Final Report

Risk Assessment Study for Battery Energy Storage System at Fore River Energy Center

Prepared for

Calpine Corporation and **Weymouth Fire Department**

CALPINE®

WEYMOUTH FIRE

October 21, 2021

LUMMUS CONSULTANTS INTERNATIONAL

Risk Assessment Study for Battery Energy Storage System at Fore River Energy Center

North Weymouth, MA

October 21, 2021

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Calpine Corporation

North Weymouth, MA

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List of Exhibits

List of Acronyms

ACES	Advancing Contracting in Energy Storage	MW	Megawatt
BESS	Battery Energy Storage System	MWRA	Massachusetts Water Resources Authority
BMS	Battery Management System	OSHA	Occupational Safety & Health Administration
BPU	Battery Protection Unit	PCS	Power Conversion System
Calpine	Calpine Corporation	PMS	Power Management System
EMS	Energy Management System	SASP	Santa Ana Storage Project
FREC	Fore River Energy Center	SCBA	Self-Contained Breathing Apparatus
gpm	Gallons per minute	SOC	State of Charge
JEC	Johanna Energy Center	TMS	Thermal Management System
Li-ion	Lithium ion	ULSD	Ultra-Low Sulfur Diesel Fuel
MOTIE	Ministry of Technology, Industry and Energy	WFD	Weymouth Fire Department

1 Executive Summary

Lummus Consultants International LLC was retained by Calpine Corporation to conduct a Risk Assessment Study for a proposed lithium-ion Battery Energy Storage System ("BESS") to be installed at their Fore River Energy Center ("FREC") in North Weymouth, Massachusetts. The Weymouth Fire Department is an additional party to this Risk Assessment Study due to their obvious involvement in any future fire incident and their valuable insights to minimize the probability of any future fire incident.

The scope of work was developed and agreed to by a representative from Calpine Corporation and the Weymouth Fire Department. This report addresses the specific items we were requested to evaluate with regard to fire risks associated with lithium-ion BESS facilities:

Lithium-ion BESS Technology and Experience

Lithium ion battery technology has evolved over the last decade. The evolution has been driven by improvements in materials and a better understanding of the battery performance. BESS projects are underway which will improve industry knowledge, advance energy storage technology, and promote the benefits to grid operations. This expanding knowledge base will include the means and methods for better fire prevention and mitigation, which will reduce fire risks at subsequent BESS projects. The lessons learned at other BESS projects will improve the design, construction, and operation of the facility at FREC.

Proposed BESS Equipment and Arrangement

The proposed BESS project at FREC is not defined in detail currently. The latest general arrangement drawing is based on a 40MW/80MWh (2-hour) project. As project development activities progress, more details and improvements will be confirmed including the selection of the specific batteries and the fire mitigation measures to be implemented.

Proposed BESS Proximity to Existing Plant

The FREC site is a congested industrial area with limited available open space. There are multiple easements which limit the placement of new BESS equipment to a specific area on the site.

Natural Gas Transmission Pipeline

One of these easements is for the natural gas pipeline that supplies FREC. Natural gas is supplied to FREC through a natural gas transmission pipeline that crosses the site to a Gas Compressor House located on the southern boundary of the property. The pipeline is a 30 inch diameter steel line buried three feet below grade. The area available for the BESS is limited on the eastern side and to the north by the easement for the natural gas transmission pipeline.

The proximity of the BESS to the underground natural gas transmission pipeline was not considered to be an additional fire or explosion risk to the pipeline. The pipeline is located underground so has some protection from heat released in a fire. Additional analysis would need to be performed to evaluate whether the gas flow in the pipeline would need to be shut-off in the event of a BESS fire.

A significant gas leak from the pipeline in the area adjacent to the BESS facility would be highly unlikely. It is difficult to evaluate hypothetical scenarios that have such low probabilities. If there were a significant gas leak from the natural gas transmission pipeline that resulted in a fire, the main concern would be with other flammable materials on the site, such as the fuel oil in the storage tank. A BESS container is not by itself flammable. It would require that the batteries inside the container be heated in order for the BESS facility to be impacted.

Causes of Lithium-ion BESS Fires

One of the challenges with energy storage systems using lithium ion batteries is the potential for fires. It takes multiple steps to get to a fire, starting with some electrical/mechanical defect/damage that leads to a failure of a cell, which then propagates to a thermal runaway event, and then to a fire. While there is only a short amount of time between cell damage and thermal runaway, there is sufficient time for monitoring equipment to recognize the condition and shut down the BESS. Even if a thermal runaway event results in a fire, there are systems that can prevent fires from escalating further.

There have been recent lithium-ion BESS fire events in South Korea, Arizona, and England. These fire events have been evaluated to understand the root causes and the effectiveness of the fire detection and suppression systems. The energy storage industry, testing laboratories, and fire protection associations have been incorporating the lessons learned from these and other events to develop more effective codes, standards, and systems to detect and suppress fires.

Local Firefighting Capabilities for Li-ion BESS Fires

There are significant local firefighting capabilities available if needed for an incident at the BESS. The primary response would be from the Weymouth Fire Department, with support from adjacent fire departments as requested. Current procedure would dispatch three engines and one ladder company as a special response to an incident at FREC. The response would include a Tier 1 Hazardous Materials response from the State HazMat team.

The Li-ion BESS fires that have occurred have been addressed by local firefighters and hazmat teams. The local fire responses involved multiple fire engines for a period of several hours with eventually one fire engine remaining on site for 12 hours or longer to ensure the fire was completely put out.

Lummus Consultants believes there are adequate emergency response resources and professional trained personnel located near the proposed BESS to provide a timely reaction commensurate with the severity of an incident. The Weymouth Fire Department has four engine companies and one ladder company and can call on the State Hazmat team in a response, as well as call for mutual aid from neighboring municipalities. There is minimal risk of a delayed response or insufficient resources to control a fire in the proposed BESS.

Recommendations to Mitigate and Manage Fire Risks

The design, manufacturing, installation, commissioning, operation, maintenance, and modification of the BESS must be in accordance with the codes, standards, and regulations that directly apply to the components and systems specified and the site where the BESS is installed.

The combination of a Battery Management System and a Thermal Management System makes more options and proactive actions available to quickly and actively suppress and eliminate thermal fault events. For a co-located facility such as the BESS at FREC, the Thermal Management System can be tied into the power plant control system to allow plant operators to monitor the temperature within each container.

Various fire detection options are available to identify the stages of thermal runaway: temperature increase, off-gases, smoke and flame. The earlier a malfunctioning battery is detected, the sooner fire prevention and suppression systems can be activated. Fire suppression systems or other methods of containing and preventing the spread of fire that are acceptable to the Weymouth Fire Department are needed if a BESS experiences thermal runaway.

The BESS fire event in Arizona resulted in injuries and loss of life to the first responders when the BESS container exploded. Explosion vents are passive protection devices which could prevent the uncontrolled rupture of the BESS container. Eliminating explosion hazards is critical for the safety of the first responders and for containing a fire should one occur, so explosion vents should be included in the design of the containers by the EPC contractor.

Management of Potentially Hazardous Fire Byproducts

Potentially hazardous byproducts of a fire at the proposed BESS include toxic smoke and wastewater from firefighting activities.

Toxic Smoke

Uncontrolled fires can generate smoke (particulate matter), carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons, nitrogen oxides (NOx), and other hazardous compounds. Li-ion batteries contain fluorine and fire tests on Li-ion batteries have detected hydrogen fluoride (HF) and other fluorine compounds. It is recommended that first responders wear self-contained breathing apparatus when responding to a Li-ion battery fire due to the toxicity of the gaseous emissions.

The actual gaseous emissions will depend on many parameters including cell chemistry, type of incident, state of charge, cell age, and ambient conditions. Common gases emitted include CO_2, CO, H_2, and hydrocarbons as well as fluorinated compounds. The gases originate from thermal decomposition and reactions of the electrolyte, binder, and electrode materials. Gaseous emissions from a smoke event will have a different composition than emissions from one with flames. Generally, events without flame/ignition will have worse gas compositions. The gaseous emissions away from the location of the fire are difficult to estimate as they are dependent on the intensity and duration of the fire and the weather conditions.

If the smoke plume from a Li-ion battery fire headed toward the eastern site boundary, firefighters would utilize a water spray fog to help direct the smoke away from the adjacent neighborhood until the smoke dissipates.

Fire Suppression Wastewater

Li-ion battery fires can be extinguished with large amounts of water. Water samples collected after extinguishing Li-ion battery fires can contain concentrations of fluoride and chloride.

Firefighting wastewater would be handled like stormwater. Site topography ranges between approximate elevations of 15 and 25 feet above mean low water. In general, drainage onsite flows from east to west toward the Weymouth Fore River. The site contains traditional subsurface drainage structures equipped with stormwater mitigation structures where stormwater is collected, inspected, and treated prior to discharge. Most of the firefighting wastewater would flow from the BESS area through the stormwater system to Forebay No. 1 and then to Stormwater Basin No. 1.

In the event of a fire in the BESS area, part of the emergency response would be the installation of a pneumatic “plumber’s plug” in the discharge pipe of Stormwater Basin No. 1. This would make the surge volume available and prevent the premature release of firefighting wastewater to the Weymouth Fore River.

The amount of water used to fight a fire at the BESS facility will depend on the extent and intensity of the fire. The equipment used to control the fire will have various capabilities. There is adequate capacity in Stormwater Basin No. 1 to retain about three to ten hours of firefighting wastewater. FREC can call in a contractor to pump water out from Stormwater Basin No. 1 for off-site testing and treatment.

Recommendations for BESS Noise and Visual Impacts Attenuation

It is anticipated that the new BESS equipment will not result in additional adverse noise or visual impacts on the local community. Calpine would be required to comply with noise limits under its existing permits, as well as with State and local noise ordinances.

Ambient Noise Impacts

Lummus Consultants reviewed a recent noise study related to the addition of new equipment at FREC. The conclusion was the new black start diesel generators would result in little or no adverse noise impact on the community. Lummus Consultants expects the noise level from the BESS equipment would be less than the black start diesel generators and would also result in little or no adverse noise impact on the community.

It was noted during the site visit at FREC that the predominate ambient sound was traffic noise from Bridge Street (Route 3A), even with both generating units running and the air-cooled condenser operating.

Screening for Visual Impacts

There is already significant visual screening along Monatiquot Street to minimize visual impacts from FREC. Lummus Consultants expects the low profile of the new BESS equipment will not impose any additional adverse visual impact on the community.

General Fire Risk of New BESS at FREC

All thermal power plants present some risk of fire due to the fuel that is used, as well as the ignition of flammable gases and liquids used in the power generating equipment. These fire risks at thermal power plants are managed through various fire suppression systems. The approach to fire protection at thermal power plants has evolved over time with experience and the involvement of the insurance industry working in conjunction with fire safety groups, such as the National Fire Protection Agency.

A Li-ion BESS presents is own set of fire risks. The battery industry, insurance companies, testing laboratories, and fire safety organizations have worked closely together to understand the causes of Li-ion BESS fires and to develop appropriate mitigation and fire protection strategies. Lummus Consultants believes the work done by the various stakeholders has greatly reduced the risk of fire at Li-ion BESS facilities, provided the recommended fire mitigation and protection measures are implemented.

Given the progress made with understanding the causes of Li-ion BESS fires and the stakeholder response, Lummus Consultants expects the addition of new BESS equipment will not result in a significant increase in the general fire risk at FREC, assuming the BESS complies with all applicable codes, standards, regulations, and procedures for the design, construction, commissioning, operation, and maintenance of the facility.

2 Introduction

Lummus Consultants International LLC ("Lummus Consultants") was retained by Calpine Corporation ("Calpine") to conduct a Risk Assessment Study for a proposed lithium ion ("Li-ion") Battery Energy Storage System ("BESS") to be installed at their Fore River Energy Center ("FREC") in North Weymouth, Massachusetts.

The Weymouth Fire Department ("WFD") is an additional party to this Risk Assessment Study due to their obvious involvement in any future fire incident and their valuable insights to minimize the probability of any future fire incident.

The scope of work was developed and agreed to by a representative from the WFD and Calpine. This report addresses the specific items we were requested to evaluate with regard to fire risks associated with Li-ion BESS facilities.

2.1 Fore River Energy Center Overview

Located about 12 miles southeast of Boston, FREC is a 731 MW, combined-cycle plant purchased by Calpine in November 2014. The plant consists of two Mitsubishi 501G combustion turbines, two heat recovery steam generators and one steam turbine. FREC started commercial operation in August 2003.

While FREC primarily operates on clean-burning natural gas, it can also run on ultralow-sulfur diesel fuel oil, depending on market conditions. This flexible, dual-fuel capability is increasingly important to enhance power reliability in the region.

Highly efficient, combined-cycle facilities like FREC consume 40 percent less fuel per megawatt-hour produced than older plants, making them cost-effective, low-carbon sources of electricity. FREC is equipped with advanced emission control technologies including selective catalytic reduction systems, oxidation catalysts and dry, low-NOx combustors. An air-cooled condenser minimizes the amount of makeup water needed for operations. In addition, its design minimizes wastewater discharge.

Calpine owns 100% of FREC. All of FREC's energy, capacity and ancillary services are sold into the competitive wholesale power markets administered by ISO-New England.

Exhibit 1 shows an aerial view of FREC and the surrounding area.

2.2 Site Visit to FREC

A site visit to FREC was conducted with selected parties on October 8, 2021. Mr. Charlie Parnell, Calpine General Plant Manager, and Deputy Chief Justin Myers, Weymouth Fire Department, attended the meeting with Mr. John Senner and Mr. Jay Peterson of Lummus Consultants. The current status of the BESS project development for FREC and the status of utility scale BESS facilities were discussed. A tour of the potential project area and related equipment was included.

Exhibit 1 Aerial View of Fore River Energy Center and Surrounding Area

2.3 Report Overview

This is a report on the results of the Risk Assessment Study performed by Lummus Consultants for a proposed BESS to be installed by Calpine at their FREC in North Weymouth, Massachusetts. Our report is based on the limited project information available currently and publicly available information for battery technology, BESS industry experience, and other references.

This is a report of the activities, observations, and conclusions by Lummus Consultants based on our review of the documentation provided by Calpine, performance data from various vendor sources, and a site visit to FREC on October 8, 2021.

Section 1 of this report provides an introduction and background information. Section 2 is a more detailed description of a typical BESS for utility scale operations. Section 3 addresses the causes for fires at Lithium Ion BESS facilities. Section 4 of this report provides a description of the current proposed BESS project development for FREC. The BESS proximity to existing plant equipment and the property line are reviewed in Section 5. Recommendations to mitigate and manage fire risks are included in Section 6. Local firefighting capabilities for Lithium ion ("Li-ion") BESS fires are highlighted in Section 7.

This report is our contract deliverable as described in our proposal to Calpine dated September 29, 2021. Our findings and conclusions were based on documents and analyses provided by Calpine. We have assumed that the information provided to us was accurate. For a complete understanding of our findings and conclusions, this report should be read in its entirety.

3 Lithium-ion BESS Technology and Experience

BESS projects are underway which will improve industry knowledge, advance energy storage technology, and promote the benefits to grid operations. This expanding knowledge base will include the means and methods for better fire prevention and mitigation, which will reduce fire risks at subsequent BESS projects.

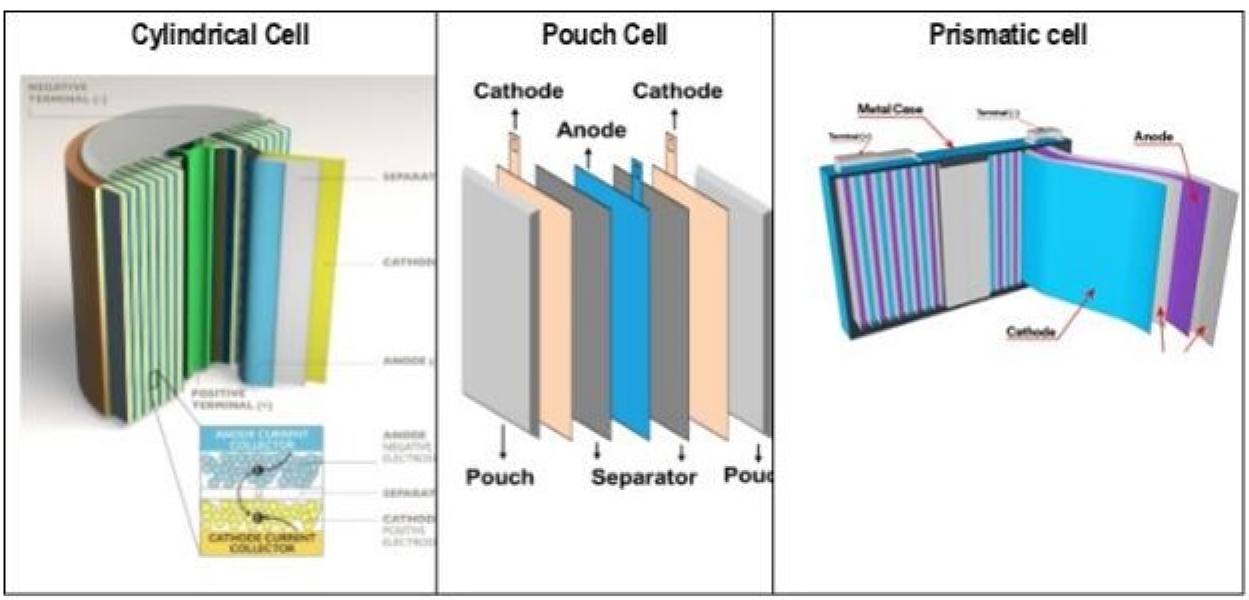
3.1 Lithium-ion BESS Technology

Lithium ion (Li-ion) batteries are composed of a positively charged electrode (cathode), a negatively charge electrode (anode), a physical barrier that separates the cathode and anode (separator) and an electrolyte that allows ions to move through the separator from the anode to the cathode during energy discharging and in the reverse direction when the battery is being charged. There are different types of lithium ion batteries depending on the application. Generally, the anode is made of graphite and the cathode a metal oxide (such as lithium cobalt oxide). The electrolyte is a lithium salt in an organic solvent (such as ethylene carbonate or diethyl carbonate).

Li-ion is used in battery applications for a number of reasons. Relative to other battery technologies, it allows a faster charge, accommodates more charge/discharge cycles, and has a higher power density. Li-Ion batteries can be physically fragile and need to be protected from deep discharge, overcharging, and short circuits. The batteries are also temperature sensitive so need to be operated in a controlled temperature environment. Another challenge is that the technology is still evolving with different materials being developed for the anode, cathode and electrolyte.

A Li-ion battery starts with a sealed battery cell. There are three main form factors of Li-ion battery cells; cylindrical, pouch and prismatic, as shown in **Exhibit 2**.

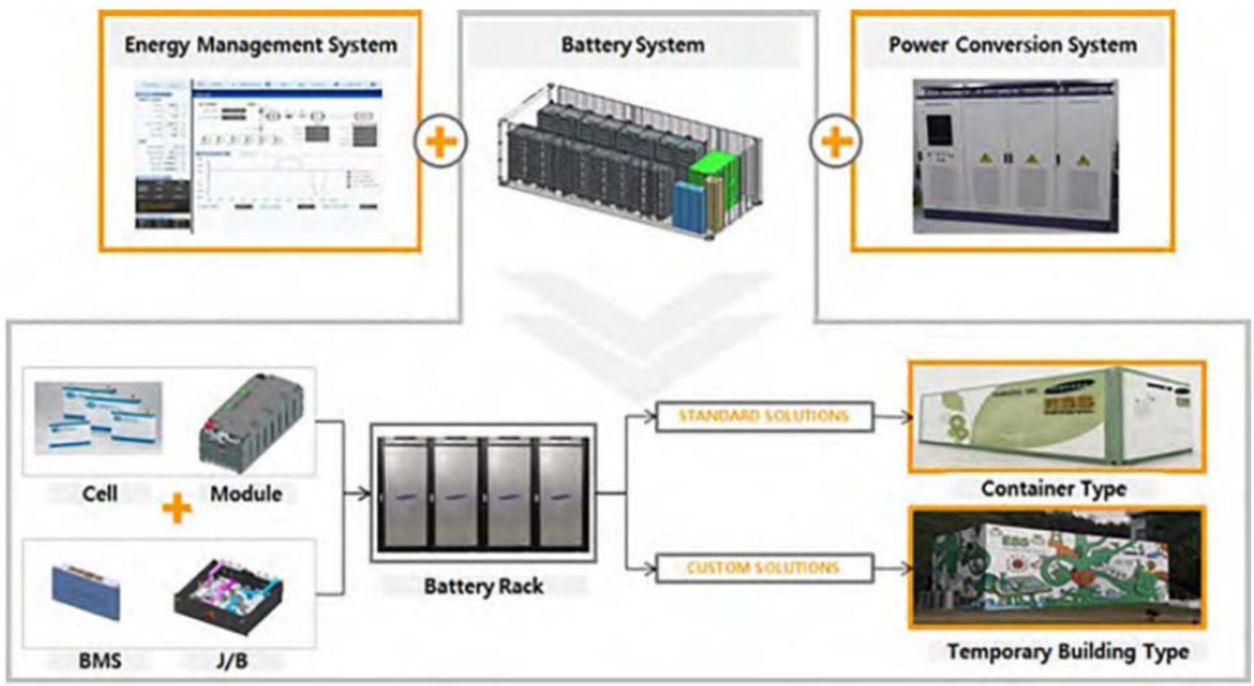
Exhibit 2 Types of Li-ion Cells



Cells may be connected together (in series and/or in parallel) in modules and modules grouped into a discrete battery pack. The packs are electrically connected in a rack, and a set of interconnected racks can be installed within a large container or building. Batteries produce and use DC power, while the electric grid is based on AC power. Consequently, a BESS will have a power conversion system to convert DC to AC power or vice versa, as well as a transformer to increase the voltage to levels suitable for distribution sub-transmission, or transmission.

Exhibit 3 shows the major components of a typical BESS.

Exhibit 3 Components of a BESS



BMS = battery management system, J/B = Junction box.

Source: Handbook of Battery Energy Storage System, December 2018. Asian Development Bank

3.2 Similar BESS Project Experience

Calpine has recent experience with a similar BESS project which will provide valuable lessons learned to benefit this project. Other similar sized BESS projects are underway which will also improve industry knowledge and advance energy storage technology.

Calpine — Johanna Energy Center in Santa Ana Energy Storage Project

In July 2021, Calpine and GE Renewable Energy announced the completion of the Johanna Energy Center ("JEC") in the Santa Ana Storage Project ("SASP") in Santa Ana, California. The JEC project contains a 20MW/80MWh (4-hour) stand-alone battery energy storage system using GE's Reservoir energy storage technology. The system, now in commercial operation, is supported by a 20-year Resource Adequacy Power Purchase Agreement. The JEC project will be able to provide energy to up to 12,000 households during peak events, and/or 24,000 households during normal load conditions. **Exhibit 4** shows the JEC project in the SASP.

Exhibit 4 Johanna Energy Center in Santa Ana, California

This grid-connected battery energy storage system represents a major step forward in Calpine's plans to grow the company's energy storage footprint. The SASP facility itself will be capable of considerable expansion in future phases.

This cutting-edge battery storage project represents another major investment in meeting the clean energy demands of an increasingly electrified world. Calpine worked with GE and the community of Santa Ana to realize the very latest in energy storage solutions.

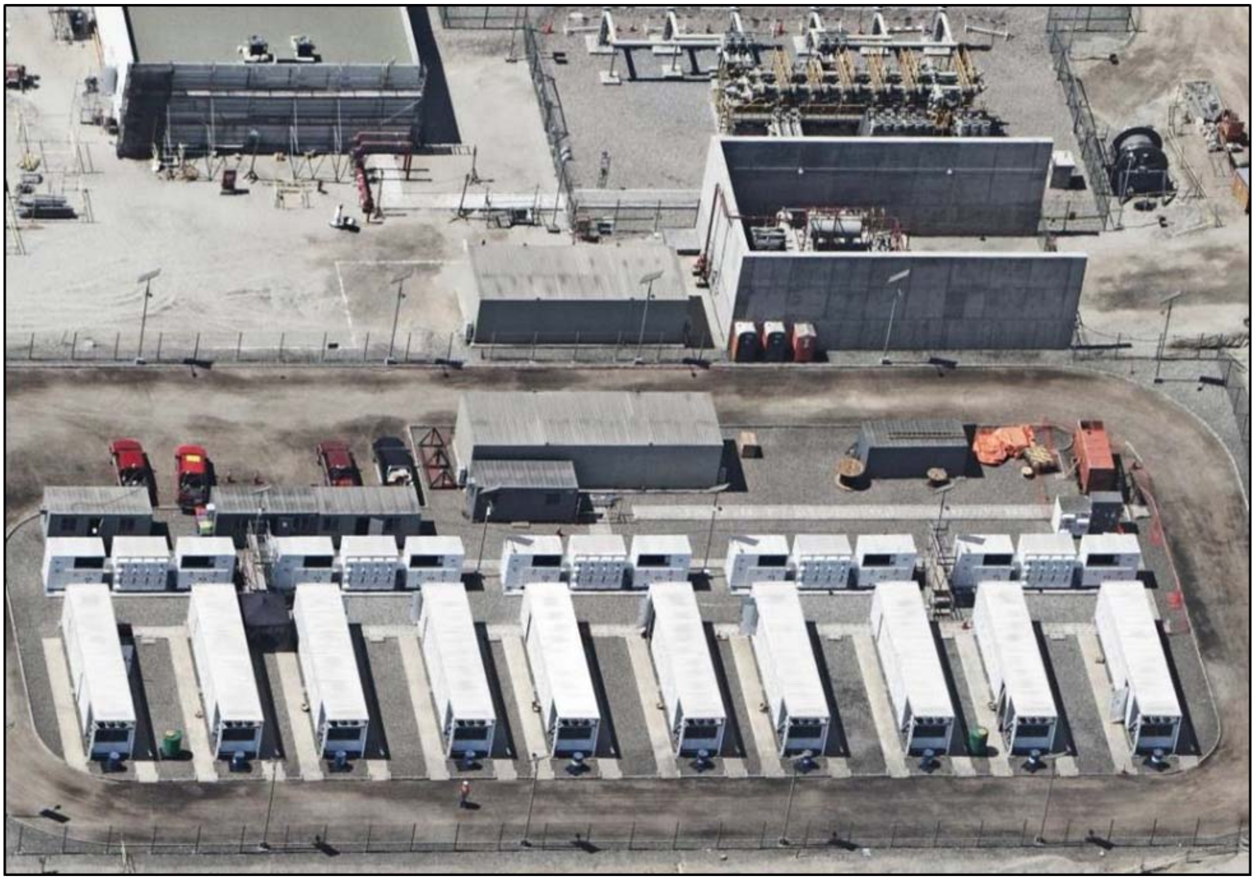
The energy storage system provides targeted local capacity to enhance grid reliability during peak periods, as fast-acting stabilization devices, the battery energy storage systems can charge and discharge rapidly to regulate frequency and contribute to grid stability, helping to balance and facilitate the ever-growing penetration of variable renewable energy.

GE's Reservoir is a flexible, compact solution that combines GE's advanced technologies and expertise in plant controls, power electronics, battery management systems and electrical balance of plant – all backed by GE's performance guarantees.

Similar BESS Project in Chile

Exhibit 5 shows a 20 MW BESS facility in Chile that consists of ten 2 MW BESS containers and associated power conversion systems. This project is similar to the proposed BESS project at FREC.

Exhibit 5 Aerial View of 20 MW BESS Facility in Chile



4 Proposed BESS Equipment and Arrangement

The proposed BESS project at FREC is not defined in detail currently. As project development activities progress, more details and improvements will be confirmed.

4.1 Site Visit

On October 8, 2021, the Lummus Consultants representative, Mr. John Senner and Mr. Jay Peterson, participated in a site visit at FREC. During the site visit, Mr. Senner and Mr. Peterson met with WFD Deputy Chief Justin Myers and Mr. Charlie Parnell, the FREC General Plant Manager. A general tour of the site included the proposed BESS area. Following that briefing, Mr. Peterson requested copies of selected documents for further review. **Exhibit 6** shows the proposed area for the BESS containers.

Exhibit 6 Aerial View of Proposed Area for BESS Facility

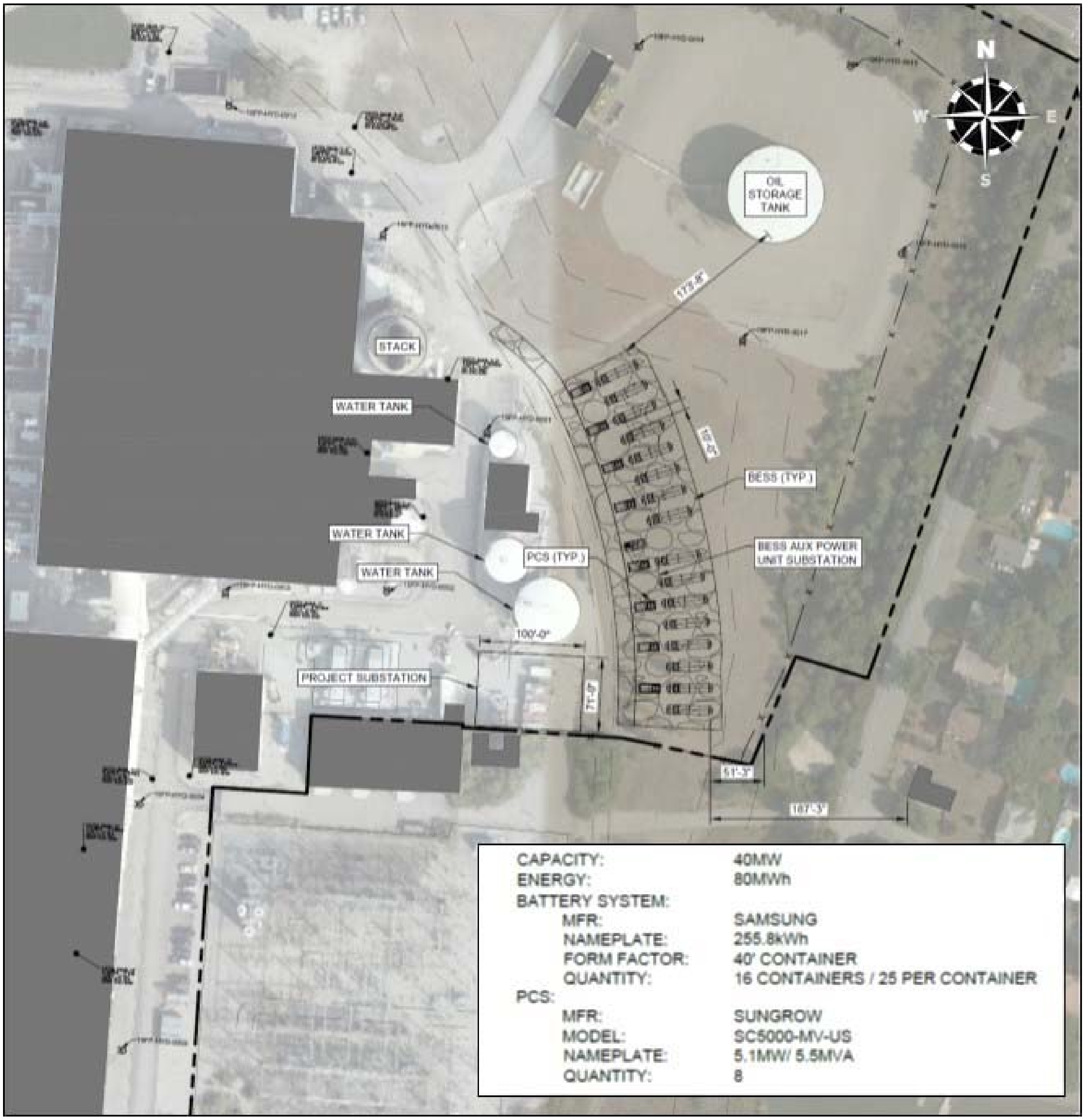
4.2 Proposed BESS Project Description

The latest general arrangement drawing revision C for the BESS project at FREC (Weymouth-GA-0001) was prepared by Mott MacDonald and dated July 29, 2021. That drawing included the following general BESS equipment description for a 40MW/80MWh (2-hour) project:

- 16 containers, 40’ each, 25 Samsung battery modules in each, 255.8 kWh per battery module;
- 8 Sungrow PCS, model SC5000-MV-US, 5.1 MW/5.5 MVA; and
- Spacing between containers is 10 feet.

Exhibit 7 is an extract from the Mott MacDonald drawing which shows the arrangement of the equipment.

Exhibit 7 Proposed BESS Facility at FREC



Calpine provided a "Battery Energy Storage (BESS) Specification" issued for preliminary review. The specification is intended for the solicitation of bids for the provision of a BESS. As no contractor has been selected for the BESS at FREC, there are limited technical details to review. However, we do note that one of the requirements of the specifications is conformance with various codes and standards. The codes and standard referenced are appropriate for a BESS.

5 Proposed BESS Proximity to Existing Plant

FREC is located at 9 Bridge Street in Weymouth, Massachusetts on approximately 36 acres of land on the east shore of the Weymouth Fore River and south of the Fore River Bridge. The site is a congested industrial area with very limited open space. There are multiple easements which limit the placement of new equipment. There is a residential neighborhood adjacent to the eastern side of the site, which must be considered in the plans for adding new facilities.

5.1 FREC Site Restrictions

FREC is a nominal 775 MW, dual-fuel, combined cycle power plant. Power is generated through two combustion turbines and one steam turbine. Heat Recovery Steam Generators are located on the exhaust end of each CT and increase the MW output capability of the power block. The physical facility of the power plant consists of a Main Building structure housing a Turbine Building, a Warehouse, and a Maintenance Building. This Main Building structure is encircled by a paved access road referred to as the "loop road." In addition to the three turbine units, the administrative offices and industrial wastewater treatment facilities are housed in the Turbine Building. The stack for the turbine exhaust and an auxiliary boiler is located outside the east wall of the Turbine Building. An oil storage tank, containment dike, and Oil Pump House are located northeast of the Main Building. A combination Fire/Service/Demineralized Water Pump House with associated water storage tanks area is located across the loop road, east of the Main Building. A Gas Compressor Building is located directly across the loop road south of the main entrance to the Main Building. Two Black Start Generators are located east of the Gas Compressor Building and directly across the loop road south of the Main Building. The elevated air cooled condenser structure is located south of the Main Building with air cooled condenser support buildings located at the ground elevation below the condensers. The principal power transformers, Diesel Generator Building, the oil/water separator, and the wastewater retention basin are located outside the west wall of the Main Building.

There is a large open grassy area that is the potential location for the BESS. However, there are significant restrictions which limit the actual space available. **Exhibit 8** illustrates the area around the proposed BESS location.

Natural Gas Transmission Easement

Natural gas is supplied to FREC through a natural gas transmission pipeline (operated by Enbridge Energy) that crosses the site to a Gas Compressor House located on the southern boundary of the property. The pipeline is a 30 inch diameter steel line buried three feet below grade. The area available for the BESS is limited on the eastern side by the easement for the natural gas transmission pipeline. **Exhibit 9** shows the surface markers for the path of the natural gas transmission pipeline within the Algonquin Gas Transmission Company easement. The path of the Algonquin easement also blocks the space available to the north of the proposed BESS area.

The proximity of the BESS to the underground natural gas transmission pipeline was not considered to be an additional fire or explosion risk to the pipeline. The pipeline is located underground so has some protection from heat released in a fire. Additional analysis would need to be performed to evaluate whether the gas flow in the pipeline would need to be shut-off in the event of a BESS fire. The BESS fire in Arizona resulted in an explosion when the BESS container was opened. The fire suppression gases dissipated when the container was opened allowing the rapid combustion of accumulated organic vapors. The resulting explosion injured the first responders and caused damage to the BESS container. Improvements to the fire protection systems for Li-ion BESS facilities should eliminate the risk of a similar explosion but if one were to occur, the damage would be to the surface facilities. Explosions follow the path of least resistance, which would be through the side and roof of a BESS container. The container floor and the supporting concrete pad are stronger than the side and roof, so would direct any explosion up and out. Consequently, we do not believe the nearby underground natural gas pipeline would be affected.

Lummus Consultants was also asked to evaluate the potential impacts on the BESS facility from a gas leak/fire from the natural gas transmission pipeline. A significant gas leak from the pipeline in the area adjacent to the BESS facility would be highly unlikely. It is difficult to evaluate hypothetical scenarios that have such low probabilities. If there were a significant gas leak from the natural gas transmission pipeline that resulted in a fire, the main concern would be with other flammable materials on the site, such as the fuel oil in the storage tank. A BESS container is not by itself flammable. It would require that the batteries inside the container be heated in order for the BESS facility to be impacted.

Eversource Power Transmission Easement

The area available for the BESS is limited on the western side by the Eversource easement for underground power transmission cables. **Exhibit 8** shows the Eversource easement between the proposed BESS substation area and the curved area for the proposed BESS containers.

Site Property Line

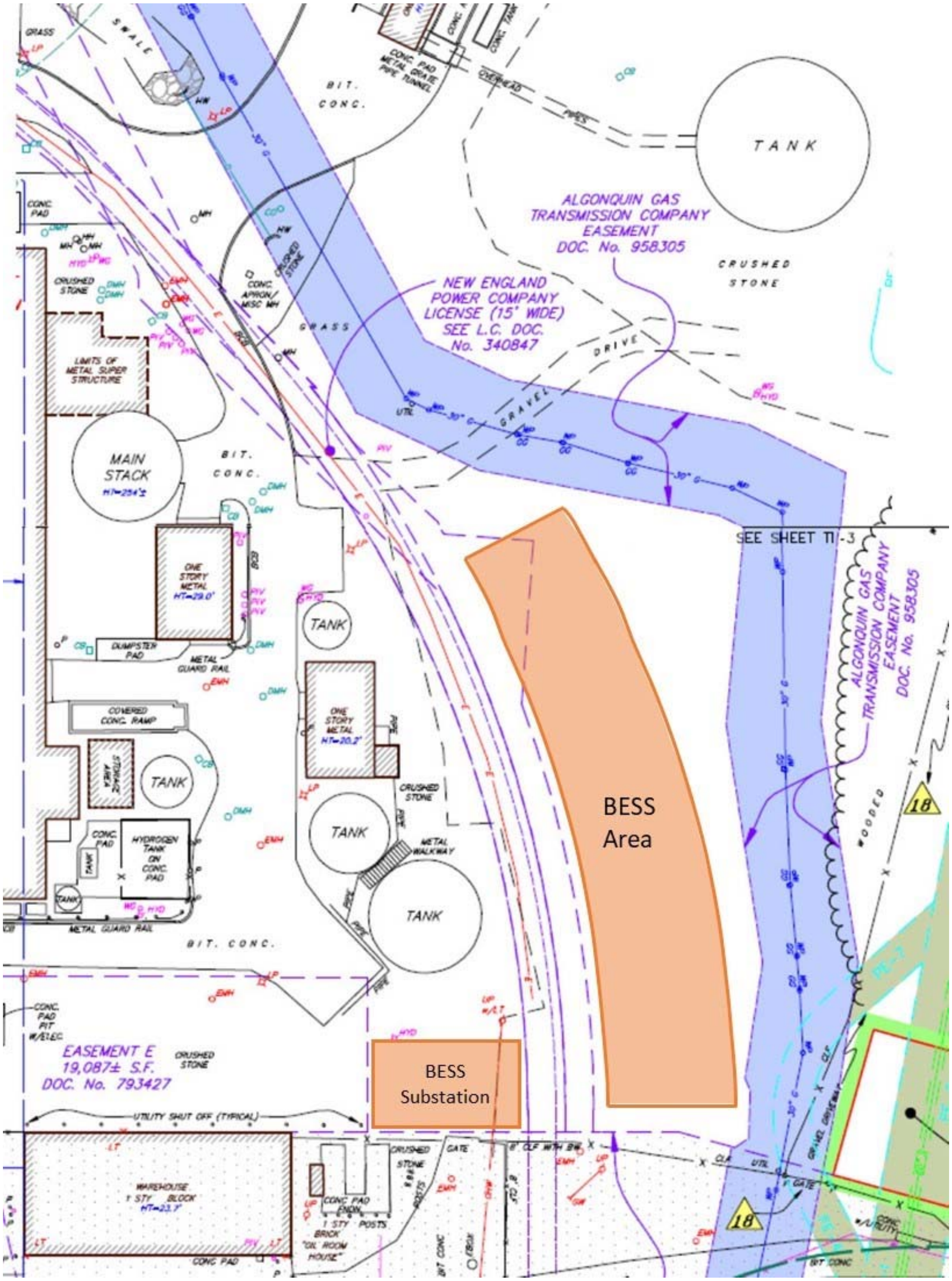
The FREC site property line limits the space available to the south of the proposed BESS area.

5.2 FREC Equipment Limitations

FREC's dual-fuel capability is achieved by combusting either natural gas or ultra-low sulfur diesel fuel ("ULSD"). ULSD is typically transferred to the bulk oil storage tank (Tank 36) via a 6-inch inter-facility pipeline connected to the Sprague Energy Corporation petroleum terminal located on the west shore of the Fore River. This pipeline runs through a tunnel under the Fore River. Tank 36 is a 2.25 million-gallon ULSD storage tank located northeast of the Main Building near the eastern property line and south of Route 3A (Bridge St.). The adjacent Fuel Oil Pump House contains two transfer stations to accept tank truck deliveries of ULSD. A containment dike surrounds the storage tank. This ULSD infrastructure limits the space available for the BESS north of the open grassy area.

The Fire/Service/Demineralized Water Pump House with associated water storage tanks area is located across the loop road, east of the Main Building. This infrastructure limits the space available for the BESS on the western side of the open grassy area.

Exhibit 8 Proposed Area for BESS Facility



5.3 Adjacent Neighborhood

The neighborhood along Monatiquot Street and further east must be considered in the plans for adding new facilities at FREC. The primary concerns would be adverse noise and visual impacts. This suggests maximizing the distance from new BESS equipment to nearby residents. The arrangement of the new BESS equipment should be as far as possible from the eastern site property line.

Lummus Consultants expects the low profile of the new BESS equipment will not impose any additional adverse visual impact on the community.

Exhibit 9 Proposed BESS Area at FREC

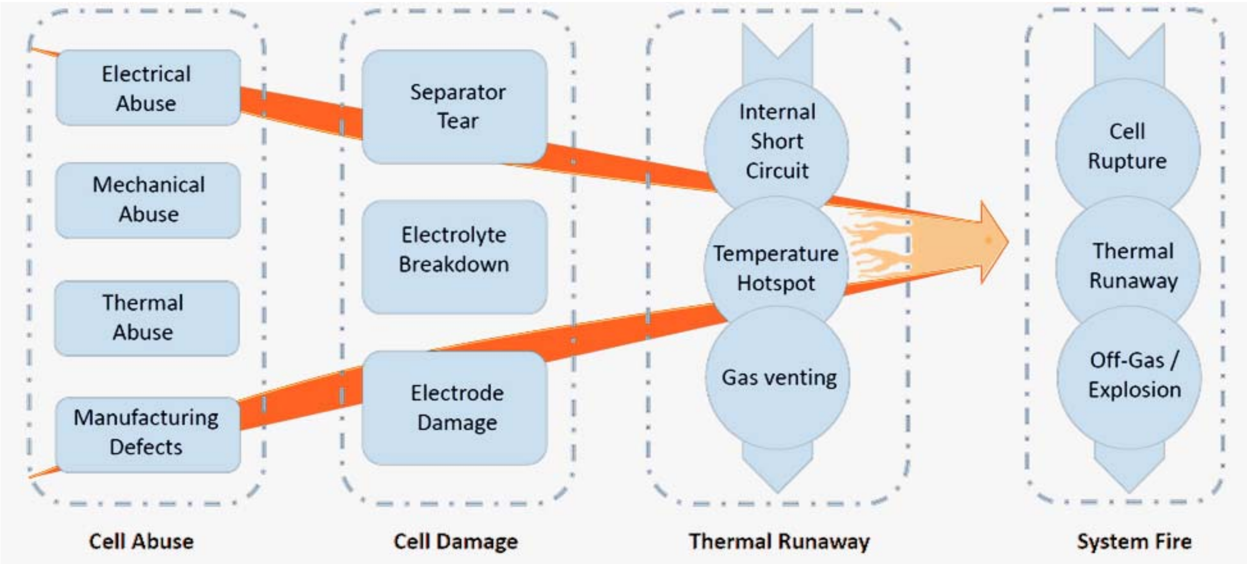
6 Causes of Li-ion BESS Fires

One of the challenges with batteries, and in particular lithium ion batteries, is the potential for fires. Fires result from a fault in a battery cell that results in a cell becoming overheated, causing deterioration and eventual failure of the cell separator, with subsequent electrolyte decomposition and volatilization. This leads to a thermal runaway venting in the cell that can then propagate to other cells in an energy storage battery module. The vented thermal runaway causes flammable gas to be emitted into the battery enclosure, where the resulting flammable mixture can be ignited by hot module casings, electrical connectors, or ejected sparks from the involved module. The flammable gases are generated by heating of the organic electrolyte.

The initiating event can be a fault caused by a manufacturing defect, physical damage, or electrical damage. A manufacturing defect could be a defective separator, or the presence of contaminants such as moisture or metal particles in a cell. Physical damage can be caused by mishandling the battery or operating or storing the battery at a high or low temperatures or charging the battery at low temperature. Electrical damage can be caused by overcharging and deep discharge events.

The pathways to a Li-ion BESS fire are shown in **Exhibit 10**. It takes multiple steps to achieve a thermal runaway event and then a fire and explosion.

Exhibit 10 Pathways to Li-ion BESS Fire



Three different runaway gas explosion hazard scenarios can occur.

1. In one scenario (Prompt Explosion Event), the flammable gas mixture is ignited soon after it is formed near the initiating module, such that there is only a minor deflagration and a subsequent fire.
2. In the second scenario (Delayed Explosion Event), batteries in thermal runaway release flammable gases without igniting initially, and a delayed explosion associated with the accumulation of additional flammable atmosphere then occurs.

3. In the third scenario (Delayed Explosion Event), there is an initial fire with accumulation of incomplete combustion products and possibly fire suppression agent, until something happens, e.g. oxygen addition to the rich gas mixture, to suddenly render the mixture ignitable.

While there is only a short amount of time between cell damage and thermal runaway, there is sufficient time for monitoring equipment to recognize the condition and shut down the BESS. Even if a thermal runaway event results in a fire, there are systems that can prevent explosions from occurring.

6.1 Recent Li-ion BESS Fire Events

There have been recent Li-ion BESS fire events in South Korea, Arizona, and England.

South Korea — Multiple BESS Facilities

Beginning with a battery energy storage system fire at a wind farm in Gochan County, Jeollabuk-do in August 2017, there have been more than 25 Li-ion BESS project fires reported within South Korea.

On December 12, 2018, the South Korea Ministry of Technology, Industry and Energy ("MOTIE") commissioned the "Joint ESS Fire Accident Investigation Committee" with the goal of objectively evaluating the causes of these fires and preventing future occurrences. Initially, most of the installations which caught fire in South Korea were completely burnt and the investigation committee found it difficult to identify the root cause(s) of the fires.

As part of the ongoing investigation, the committee analyzed relevant information from available data, company interviews, field visits and in-depth discussions with experts. After the investigation was completed, the committee identified four probable root causes for the fires:

1. **Lack of battery protection against electric shocks**

   Systems were not able to properly protect against electrical hazards due to ground faults or short circuits. When large electrical surges were imposed on the battery system the fuse was not able to quickly interrupt the current which led to catastrophic failure of the contactors. The short circuit current allowed the failures cascade to the bus bar which resulted in fires inside the ESS. This failure mode was confirmed by the committee during their fire accident investigation.

2. **Insufficient oversight in the battery's environment**

   Of the fire incidents that occurred, at least 18 were installed in the mountains or coastal areas. It was concluded that these environments resulted in harsh conditions including large temperature swings, high humidity and elevated levels of dust and particulates which ultimately led to failure modes resulting in fires. The elevated humidity levels and large temperature swings resulted in condensation, and resulting residue after drying, within the battery system. This effect was determined to degrade the electrical insulation inside the battery modules between the cells and module ground which resulted in short circuits and subsequent fires. This cause was believed to be made worse by modules fans designed to air-cool the battery modules.

3. Inattention to installation details

It was determined that human error during installations can also lead to system faults resulting in ESS fires. Not many details were provided by the investigation committee, but cases such as faulty wiring or mechanical damage to the batteries during installation were sited.

4. Missing BESS integration controls and protection systems

The integrated protection and management systems were found to be insufficient with the BESS. It was confirmed by the committee that gaps in the integration of the BMS, Energy Management System ("EMS"), and Power Management System ("PMS") can result in conditions that lead to fire. Integration issues included inadequate information sharing between systems, system operating sequence, and checking for abnormalities of the batteries after Power Conversion System ("PCS") maintenance or troubleshooting.

The committee also identified defects in battery cells including cutting defects and poor coating of the electrode materials. However, testing over 180 charge and discharge cycles did not result in fires, so the cells defects were not listed among the root causes for the system fires.

A more detailed discussion of one of these events is discussed below.

An explosion event occurred at a 1.0 MWh Korean Li-ion BESS facility. The BESS consisted of 15 racks, each containing nine modules, which in turn contained 22 lithium ion 94 Ah, 3.7 V cells. A 250 kW PCS was connected to the battery through a Battery Control Panel. Electrical protection included module fuses and rack fuses.

The initiating event in this incident was a series of PCS faults. The faults occurred shortly after the battery was fully (95%) charged and began to discharge. However, the PCS faults produced a current reversal and forced battery charging, with a thermal runaway when the battery was at a 90.8% State of Charge ("SOC").

The electrical faults in this incident caused a cell voltage imbalance and ground fault in one of the battery modules. Data records indicate the cell voltage imbalance within the module rose to 3 V, whereas the battery manufacturer recommends the system be tripped when voltage imbalance exceeds 0.10 V. The corresponding recorded cell temperature rise was at least 64 °C, producing a cell temperature in excess of the 80 °C threshold for the onset of cell membrane deterioration and exothermic decomposition reactions. The absence of any battery data after the onset of thermal runaway suggests that the flammable electrolyte decomposition gases were ignited soon after thermal runaway in at least one module.

Recommended safety improvements included Surge Protection Devices and limitations on the charging rate and the maximum allowable SOC.

Arizona Public Service — McMicken BESS Facility, Phoenix, Arizona

On April 19, 2019, at around 5:41 p.m., a fire alarm was issued for Arizona Public Service's McMicken BESS in suburban Phoenix. The facility is a 2 MW, 2 MWh BESS and was housed in a container arranged to hold 36 vertical racks separated into two rows on either side of a 3-foot-wide hallway. Twenty-seven racks held 14 battery modules manufactured by LG Chem, an 80-kilowatt inverter manufactured by Parker, an AES Advancion node controller used for data collection and communication, and a Battery Protection Unit ("BPU") manufactured by LG Chem. The battery modules in turn contained 28 lithium-ion battery cells of nickel manganese cobalt (NMC) chemistry. These modules were connected in series, providing a per-rack nominal voltage of 721 volts. With 27 full racks, there were 10,584 cells in the container.

The facility was put into service in March 2017 and was equipped with an HVAC system to control the temperature in the BESS container and an automatic fire suppression system using a gaseous suppression agent (Novec 1230). **Exhibit 11** shows the McMicken BESS Facility.

Exhibit 11 Arizona Public Service — McMicken BESS Facility

Several cell thermal runaways occurred within one rack. The cause of the thermal runaway event is disputed with one study assigning the root cause to an internal short circuit due to abnormal dendritic growth within a single cell. A separate study conducted for the battery manufacturer concluded the initial thermal runaways were caused by external arcing near the cells.

The local fire department responded to the fire alarm with three fire engines, arriving at the scene within 10 minutes. Upon arrival at the fire site, firefighters observed a dense ground level white smoke or fog emanating from the BESS. The responding firefighters requested an additional mutual aid response from a HAZMAT team that was equipped with gas sensors to monitor CO and HCN concentrations. The CO and HCN concentrations in the cloud were above 500 ppm and 50 ppm, respectively. After conferring with Fire Department, APS, and contractor personnel, the HAZMAT team decided to delay accessing the BESS until the concentrations and vapor volume were reduced.

By shortly before 8:00 p.m. that night the external gas concentration and temperature readings subsided and the firefighters opened the BESS unit door. A visible white vapor cloud immediately poured out of the door as it was opened. One of the firefighters used a thermal imaging camera to measure interior temperatures, reported that the maximum temperature was 40 °C, and there was no visible flaming or arcing.

A few minutes after 8 p.m., an explosion occurred. The blast wave pressures and velocities propelled the firefighters, with one firefighter blown approximately 22 m away from the door, passing under a chain link security fence. A second firefighter was also propelled underneath the chain link fence, stopping 10 m from the door. The emerging jet flame from the ESU, which was observed to be at least 23 m in length and 6 m high, produced severe burn injuries. All four HAZMAT firefighters were hospitalized, two with severe burn and trauma injuries, including facial and head injuries despite their wearing helmets and face shields. Several other firefighters needed HCN decontamination and overnight monitoring in a hospital.

Although the cause of the initial thermal runaway is in dispute, there is no dispute about the cause of the explosion. The investigation verified that the Novec 1230 suppression agent had discharged as designed, but the system was inherently unable to curtail the progression of cell thermal runaways in the rack.

The Novec 1230 design concentration of 10 v% should have been sufficient to prevent ignition of the flammable gas generated from the initial cell runaways, but the agent concentration decreased as leakage occurred. In fact, the room integrity tests conducted upon commissioning of the Novec 1230 system indicated that the leakage rate was too large to retain the design concentration for 10 min, as required by NFPA 2001, 2015.

The DNV·GL and UL investigation reports suggest that the source of the white smoke or fog seen emanating from the BESS unit during this incident was probably Novec 1230.

The HCN measured by the firefighters was produced by the electrolyte decomposition and possibly by burning of polymeric materials in the battery.

When the APS BESS door was opened, a significant amount of Novec 1230 and other gases flowed out and were replaced with air. The resulting decreased residual Novec 1230 concentration and suddenly increased oxygen concentration, combined with runaway generated gases, formed a flammable mixture in a portion of the enclosure. The UL investigation report states that the flammable mixture producing the deflagration was ignited either by the still hot battery surfaces, by arcing, or by molten material generated and ejected in ongoing thermal runaways.

ØRSTED — Carnegie Road, Liverpool, England

Danish power company, Ørsted, installed a 20 MW Li-ion BESS facility at Carnegie Road Station in Liverpool, England that went commercial in early 2019. The BESS shown in **Exhibit 12** consisted of three battery containers, as well as the associated PCS, all supplied by NEC.

Exhibit 12 ØRSTED Carnegie Road BESS in Liverpool, England

In September 2020, a fire occurred at this BESS facility. The fire occurred in one of the battery containers on September 15, 2020. The local fire department responded at 1 a.m. and used water sprays to tackle the fire, asking residents nearby to keep their windows and doors closed due to smoke from the incident. The blaze went on for several hours. It was noted that by 7:30 a.m. the fire response at the site had been scaled down. A further update at 11:45 a.m. stated one fire engine was still at the scene, with firefighting still continuing, although by that stage only one hand-held pump was in use. News articles indicated that the incident was being investigated, but no root cause report has been issued to our knowledge.

6.2 Heat Release from Li-ion BESS Fire

The heat released from a Li-ion BESS fire can be highly variable. It depends on the battery design and chemistry and the manner in which the fire propagates (exposure to air/oxygen). Most Li-ion batteries have flammable electrolytes that will volatilize when heated and eventually ignite. The batteries, cable, and supporting equipment also have plastic components that burn when heated to a sufficiently high temperature.

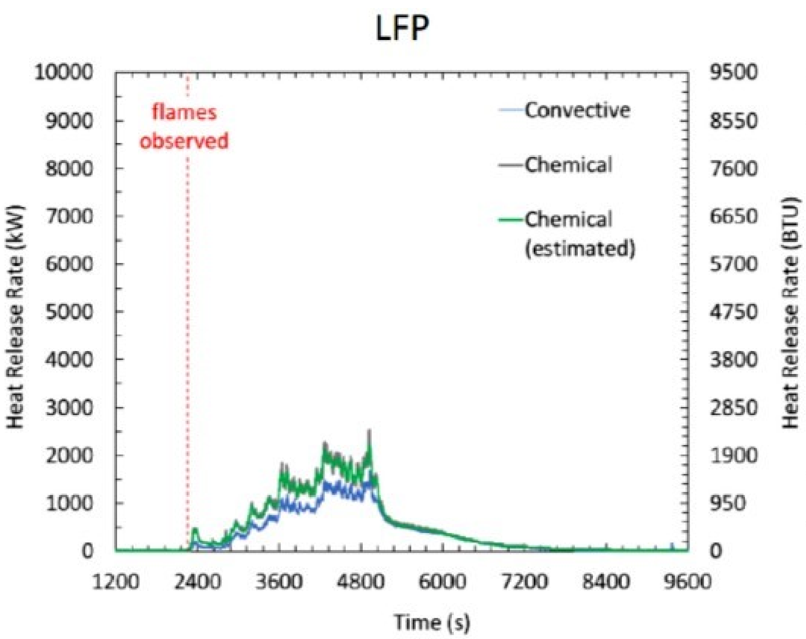
NFPA's Fire Protection Research Foundation issued a report on "Sprinkler Protection Guidance for Lithium-Ion Based Energy Storage Systems" dated June 2019. The report referenced data from FM Global on burns of various Li-ion battery technologies including the heat release measured during the trial burns.

Two different Li-ion battery chemistries were tested – Lithium Iron Phosphate (LFP) and Lithium Nickel Oxide/Lithium Manganese Oxide (LNO/LMO). The large-scale free burn tests were conducted with the LFP and LNO/LMO equipment to evaluate the overall fire hazard and performance of sprinkler protection. The two large-scale free burn tests were conducted with full ESS racks located in an indoor open-air environment under a 20-MW fire products collector. This approach allowed for real-time measurement of the chemical and convective heat release rate from the fire and magnitude of radiant exposure to surrounding objects, which was used to compare the relative hazard of the LFP and LNO/LMO systems.

The free burns were conducted on a full rack of each type of battery. The LFP rack had an energy capacity of 83 kWh and included 16 modules, each with 78 batteries. The LNO/LMO rack had an energy capacity of 125 kWh and included 16 modules, each with 64 batteries.

The LFP modules burned at between 400 to 600 °C until the fire self-extinguished. **Exhibit 13** shows the LFP heat release rate diagram along with key test results. The total chemical energy released over the fire duration was approximately 2.7 MMBtu/hr for an 83 kWh rack of LFP modules. This is equivalent to 32.5 Btu/Wh (34.3 kJ/Wh) of battery capacity.

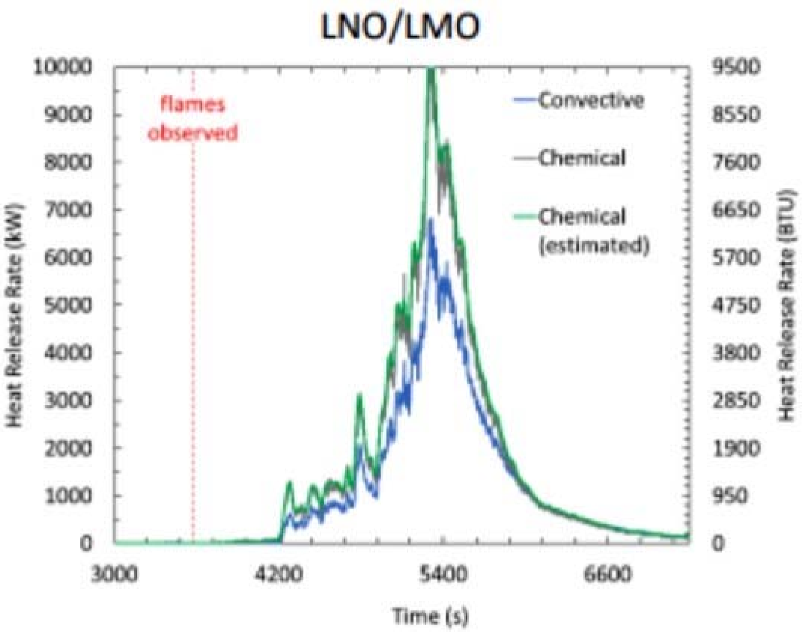
Exhibit 13 LFP Heat Release Rate Diagram



1. Time to Ignition	2,250 secs
2. Peak Chemical HRR	2,540 kW / (2,407 Btu/s)
3. Peak Convective HRR	1,680 kW / (1,592 Btu/s)
4. Total Chemical Energy Release	3,810 MJ / (3,613,600 Btu)
5. Total Convective Energy Release	2,770 MJ / (2,627,200 Btu)
6. Nominal Fire Duration	4,750 secs
7. Burn Out (HRR<100 kW)	7,270 secs
Average HRR (4 /(6 – 1))	2.7 MMBtu/hr

Initially, the LNO/LMO modules followed a similar heat release as the LFP modules but at around 5,000 seconds into the free burn, the heat release and temperature spiked up with the combustion temperature then rapidly increased to over 1,000 °C. **Exhibit 14** shows the LNO/LMO heat release rate diagram along with key test results. The total chemical energy released over the fire duration was approximately 7.3 MMBtu/hr for a 125 kWh rack of LNO/LMO modules. This is equivalent to 58.4 Btu/Wh (61.6 kJ/Wh) of battery capacity.

Exhibit 14 LNO/LMO Heat Release Rate Diagram



1. Time to Ignition	3,565 secs
2. Peak Chemical HRR	10,660 kW / (10,100 Btu/s)
3. Peak Convective HRR	6,840 kW / (6,480 Btu/s)
4. Total Chemical Energy Release	6,390 MJ / (6,060,600 Btu)
5. Total Convective Energy Release	4,668 MJ / (4,427,400 Btu)
6. Nominal Fire Duration	3,000 secs
7. Burn Out (HRR<100 kW)	7,270 secs
Average HRR (4 /(6 – 1))	7.3 MMBtu/hr

The Research Institute of Sweden issued a presentation dated March 2018 on the Thermal Propagation of Lithium-Ion Batteries. In the presentation, the total heat release from a Li-ion battery fire was estimated at between 17 and 75 kJ/Wh. The free burn test results fall into the middle of this range.

For the BESS at FERC, each container is proposed to have twenty-five 256 kWh racks/modules for a total container electrical capacity of 6,400 kWh. The heat released from a full container fire would range from 208 MMBtu (32.5 Btu/Wh x 6,400,000 Wh) to 374 MMBtu (58.4 Btu/Wh x 6,400,000 Wh). Assuming a fire duration of 4,000 seconds for each rack/module and the fire initiation is staggered by 2,000 seconds for each rack/module, the total fire duration would be 14.4 hours (25 racks/modules x 2,000 seconds + 2,000 seconds). Consequently, the average heat release rate would range from 14.4 MMBtu/hr to 26.0 MMBtu/hr. If the fire progresses more rapidly, the heat release rate would be greater.

7 Local Firefighting Capabilities for Li-ion BESS Fires

There are significant local firefighting capabilities available if needed for an incident at the BESS. The primary response would be from the Weymouth Fire Department, with support from adjacent fire departments as requested.

Weymouth Fire Department

The Weymouth Fire Department is comprised of 99 paid, permanent, full-time uniformed members, operating four engine companies and one ladder company. Annual responses average 7,500 incidents. There is an extensive and on-going training program to ensure all firefighters have the knowledge, tools, and techniques needed to protect personnel and property.

Weymouth Fire Department Station One, shown in **Exhibit 15**, is located at 195 North Street in North Weymouth. Station One is one mile from FREC. Engine One could be dispatched and arrive at the BESS within a few minutes of an alarm notification. Engine One is a 2018 Pierce Enforcer, which carries four firefighters and adequate equipment for an initial response to the situation. Engine One has a pumping capacity of about 1,500 gpm.

Exhibit 15 Weymouth Fire Department Station One

Additional Weymouth Firefighting Resources

Additional resources are available in the Weymouth Fire Department. Current procedure would dispatch three engines and one ladder company as a special response to an incident at FREC. The response would include a Tier 1 Hazardous Materials response from the State HazMat team. Station Two is located at 636 Broad Street. Station Two has Engine #2 (2014 Pierce Enforcer). Station Three is located at 138 Winter Street in Weymouth. Station Three has Engine #3 (2020 Pierce Enforcer) and Ladder #1 (2020 Pierce Enforcer). Station Five is located at 246 Park Avenue in South Weymouth. Station Five has Engine #5 (2021 Pierce Enforcer) and a Mass Decontamination Unit.

Quincy Fire Department

If the situation demands additional resources, Weymouth Fire Department receives mutual aid from the Metro Fire District, as well as Norfolk and Plymouth Counties. The closest support is available from Quincy Fire Department Station Three, shown in **Exhibit 16**. Quincy Fire Department Station Three is located at 615 Washington Street in Quincy Point. Station Three is only three-quarters of a mile from FREC. Engine Three could be dispatched and arrive at the BESS within a few minutes of a request for assistance. Engine Three carries four firefighters and adequate equipment to support an increased response to the situation. Engine Three has a pumping capacity of about 1,250 gpm. The Quincy Fire Department has seven other fire stations strategically located throughout the City of Quincy.

Exhibit 16 Quincy Fire Department Station Three

Summary

The first priority in an emergency response is life safety, and then its fire suppression. Lummus Consultants believes there are adequate emergency response resources and professional trained personnel located near the proposed BESS to provide a timely reaction commensurate with the severity of an incident. There is minimal risk of a delayed response or insufficient resources to control a fire in the proposed BESS.

8 Recommendations to Mitigate and Manage Fire Risks

Recommendations to mitigate and manage fire risks include BESS best practices, battery thermal management, fire detection measures, fire suppression methods, and explosion/deflagration protection.

8.1 BESS Best Practices

The Advancing Contracting in Energy Storage ("ACES") Working Group is an independent industry led and funded effort founded to develop a best practice guide for the energy storage industry. ACES prepared and issued its "Energy Storage Best Practice Guide" in December 2019. One of the topics covered in the guide was Safety.

Safety Best Practices start with safety standards and model codes. The components of a BESS should be tested using established procedures to confirm that they have met applicable safety standards. The installation of the BESS would subsequently be in accordance with adopted standards for the installation, as well as the overarching standards and model codes that cover many topics including BESS safety.

Exhibit 17 provides a snapshot of key safety-related standards, model codes, and guidelines that apply to energy storage systems.

Exhibit 17 Key Safety-Related Standards, Model Codes and Guidelines

Best practices can be simplified by being able to provide specific information related to safety, as well as performance and reliability. Best practices are as follows:

1. The BESS product has documentation that verifies it has been tested to relevant safety standards and its performance and reliability have been measured and are reported in accordance with applicable test standards covering performance and reliability.
2. The BESS product has been listed by an accredited third-party entity involved in a conformity assessment that validates that the continued production of the BESS product is consistent with the product sample(s) tested per practice item one.
3. The installation and commissioning of the BESS product is in accordance with the codes, standards and regulations that directly apply to the components and systems specified and the site where the BESS product is installed, and that its operation, maintenance, and any addition, repair, or renovation to the BESS meets those same codes, standards, and regulations.
4. Where the BESS product and installation does not conform to the aforementioned practices, it has been field evaluated by an accredited or recognized third-party entity to document that it is at least equivalent in terms of safety, performance, and reliability.

8.2 Battery Thermal Management

The proper thermal management of a Li-ion BESS is critical to mitigating many of the fire risks associated with a Li-ion BESS. Typical lithium batteries have an ideal temperature of about 25 °C (77 °F). Significant deviation from this temperature, both warmer and cooler, may have severe consequences.

Charging a Li-ion BESS at low temperatures accelerates dendrite growth, which has been linked to thermal runaway. Once thermal runaway is started in one battery cell, it can cause a chain reaction within the enclosure. The best approach to reduce exposure to dendrite growth is to properly control the Li-ion BESS ambient conditions so that a low temperature charging event does not occur.

Overall performance of the system is also closely tied to the thermal condition of the battery cells. Both charging and discharging add heat to the battery and must be regulated in relation to the thermal state. Charge and discharge must also be limited at both high and low battery temperatures.

For a co-located facility, such as the BESS Facility at FREC, the thermal management system should be tied into the power plant control system to allow the plant operators to monitor the temperature within each of the enclosures.

Air Cooling and Heating

The most common method of transferring thermal energy both away and into batteries is through air cooling and heating. Air cooling and heating can be accomplished using commonly available HVAC units. Li-ion battery packs are designed to shed heat to the outer case. From there, it is assumed that the provided air movement removes the heat. Proper care must be taken to ensure the even distribution of air flow around the battery packs.

Liquid Cooling and Heating

Liquid cooling and heating is a more effective means of controlling the Li-ion BESS environment. Water has the ability to absorb more energy than air so allows for better thermal stability of the battery during times of temperature extremes. The capabilities of air cooling versus liquid cooling is mostly a question of power density. Each method will have a power density limit that it is capable of cooling. The balance of size, weight, complexity, performance, safety, and cost need to be considered—and will vary depending on the conditions.

Battery Management Integration

The Thermal Management System should not be an afterthought. Communication with the Battery Management System is a significant benefit of integration with the battery unit at the design level. Fault mitigation and performance optimization are just a couple of benefits. The combination of a Battery Management System and a Thermal Management System make many more options and proactive actions available to quickly and actively suppress and eliminate thermal fault events. A well designed and executed TMS system that is working with, and receiving key directives from the BMS can potentially expand the battery unit's operational capabilities to a significant degree.

8.3 Fire Detection

Various fire detection options are available to identify the stages of thermal runaway: temperature increase, off-gases, smoke and flame. The earlier a malfunctioning battery is detected, the sooner fire suppression systems can be activated. Detection options, from slowest to quickest to activate, include:

- Traditional Spot and Heat Detection – Placed inside the BESS enclosure to detect presence of smoke or heat. However, by the time traditional detection activates, thermal runaway of a lithium ion battery is well underway. This method is not recommended for those who hope to suppress the fire and preserve the BESS.
- Thermal Imaging – Mounted outside to monitor multiple BESS units for increased temperatures from the HVAC exhaust vents. Thermal imaging provides an economic alternative to other methods which require detection within each BESS unit.
- Gas Detection – Detects presence of off-gas within a BESS unit once it reaches a certain threshold.
- Integrated Gas and Smoke Detection – Continuously samples the air for presence of gas or smoke particles within a BESS unit.
- Localized Gas Detection – Provides localized gas detection and reporting within individual lithium ion battery racks.

8.4 Fire Suppression

Fire suppression systems are needed if a Li-ion BESS experiences thermal runaway. Two systems are commonly used. The first is a water mist system that use fine water droplets to clear the air of combustible gas and particulates, while providing a prolonged cooling effect to help inhibit the transfer of heat from one cell to another. Finally, water mist is safe to use for protecting and preserving electronics.

Gaseous agents (such as 3M Novec™ 1230 Fire Protection Fluid™, FM-200) can also be used. These gaseous agents suppress incipient fires and are ideal for electrical Class C fires detected within a transformer, inverter or HVAC motor. Gaseous agents require a certain concentration to be effective. As seen in the McMicken BESS fire, the gaseous agent was initially effective, but leaks followed by opening of the container reduced the concentration to a point where an explosion occurred.

8.5 Explosion/Deflagration Protection

A number of the most serious Li-ion BESS fires resulted in explosions. These could have been avoided or the damage minimized if the BESS container had been equipped with explosion vent panels. If a deflagration occurs within a BESS container, the explosion vents installed on the top of the container will burst at a predefined low burst pressure, releasing the pressure and flames in a controlled way and thereby preventing an uncontrolled rupture of the container. Explosion vents are "passive" protection devices.

9 Management of Potentially Hazardous Fire Byproducts

Potentially hazardous byproducts of a fire at the proposed BESS include toxic smoke and wastewater from firefighting activities.

9.1 Smoke Produced from a Li-ion BESS Fire

In order to understand the potential hazards associated with Li-ion batteries, various tests have been conducted to simulate what occurs in a fire. In the "Hazard Assessment of Lithium Ion Battery Energy Storage Systems" prepared by the Fire Protection Research Foundation in February 2016, two fire tests were conducted. The first test used an internal heat source to ignite a Li-ion battery and the second test used on external heat source to ignite the battery. An internal fire would be similar to a thermal runaway event while an external fire simulates a fire expanding from an initial event to neighboring battery modules. The gaseous sampling showed typical products of incomplete combustion such as carbon monoxide (CO) as well as hydrofluoric acid (HF). The source of the fluorine in the HF is the lithium salt in the battery electrolyte. Other Li-ion battery tests have been conducted that show a wide range of HF emissions (20 mg/Wh to 200 mg/Wh) depending on the battery chemistry and configuration

During the external ignition test, the maximum range for the portable detector utilized in testing, which was 100 ppm, was exceeded after 30 minutes of burner exposure. During the internal ignition test, the maximum recorded HF was 26 ppm, as less battery cells were involved compared to the external ignition test. Both of these measurements are greater than the recommended exposure levels over an 8-hour period as specified by the Occupational Safety & Health Administration ("OSHA"). It is recommended that first responders don typical firefighting self-contained breathing apparatus ("SCBA") equipment when responding to an outdoor Li-ion battery fire. CO was also detected in both fire tests, though more significantly in the internal ignition fire test.

The actual gaseous emissions will depend on many parameters including cell chemistry, type of incident, state of charge, cell age, and ambient conditions. Common gases emitted include CO_2, CO, H_2, and hydrocarbons as well as fluorinated compounds. The gases originate from thermal decomposition and reactions of the electrolyte, binder, and electrode materials. Gaseous emissions from a smoke event will have a different composition than emissions from one with flames. Generally, events without flame/ignition will have worse gas compositions.

The application of a water mist on the battery test burns resulted in short-term spikes in HF production but no overall increase in HF production. It is speculated that a water mist would reduce the HF emissions from a BESS fire as some of the HF would be collected by the water droplets. The battery tests conducted involved a cell or multiple cells so may not accurately represent the effect of a water mist spray on the gaseous emissions from a BESS fire.

The gaseous emissions away from the location of the fire are difficult to estimate as they are dependent on the intensity and duration of the fire and the weather conditions. Based on our discussions with the Weymouth Fire Department, if the smoke plume from a Li-ion battery fire headed toward the eastern site boundary, firefighters would utilize a water spray fog to help direct the smoke away from the adjacent neighborhood.

9.2 Management of Firefighting Wastewater

Li-ion battery fires can be extinguished with large amounts of water. Water samples collected after extinguishing Li-ion battery fires can contain concentrations of fluoride and chloride.

FREC obtains potable and makeup process water from the Massachusetts Water Resources Authority ("MWRA") via the City of Quincy, then discharges industrial and sanitary wastewater to the Weymouth Sewer System, which is within the MWRA District.

Firefighting wastewater would be handled like stormwater. Site topography ranges between approximate elevations of 15 and 25 feet above mean low water. In general, drainage onsite flows from east to west toward the Weymouth Fore River. The site contains traditional subsurface drainage structures equipped with stormwater mitigation structures where stormwater is collected, inspected, and treated prior to discharge.

FREC operates three underground oil/water separators. A 3,000-gallon oil/water separator, located between the transformers and the ACC, is operated as a component of the Industrial Wastewater System. The two 2,000-gallon oil/water separators are dedicated to the treatment of stormwater run-off from the property. One is located directly to the east of Stormwater Basin No. 1 Fore Bay. The second is located outside the northeast corner of the main building.

Stormwater is discharged via three outfall points, identified as Outfalls 001 through 003, which are associated with three corresponding drainage areas. Outfall 001 discharges stormwater from industrial activities south of Bridge Street and is associated with the Facility North Plant Drainage Area as well as small areas of the North Parcel Drainage Area. Outfall 002 discharges stormwater from industrial activities south of Bridge Street and is associated with the Facility South Plant Drainage Areas. Outfall 003 discharges a combination of groundwater and river water collected in the fuel oil tunnel located north of Bridge Street and the storm water runoff from the North Parcel Drainage Area.

The majority of the stormwater from the North Parcel Drainage Area drains to the stormwater pond constructed by MassDOT (i.e., the bridge authority) during the construction of the new bridge and removal of the old bridge. This new stormwater basin is located in the northwest corner of the site near the bridge and is managed by MassDOT. Since groundwater and river water (analogous to spring water) are authorized non-stormwater discharges, the discharge from Outfall 003 is covered under the 2021 Multi-Sector General Permit. However, since the stormwater from the North Parcel Drainage Area is not associated with industrial activity, monitoring is not required for Outfall 003.

Areas of the facility with drainage from areas of industrial activity are directed to the detention basin systems. Deep sump catch basins are located upstream of the detention basins to enhance solids removal. Deep sump catch basins operate as traditional catch basins but with a deeper sump; they are able to collect and contain a larger volume of sediments. Stormwater Basin No. 1 and Forebay are located just north of the warehouse and maintenance shop; this system collects stormwater from around the turbine building prior to discharge to Outfall 001. Stormwater Basin No. 2 Forebay and Main Chamber under the ACC collects stormwater from around the ACC and Gas Compressor Building prior to discharge to Outfall 002.

The working capacity of Forebay No. 1 is about 50,000 gallons. Overflow from Forebay No. 1 drains to Stormwater Basin No. 1, shown in **Exhibit 18**. That basin is normally filled from elevation 8.6 feet (bottom of basin) to about elevation 14 feet, which is a capacity of about 325,000 gallons. The spillway on Basin No. 1 is at elevation 17 feet. The surge volume to fill the basin from 14 feet to 17 feet is about 290,000 gallons for a total capacity of about 615,000 gallons. Most of the firefighting wastewater would flow from the BESS area through the stormwater system to Forebay No. 1 and then to Stormwater Basin No. 1.

In the event of a fire in the BESS area, part of the emergency response would be the installation of a pneumatic "plumber's plug" in the discharge pipe of Stormwater Basin No. 1. This would make the surge volume available and prevent the premature release of firefighting wastewater to the Weymouth Fore River. This procedure would take just a few minutes and results in a more coordinated response to the incident.

The amount of water used to fight a fire at the BESS facility will depend on the extent and intensity of the fire. The equipment used to control the fire will have various capabilities. A ladder company can apply about 1,000 gpm to a fire. An engine company using a 2.50 inch hose can apply about 500 gpm to a fire. An engine company using a 1.75 inch hose can apply about 200 gpm to a fire. The duration of the fire and the approach taken to control it would determine the total amount of firefighting wastewater.

If the surge capacity of the stormwater basin is 290,000 gallons and there is a large fire with multiple engines responding, the total firefighting water could be 1,700 gpm or more. At 1,700 gpm, it would take almost three hours to fill Stormwater Basin No. 1. A small fire with one engine working a 500 gpm hose would take almost ten hours to fill Stormwater Basin No. 1.

In the event of a fire, FREC can call in a contractor to pump water out from Stormwater Basin No. 1 for off-site testing and treatment.

Exhibit 18 Stormwater Retention Basin No. 1 at FREC

10 Recommendations for BESS Noise and Visual Attenuation

At most power generation facilities, the primary generators of noise are the rotating equipment, such as the gas and steam turbines, large fans, and pumps. A BESS facility does not have any large rotating equipment, so is not a significant noise generator. Each of the BESS containers is full enclosed with the externally mounted HVAC systems. HVAC systems are a potential source for low levels of noise and can be mounted on the opposite side of the containers from the noise receptors to further reduce any low level noise generated.

It is anticipated that the new BESS equipment will not result in additional adverse noise or visual impacts on the community. Calpine would be required to comply with noise limits under its existing permits, as well as with State and local noise ordinances. If the noise levels exceed the limits, Calpine would be required to implement measures to mitigate the noise to be in compliance with its permits and the noise ordinances.

10.1 Review of Recent Noise Study

Lummus Consultants reviewed a recent noise study related to the addition of new equipment at FREC. The noise study prepared by Hessler Associates, Inc. dated July 28, 2017 evaluated the potential community noise impact associated with the installation of two black start diesel generator packages at FREC, shown in **Exhibit 19**. As part of this noise study, ambient noise levels were measured over a one-week period from July 22 to 29, 2017 at a location near the boundary with the residential area on Monatiquot Street. FREC went into an outage on July 28, 2017 allowing the measurement of sound levels both with and without FREC in operation. There was no meaningful difference in the sound levels measured during the outage period and prior to the outage when FREC was operating at full or partial load.

Exhibit 19 FREC Black Start Diesel Generators

In general, their analysis indicated that the generators will not produce a sound level that exceeds the minimum background sound level by more than 10 dBA and that the sound emissions from the generators will comply with the state noise standard. Their conclusion was the generators would result in little or no adverse noise impact on the community.

Lummus Consultants expects the noise level from the BESS equipment would be less than the black start diesel generators and less than the main power plant, so would result in little or no adverse noise impact on the local community.

It was noted during the site visit at FREC that the predominate ambient sound was traffic noise from Bridge Street (Route 3A), even with both generating units running and the air-cooled condenser operating.

10.2 Potential BESS Visual Impacts

There is already significant visual screening along Monatiquot Street to minimize visual impacts from FREC. There is an earthen berm along the property line planted with mature trees and a border fence. Calpine has offered to plant additional trees along the property line to further visually screen the site from the adjacent neighborhood. The density of this screening blocks almost all low-level views of the plant except for the top of the chimney.

Lummus Consultants expects the low profile of the new BESS equipment will not impose any additional adverse visual impact on the community.

11 Lummus Consultants Personnel

This section includes an experience summary for the Lummus Consultants personnel responsible for this assignment.

John J. Senner Director

Mr. Senner is a management consultant with over 30 years of consulting experience in the development, analysis, and financing of electric power generating and independent power facilities. He has evaluated all conventional power generation technologies and numerous non-conventional and renewable power generation technologies include solar photovoltaic and the combustion or gasification of biomass and municipal solid waste. He has provided support to numerous financial institutions, private equity firms, independent power producers, major municipalities, and special purpose entities on technical, environmental, and commercial issues related to power generation, solid waste management and independent power projects. The projects he is currently involved in include a new power project in Guam that consists of a combined cycle plant with a co-located battery energy storage system, a geothermal power project in Nicaragua, as well as several combined cycle power projects in Asia utilizing LNG as the fuel. He is also directing the independent technical review for the US Department of Energy of a carbon black and hydrogen production project in Nebraska. He has evaluated various power sales, fuel supply, and EPC agreements and developed detailed financial models to assess the financial feasibility of electric generation projects and generation companies. Mr. Senner joined Lummus Consultants International LLC (formerly Shaw Consultants International, Inc. and Stone & Webster Management Consultants, Inc.) in 1998 and is currently a Director.

Education

Cornell University, College of Engineering, BS in Chemical Engineering, 1983

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