufacturers are expected to further reduce production costs. While there is still a wide range of project cost expectations, lithium-ion OEMs and installers are continuing to expand their reach in the utility market sector.

2.3.2 Flow Battery Technology

Several flow battery OEMs offer containerized products for commercial, industrial, and smaller utility applications. Multiple OEMs are developing their technologies to better suit larger utility-scale (> 20 MWh) applications. This Study includes flow battery alternatives that are indicative of vanadium redox and iron flow batteries.

Flow batteries utilize an electrode cell stack with externally stored electrolyte fluid to hold the electrical charge. Roundtrip efficiencies are generally lower than lithium-ion technologies at around (65%-75% AC-AC), but flow batteries do not experience the performance degradation issues seen on lithium technologies, and therefore do not require capacity augmentation during the project life. The benefits of flow batteries include longer life (20-30 years) and minimal limitations on cycling and depth of discharge. The two most common types are reduction-oxidation (redox) and hybrid flow batteries.

A redox flow battery is comprised of positive and negative electrode cell stacks separated by a selectively permeable ion exchange membrane, in which the charge-inducing chemical reaction occurs, and tanks for the positive and negative electrolyte fluids. Pumping, piping, controls, and possibly mechanical cooling/heating systems make up the balance of plant.

The battery is charged as the liquid electrolytes are pumped through the electrode cell stacks, which serve as a catalyst and transport medium to the ion-inducing chemical reaction. The excess positive ions at the anode are allowed through the ion-selective membrane while the cathode experiences a buildup of negative ions. The charged electrolyte solution is circulated back to the storage tanks until the process is allowed to repeat in reverse for discharge as necessary. The pumps circulate in the same direction, but the polarity is reversed to switch from charge to discharge.

In addition to external electrolyte storage, flow batteries differ from traditional batteries in that energy conversion occurs as a direct result of the reduction-oxidation reactions occurring in the electrolyte solution itself. The electrode is not a component of the electrochemical fuel and does not participate in the chemical reaction. Therefore, the electrodes are not subject to the same deterioration that depletes electrical performance of traditional batteries, resulting in high cycling life of the flow battery.

Vanadium redox flow batteries can be designed to scale energy and power independently. The power is governed by the size and quantity of the stacks, while energy (discharge duration) is governed by the volume of electrolyte.

In a hybrid flow battery, electroactive material is deposited on the surface of the electrode during the charge cycle and then dissolved back into the electrolyte solution during discharge. An iron flow battery requires separate tanks for positive and negative electrolyte solutions, but other hybrid technologies such as zinc-bromide batteries use a single tank/single pump system. Most hybrid technologies can achieve durations of 6-12 hours, but power and energy are not fully decoupled for scalability. The storage duration is a function of both the electrolyte volume and the electrode surface area.

While there are dozens of chemistries in various stages of commercial availability, this study considers vanadium redox flow batteries and iron flow batteries for utility customers. These two technologies are commercially available in the U.S. in containerized products and multiple OEMs are developing products and/or platforms for large utility applications.

3.0 BESS SIZING

BMcD evaluated two BESS use cases and identified a range of potential battery systems to accommodate each use case.

3.1 Use Case 1: Peak Shaving

BMcD understands that CEPCI has a contracted 120 A limit from Dominion on the Awendaw circuit. When loads are above this limit, BEC shifts the entire Awendaw circuit load to the Buck Hall / Commonwealth feed. CEPCI, as the all requirements power provider, seeks to evaluate the costs for a BESS to reduce peak loads and avoid the 120 A limit.

BMcD evaluated the following data sets to develop the peak shaving use case.

- Load data from the Awendaw metering point from 1/1/2012 through 10/14/2019
- Load data from the Buck Hall recloser metering point from 6/16/2018 through 9/30/2019
- Weather data from the Charleston Airport (station 722080)
- Note that some data points were not available within those data sets

The Awendaw circuit is a winter peaking system, so the primary concern for peak shaving is typically during the winter months. To confirm this characteristic, BMcD reviewed winter vs. summer peak loading instances. From 1/1/201/ - 10/14/2019, there were 899 hours during which the Awendaw load was greater than 100 A. Of those hours, only 2.9% of them occurred during May through October.

Per recommendation by CEPCI stakeholders, BMcD initially studied loads that corresponded with temperatures less than 23°F. The table below indicates that there was limited data under these conditions based on the weather data from the Charleston Airport.

Table 3-1: Hours Per Year Under 23°F

Year	Hours < 23°F
2012	0
2013	0
2014	8
2015	15
2016	0
2017	0
2018	21

Thirteen of the hours under 23°F were coincident with loads that exceeded 120 A in the Awendaw MP data. All 21 hours under 23°F in 2018 occurred when the Awendaw MP reading was less than 3 A, which means there was likely a widespread outage or the loads were fed from the Buck Hall/Commonwealth circuit. The Buck Hall load data is blank during those but there is an increase in load seen in the Commonwealth load data that corresponds with those times. The outage reports indicate that there were documented events related to cold and ice, but it is unclear how much of the load was directly impacted.

BMcD also reviewed all hours where the Awendaw MP data exceeded 120 A, which proved to be a more useful subset of data. From 2012- 2019, there were 136 documented hours when Awendaw data exceeded 120 A, and 127 of those hours were during multi-hour events. Over the approximately 7.5-year study period, this represents approximately 0.2% of the total hours. Note that blank data and possible reading errors were excluded from the analysis, including six non-consecutive data points with data ranging from 167A to 823A. While these points may be correlated to grid stability issues, the values are much higher than the expected peaks and may skew the BESS sizing analysis. The table below provides the overview of the hours >120 A used for the use case analysis.

Table 3-2: Awendaw Circuit >120 A

AWENDAW > 120 Amps (2012-2019)	
Total Hours >120A	136
Number of Multi-hour Events	38
Max Duration (hours)	13
Max A-h Peak Event (A-h)	80
Coincident Duration for Max Peak (hours)	7

Note that the one year of available Buck Hall data only exceeds 120 A during six hours in September 2018. While the timing of these events generally corresponds to outages on the Awendaw circuit, Buck Hall data was not considered directly in the peak shaving use case analysis.

3.2 BESS Sizing for Peak Shaving

The tables below show the range of possible BESS system sizes based on two sizing criteria:

- Sizing BESS based on historical peaks
- Sizing BESS to offset future load growth

It is understood that CEPCI may balance the cost of installing a BESS against the costs of upgrading the service from Dominion from 120A to 175A, so it is important to identify the potential costs of a BESS that may offset load growth in the future.

BESS sizing requires an evaluation of the power (kW) and energy (kWh) requirements of the system. The rated power is governed by the peak load expectations and the energy rating is governed by the discharge duration expected. The nameplate energy is essentially the rated discharge power multiplied times the rated discharge duration.

Using the data from the use case analysis, BMcD reviewed the hours where the current exceeded 120 A and calculated the power and energy that would have been required to shave those peak events. Per Table 3-3 below, the peak shaving use case analysis identified a maximum 80 A-h, which occurred during a 7-hour event in February 2015. This correlates to a requirement of 3,420 kWh at 24.9 kV. This accounts only for the required energy beyond the contracted peak from Dominion, not the entire load during that time.

The peak demand during the study period was 149 A, which is 29 A greater than the Dominion limit, and correlates to approximately 1,160 kW at 24.9 kV.

Table 3-3: BESS Sizing Information for Historical Peaks

BESS Sizing Information for Historical Peaks	
Max BESS Peak Shave (A-h)	80
Coincident Duration for Max Peak (hours)	7
Max BESS Peak Shave (kWh)	3,420
Max BESS Peak over Dominion Limit (kW)	1,240
Avg Peak Event Duration	3.6
Avg BESS Peak Requirement (A-h)	27
Avg BESS Peak Requirement (kWh)	1,160
Avg BESS Demand During Avg. Event (kW)	320

The historical peak information may be useful to identify the lower cost boundary for BESS technology for this use case. The upper cost boundary for a peak shaving BESS use case would need to account for estimated load growth. CEPCI has a preliminary useful life assumption of seven years for a BESS installed in 2020 and provided load growth projections that show a 7,432-kW anticipated peak load on the Awendaw circuit for the year 2027. The table below shows a preliminary review of this projected peak and the impact on BESS sizing. If the BESS was responsible to offset the Awendaw loads greater than 120 A through 2027, then approximately 54 A, or 2,300 kW may be required.

Table 3-4: BESS Sizing Information for Projected Load Growth

BESS Sizing Information for 2026 Peak	
Plan 2027 Peak Load (kW)	7,432
Plan 2027 Peak Load (Amps)	174
Plan BESS Peak >120A Limit	54
Plan BESS Max Power Requirement (kW)	2,300

Using the historical information and the projected loads, Table 3-5 below shows the possible range of BESS sizing scenarios for the peak shaving use case. The maximum sizing scenario is based on the 2,300-kW identified to cover future peaks, assuming an 8-hour duration. With additional load growth, it would make sense that the number of peak events in which the load is greater than 120A will increase, as will the expected duration of those events. 8-hours is used to identify the potential cost scale of a longer duration system, but additional study would be required to better analyze the BESS according to the potential load shape for projected peaks.

Both the minimum and maximum load cases include a 5% margin on the power and energy requirements, plus 25% overbuild. Overbuild means that the installed energy capacity is higher than the nominal capacity. Approximately half of the overbuild accounts for overcoming system losses, battery minimum state of charge, and HVAC/aux load losses. The rest of the overbuild is calculated to overcome degradation and provide nameplate energy at the end of the assumed seven-year project life. This is a preliminary assumption based on 1.8% energy capacity degradation per year.

Actual lithium-ion degradation rates will vary based on the OEM/chemistry. Generally, there are two components of degradation: calendar degradation and cycle degradation. Calendar degradation occurs over time, regardless of the use case. Cycle degradation means that the battery degrades depending on how (and how often) it is cycled. For a peak shaving use case outlined above, the assumed degradation rate may be conservative, but additional study would be required during detailed design phases to further identify degradation and performance according to the chemistry and OEM warranty/guarantee implications.

It is important to consider that 4- hour or 8-hour battery can exhibit a longer discharge duration under lower load conditions. For example, Table 3-3 suggests that the levelized hourly demand for the average peak event is only 320 kWh. A 1,000 kW, 4-hr system is rated for 4,000 kWh, so it could technically discharge 320 kW for over twelve hours during such an event.

Table 3-5: Preliminary BESS Sizing Range

BESS Size Range Disscussion 2012 - 2019	
Assumed Sizing Margin	5%
BESS Min Rated Power (kW)	1,310
BESS Min Energy (kWh)	3,590
Assumed BESS Oversize (%)	25%
BESS Installed Energy (kWh)	4,490
BESS Max Rated Power (kWh)	2,420
Assumed Max Duration (hours)	8
BESS Max Energy (kWh)	19,360
Assumed BESS Oversize (%)	25%
BESS Installed Energy (kWh)	24,200

3.3 Use Case 2: Islanding

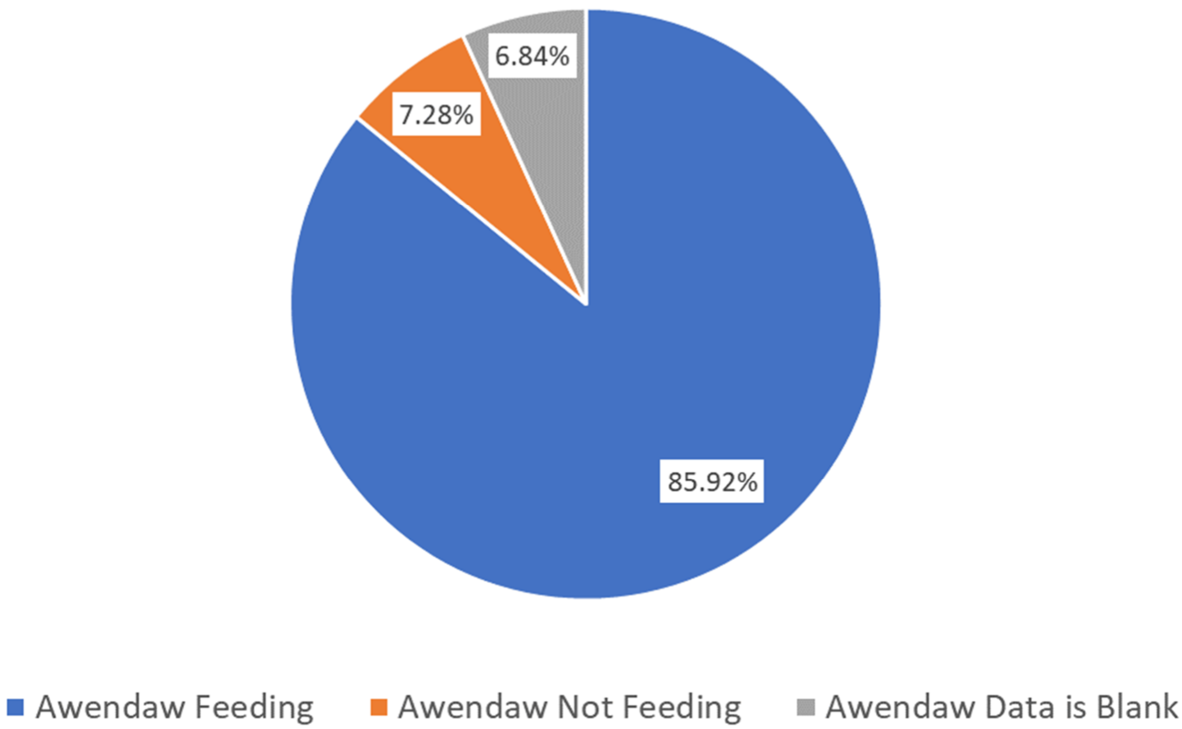
BMcD also reviewed a potential use case for a battery to supply the entire Awendaw circuit during an outage event. BMcD evaluated the following data sets to develop the islanding use case.

- Load data from the Awendaw, SeeWee, and Commonwealth metering points from 1/1/2016 through 10/14/2019
- Load data from the Buck Hall recloser metering point from 6/16/2018 through 9/30/2019
- Weather data from the Charleston Airport (station 722080)
- Note that some data points were not available within those data sets

Per above, the Awendaw circuit is the primary feeder for the McClellanville area, but the Commonwealth circuit (via the Buck Hall recloser) may be used during unplanned outages, maintenance events, or when the load approaches the Dominion load limit. Figure 3-1 below shows that the load was fed from the Awendaw metering point approximately 86% of the time for this hourly data set (1/1/2016 – 10/14/2019).

During the other 14% of hours, the load is either fed by another circuit or the data is blank. A significant majority (over 1,500 hours) of blank data occurs continuously during July, August, and September 2017. CEPCI suggested communication issues may have been at issue during this time. There is not a strong correlation between outage data provided by CEPCI and blank data on the Awendaw circuit.

Figure 3-1: Source of McClellanville Load (1/1/2016 – 10/14/2019)



During the time when the Awendaw metering point is not the primary feed, and when the data is not blank, there are two other data sets to review. Per Table 3-6 below, the 7.28% slice represents 2,416 hours during the study period.

The Buck Hall data represents the clearest picture of the secondary feed, but it is only available from 6/16/2018 – 9/30/2018. In total, there are 376 hours during that time where the Buck Hall circuit is active and the Awendaw feed is not.

Table 3-6: Secondary Feeds for Awendaw Circuit

Scenario	Hours	% of Total
Buck Hall Feeding	376	1.13%
Commonwealth Feeding	2,040	6.14%
Total	2,416	7.28%

There is load on the Commonwealth circuit during the rest of the time when no load is present on Awendaw or Buck Hall (2,040 hours), but as seen on the system maps in Section 2, the Commonwealth metering point includes additional loads upstream of the Awendaw or Buck Hall metering points.

The 2,416 hours represented in this slice are made up of 60 disparate events, 26 of which are longer than 1 day, and four of which are longer than a week.

BMcD also evaluated outage logs during the study timeframe, but the correlations between logged outage data and secondary energy supply are not apparent. Only 59 hours of the 2,416 hours in Table 3-6 coincide with documented outages on the Awendaw circuit.

3.4 BESS Sizing for Islanding

For an islanding event, the assumption is that a BESS would be sized to support the entire Awendaw circuit when the primary feed is not available. As in the peak shaving use case, the BESS sizing exercise must consider power and discharge duration capabilities.

The power rating would be determined by an evaluation of the historical and anticipated peak loads. Table 3-7 below shows the historical peak loads on the Awendaw circuit, and Table 3-8 shows the projected peak loads, per information provided by CEPCI.

Table 3-7: Awendaw Historical Peaks

Awendaw Historical Peaks		
Year	Peak Load (A)	Peak Load (kW)
2012	122	5,236
2013	118	5,030
2014	133	5,689
2015	142	6,081
2016	128	5,460
2017	139	5,948
2018	149	6,376
2019*	134	5,734
*Based on partial year data		

Table 3-8: Awendaw Projected Peaks

Awendaw Projected Peaks		
Year	**Peak Load (A)**	**Peak Load (kW)**
2020	153	6,560
2021	156	6,678
2022	156	6,798
2023	159	6,921
2024	162	7,045
2025	165	7,172
2026	168	7,301
2027	171	7,432

The highest peak on the Awendaw system during the study period was nearly 6,400 kW in 2018. Due to population and load growth expectations in the area, CEPCI expects to surpass the 2018 peak in 2020 and beyond. The capital costs presented for the islanding use case will be shown to cover the peak load in 2027, which is the assumed end of the useful life of the BESS.

The duration of the BESS for this use case is more challenging to uncover from historical data. Lithium-ion and flow battery technologies are generally sized in terms of hours. Per the use case analysis above, there are dozens of events when the Awendaw feed is not supplying the circuit for longer than a day. Outage logs provided by CEPCI do not present a clear depiction of the actual load shortfall during the event.

Four-hour and eight-hour systems are common industry sizing benchmarks, so BMcD is evaluating both durations to provide CEPCI with indicative costs for this use case. The BESS alternatives will be rated for 7.5 MW to accommodate the load growth expected in 2027, but they are not sized to consider islanding and peak shaving use cases simultaneously. Lithium-ion technologies will include 25% overbuild to accommodate degradation so that the unit may be capable of four or eight hours at nameplate power at the end of the project life. This is a preliminary assumption based on 1.8% energy capacity degradation per year.

An 8-hour flow battery option is also included in the capital cost section for comparison to lithium-ion technologies.

Additional information for the systems is included in the summary tables in Section 5.3. It is apparent that the footprints of the 8-hour BESS alternatives may not fit in the current two-acre parcel assumed for the site. Additional land may need to be purchased and/or cleared.

Table 3-9: Preliminary Lithium-ion BESS Sizing Range for Islanding

BESS Size Range for Islanding	
Plan 2027 Peak Load (kW)	7,432
BESS Rated Power (kW)	7,500
BESS Assumed Min Duration (hours)	4
BESS Min Rated Energy (kWh)	30,000
Assumed BESS Oversize (%)	25%
BESS Installed Energy (kWh)	37,500
BESS Assumed Min Duration (hours)	8
BESS Min Rated Energy (kWh)	60,000
Assumed BESS Oversize (%)	25%
BESS Installed Energy (kWh)	75,000

Actual lithium-ion degradation rates will vary based on the OEM/chemistry. Generally, there are two components of degradation: calendar degradation and cycle degradation. Calendar degradation occurs over time, regardless of the use case. Cycle degradation means that the battery degrades depending on how (and how often) it is cycled. For an islanding use case outlined above, the assumed degradation rate may be conservative, but additional study would be required during detailed design phases to further identify degradation and performance according to the chemistry, OEM, and warranty/guarantee implications.

It is also important to consider that a 4-hour or 8-hour battery can exhibit a longer discharge duration under lower load conditions.

4.0 INTERCONNECTION SCOPE AND RELIABILITY IMPACTS

Interconnection to the overhead 24.9 kV for grid-connected peak shaving only operation requires a simpler and less capital-intensive interface than if the BESS system also requires deployment in an islanded configuration. Therefore, the grid-connected peak shaving configuration will be discussed first. Then, modifications required for islanded operation will be developed and discussed.

The BESS, regardless of power and energy rating, are designed with three-phase, low-voltage (480 V) output of the inverter power conversion system (PCS). An electrically operated 480 V main circuit breaker provided at the PCS output facilitates protection of the BESS from utility sourced faults and synchronization, connection/disconnection and parallel operation with the interconnected utility. In addition, a pad mounted 480Y/277 V – 24,940Y/14,400 V oil-filled generator step-up transformer (GSU) is connected to the BESS main breaker. The primary side of the GSU terminates to 25 kV #1/0 AWG AL underground residential distribution (URD) 1/3 concentric-neutral cable routed in direct buried PVC conduit to a pole-mounted fused cutout via a primary riser. The primary riser pole starts the approximate one-half mile overhead three-phase circuit extension to the existing distribution circuit. A separate line fuse cutout at the interconnection to the existing three-phase overhead line is recommended to clear any faults between the interconnection point and primary riser fuse cutout without impacting the rest of the existing overhead circuit.

During normal operation, the BESS charging and discharging operations are controlled by the BESS PCS controller per local or remote commands. The constructed cost for this grid-connected option is estimated to be approximately $65,000.

To facilitate islanded operation and protection of the BESS, a medium-voltage circuit breaker must be added at the primary winding of the GSU. A two section NEMA 3R outdoor metalclad switchgear enclosure with a single draw-out circuit breaker and line and load side voltage transformers (VTs) for synchronization and dead-bus checks are required. To preclude the need for a separate 125 VDC system for switchgear control power, capacitor-trip type circuit breaker control will be implemented. An SEL-700GT relay or equal installed at the interconnection circuit breaker will provide control and protection of the BESS to utility interface. The additional cost to install this primary GSU is estimated to be approximately $230,000.

In addition, fiber optic communication with the following remote reclosers is required to separate the islanded distribution circuit from the rest of the system:

- Buck Hall DL2025
- Tibwin DL2420
- Awendaw Circuit 1 Recloser

One or all of these reclosers will need to be opened and verified open to provide islanding sectionalizing to limit load connected to the islanded BESS. Fiber optic communication is assumed because wireless communication is not reliable in this area due to geography. When islanded, selective coordination between protective devices, mainly line/transformer fuses, will likely not be feasible. The BESS PCS is an inverter system and therefore can only supply a relatively small amount of short circuit current in excess of its rated output for a short duration under external fault conditions. Implementing a grounded wye primary GSU will maximize the available line-to-ground short circuit current and preclude lightning arrester operation under fault conditions; however, the magnitude of line-to-ground short circuit current will likely be insufficient to operate line/transformer fuses. Without replacement of upstream line/transformer fuses or addition of upstream reclosers with individual phase voltage sensing, the added 25 kV circuit breaker at the GSU primary winding will be required to trip via voltage or negative sequence protection elements set to detect faults in the islanded distribution system. This will result in loss of the entire islanded system.

5.0 SCREENING LEVEL COST ESTIMATES

5.1 Capital Costs

Based on the use case evaluations above, BMcD provided cost estimates for BESS technologies to cover the range of potential sizing scenarios discussed. Scope assumptions for capital and O&M costs are provided below and the cost estimate information is provided in Section 5.3.

- Estimates are screening-level in nature and do not reflect guaranteed costs. Estimates concentrate on differential values between options and not absolute information. All information is preliminary and should not be used for budgeting, design, or construction purposes. Estimates are based on BMcD experience.
- All capital cost and O&M estimates are stated in 2020 US dollars (USD). Escalation is excluded.
- Estimates assume an Engineer, Procure, Construct (EPC) fixed price contract for project execution.
- Site is assumed to be flat with minimal rock. Helical piles assumed to support BESS containers.
- EPC cost includes the following items:
    - Lithium-ion BESS containers: battery racks, lighting, communications/controls, and auxiliaries are located inside unmanned, pre-engineered enclosures. HVAC units are field mounted to side or roof of the enclosures.
        - Fire suppression assumes FM-200 clean agent system for primary suppression, and sprinkler/dry pipe with fire department hookup for secondary suppression.
        - 25% overbuild estimated to account for minimum state of charge, system losses, and seven-year life with no augmentation
    - Flow batteries for the peak shaving use case are assumed to be containerized units including power modules/stacks, tanks with electrolyte, pumps, auxiliaries, communications/controls, and secondary fluid containment within a pre-engineered enclosure
    - Flow batteries for the islanding use case are assumed to be decoupled solutions. This means that the OEM would provide the power stack modules/skids with onboard pumping and controls. The OEM would also supply the electrolyte solutions and field support for tank fills. The EPC would provide the electrolyte tanks and interconnecting piping, electrical, and installation for the battery and BOP systems.
    - Switchboard and site controller
    - Inverters
    - Pad mounted 24.9kV transformer

  - Indirect costs
    - Engineering
    - Construction management
    - Startup / commissioning
    - EPC fee, workmanship warranty, contingency
- Screening level costs are intended to be representative of the class of technology (lithium-ion and flow) and not intended to differentiate between battery OEMs or chemistries (NMC vs. LFP vs. NCA for lithium technologies or vanadium redox vs. iron flow for flow technologies).
- Interconnection costs are based on scope outlined in Section 4.0
- Owner's cost allowances account for the following items:
  - Project development
  - Owner's project management, legal, and training costs
  - Owner's engineer
  - Permitting
  - Construction power
  - Site security during construction
  - Operating spares
  - Builder's risk insurance
  - Owner's contingency (5% for screening)
- Exclusions
  - Demolition or removal of hazardous materials
  - Land costs
  - Sales tax, property tax, property insurance
  - Operation and maintenance (O&M) costs
  - Escalation
  - Water pipeline to site
  - Decommissioning costs or salvage values

5.2 O&M Costs

O&M estimates for the lithium-ion and flow battery BESS alternatives are shown in the summary tables, based on BMcD experience and recent market trends. BESS O&M costs are modeled to represent the fixed and variable portions of service contracts and/or capacity maintenance guarantees. For all options, the BESS is assumed to be monitored and operated remotely. The technical life of the project is assumed to be seven years.

5.2.1 Lithium-ion Systems

BESS O&M costs are modeled as fixed and variable costs. Fixed costs include routine system and site maintenance that should be performed regardless of the use case. These costs include items that may be performed weekly, monthly, annually, or at longer intervals, such as the following:

- Enclosure inspections and integrity checks
- Inspect wiring and breakers
- Alarm responses
- HVAC filter replacements
- Enclosure cleaning
- Instrument and sensor calibrations
- Data backup
- HVAC refrigerant checks and fills
- HVAC compressor maintenance
- Inverter maintenance

Lithium-ion battery augmentation costs may vary depending on the use case, so they may be modeled as variable O&M on a $/MWh basis. Overbuild and augmentation philosophies will vary among projects, use cases, and owners. For this Study, it is assumed that CEPCI would overbuild the system to account for seven years of degradation. During operation, it is assumed that CEPCI would let the batteries degrade and not augment the system. Therefore, no variable O&M costs are included in the Study.

5.2.2 Flow Battery Systems

Flow battery O&M costs are modeled as fixed costs only. Flow battery maintenance is not dependent on cycling characteristics and performance degradation is not anticipated when maintenance is performed to O&M recommendations. Therefore, there is no augmentation or variable O&M costs included.

Because this is a developing technology, there is little field verified O&M information, so the cost estimates are based on budgetary quotations from OEMs plus additional costs for inverter and general site maintenance. Fixed costs assume that CEPCI enters into a service contract with the OEM that accounts for preventative and routine maintenance. An additional allowance is included for the inverter(s) and general site maintenance. Routine maintenance items may include the following:

- Enclosure inspections and integrity checks
- Inspect wiring and breakers

- Check controls and leak detection system
- Alarm responses
- Enclosure cleaning
- Instrument and sensor calibrations
- Data backup
- Electrolyte pH checks and rebalancing, as necessary
- Pump and piping maintenance
- Inverter maintenance

5.3 Summary Tables

Table 5-1: Summary Table for Peak Shaving Alternatives

BASE PLANT DESCRIPTION	Lithium-ion 1 MW - 4 hr	Lithium-ion 2 MW - 4 hr	Flow 1 MW - 8 hr	Lithium-ion 2.5 MW - 8 hr	Flow 2.5 MW - 8 hr
Assumed Land Use (Acres)	0.3	0.5	0.8	1.0	1.5
Storage System Initial Overbuild (%)	25%	25%	N/A	25%	N/A
Storage System Augmentation (%/yr)	0.0%	0.0%	0.0%	0.0%	0.0%
Storage System AC Roundtrip Efficiency (%)	85%	85%	70%	85%	70%
Technology Rating	Mature	Mature	Developing	Mature	Developing
BESS Performance					
Net Plant Output, kW	1,000	2,000	1,000	2,500	2,500
Discharge Duration, hr	4	4	8	8	8
Net Plant Energy Capacity, kWh	4,000	8,000	8,000	20,000	20,000
ESTIMATED CAPITAL AND O&M COSTS					
EPC BESS Project Capital Costs, 2020 MM$	$2.4	$4.2	$5.9	$9.4	$13.7
EPC Interconnection Capital Costs, 2020 MM$	$0.07	$0.07	$0.07	$0.07	$0.07
Owner's Cost Allowance, 2020 MM$	$0.9	$1.0	$1.1	$1.3	$1.5
Total Project Costs, 2020 MM$	**$3.4**	**$5.2**	**$7.0**	**$10.8**	**$15.3**
EPC Cost Per kWh, 2020 $/kWh	**$610**	**$520**	**$730**	**$470**	**$690**
Total Cost Per kWh, 2020 $/kWh	**$850**	**$650**	**$880**	**$540**	**$770**
O&M COSTS					
Fixed O&M Cost, 2020$MM/Yr	$0.02	$0.04	$0.03	$0.09	$0.07
Variable O&M Cost, $/MWh (Augmentation Costs)	N/A	N/A	N/A	N/A	N/A

Table 5-2:Summary Table for Islanding Alternatives

BASE PLANT DESCRIPTION	Lithium-ion 7.5 MW - 4 hr	Lithium-ion 7.5 MW - 8 hr	Flow 7.5 MW - 8 hr
Assumed Land Use (Acres)	1.0	2.0	3.5
Storage System Initial Overbuild (%)	25%	25%	N/A
Storage System Augmentation (%/yr)	0.0%	0.0%	0.0%
Storage System AC Roundtrip Efficiency (%)	85%	85%	70%
Technology Rating	Mature	Mature	Developing
BESS Performance			
Net Plant Output, kW	7,500	7,500	7,500
Discharge Duration, hr	4	8	8
Net Plant Energy Capacity, kWh	30,000	60,000	60,000
ESTIMATED CAPITAL AND O&M COSTS			
EPC BESS Project Capital Costs, 2020 MM$	$13.4	$23.2	$38.8
EPC Interconnection Capital Costs, 2020 MM$	$0.31	$0.31	$0.31
Owner's Cost Allowance, 2020 MM$	$1.7	$2.3	$3.1
Total Project Costs, 2020 MM$	**$15.4**	**$25.8**	**$42.2**
EPC Cost Per kWh, 2020 $/kWh	**$450**	**$390**	**$650**
Total Cost Per kWh, 2020 $/kWh	**$510**	**$430**	**$700**
O&M COSTS			
Fixed O&M Cost, 2020$MM/Yr	$0.15	$0.30	$0.18
Variable O&M Cost, $/MWh (Augmentation Costs)	N/A	N/A	N/A

6.0 NEXT STEPS

The information in this report summarizes key findings including sizing and cost information for BESS systems for two use cases: peak shaving and islanding. This Study supports CEPCI's technical and economic feasibility studies to improve system reliability on the Awendaw circuit. It is understood that BESS implementation may be evaluated against the costs to upgrade the existing distribution system to increase the load limits from Dominion. BMcD recommends CEPCI continue project development and scoping activities that may include, but not necessarily limited to, the following:

- **Critical Load Analyses**:
  CEPCI may wish to identify critical loads and demand reduction options that can help limit the power requirements of the BESS.
- **Risk / Reliability Assessments**:
  CEPCI may wish to compare the costs and system reliability characteristics of BESS alternatives to generation and/or transmission alternatives.

If the project risk profile and economics remain favorable after completion of the recommended scoping studies, then BMcD recommends CEPCI proceed with necessary project execution activities to further define the project scope, schedule, and budget. To reduce project cost risk, CEPCI may consider the following activities:

1. Investigate environmental permitting requirements
2. Identify preferred technology option based on feasibility studies and risk analyses.
3. Perform a Project Definition Report to further refine scope and assess potential risks of the project to finalize project definition, scope, and costs.
4. Commence other permitting activities.
5. Negotiate and award EPC contract.

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