Approval of revised Battery Safety Management Plan and Air Quality report Executive Summary

BST&T has conducted a thorough review of the Cleve Hill Solar Park (CHSP) Battery Safety Management plan (BSMP) including the Air Quality Battery Failure Plume Assessment and has agreed content revisions with Cleve Hill Solar Park Ltd (CHSPL), Envams, Hoare Lea and Kent Fire & Rescue Service (KFRS).

The review was undertaken on the understanding that:

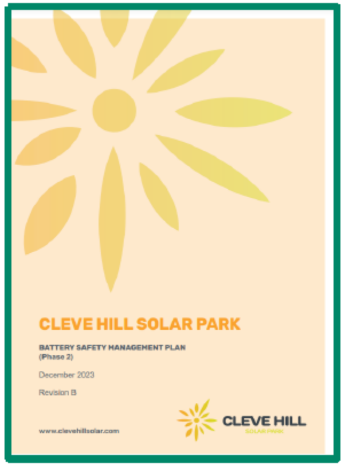
(1) Work No. 2(a) must not commence until a Battery Safety Management Plan (“BSMP”) has been submitted to and approved by the relevant planning authority.

(2) The BSMP must prescribe measures to facilitate safety during the construction, operation and decommissioning of Work No.2(a) including the transportation of new, used and replacement battery cells both to and from the authorised development.

(3) The BSMP must accord with the outline battery safety management plan.

(4) The relevant planning authority must consult with the Health and Safety Executive and Kent Fire and Rescue Service before determining an application for approval of the BSMP.

(5) The BSMP must be implemented as approved.



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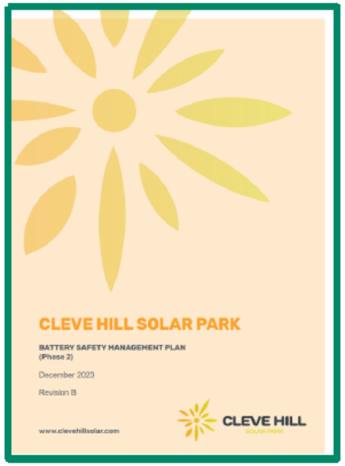
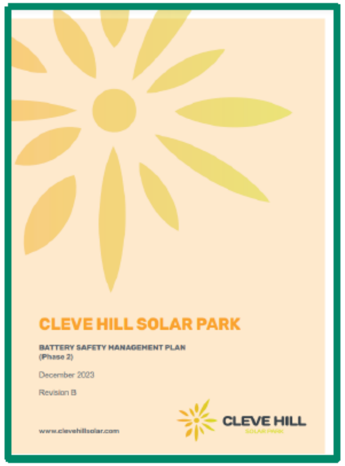
Approval of revised Battery Safety Management Plan and Air Quality report Executive Summary

BST&T Conclusions:

1. **The BSMP accords with the outline BSMP and incorporates the latest safety standards and best practice guidelines.**
2. **The BSMP prescribes measures to facilitate safety during the construction, operation and decommissioning of Work No.2(a) including the transportation of new, used and replacement battery cells both to and from the authorised development.**
3. **The developer has provided all requested information to Kent Fire & Rescue Service (KFRS)**
4. **Kent Fire & Rescue Service (KFRS) has been fully consulted by the developer and will send a note of approval of the BSMP to Swale Borough Council**
5. **The BESS manufacturer CATL has certified and tested the EnerC+ system to all requisite current safety and test standards. The final UL 9540 certification of the BESS enclosure is expected to be obtained in Q1 2024. For the avoidance of doubt, this upcoming certification is part of a normal ongoing compliance process and is not a legitimate reason to delay approval of the BSMP.**
6. **The EnerC+ BESS system and fire and explosion protection systems conform to NFPA 855 (2023) standards and incorporate additional levels of monitoring and controls which are considered to be best practice.**
7. **The site design and BESS system conform to UK National Fire Chiefs Council guidelines (2023), any deviations from these guidelines are agreed with KFRS**
8. **The developer will undertake additional site-specific risk analysis reviews once the contractor is appointed, these include site specific consequence modelling for first responders, HAZOP / Hazid operations peer review, Fire Protection System sign off, etc. This post-consent, pre-construction work is normal, and in line with current industry expectations and best practice.**



Approval of revised Battery Safety Management Plan and Air Quality report Executive Summary



To assist in the safety review the following additional test and safety documentation which cannot be shared in the public domain was provided by CHSPL to BST&T under a Non-Disclosure Agreement:

1. CATL EnerC+ BESS Hazard Mitigation Analysis (HMA) report by Jensen Hughes (USA) which was conducted to NFPA 855 (2023) standards.
2. CATL EnerC+ Fire Protection Assessment for NFPA 69 Compliance (explosion prevention standard) report by TLB Fire Protection Engineering, Inc. (USA) which was conducted to NFPA 855 (2023) standards utilising Computational Fluid Dynamics (CFD) modelling.
3. CATL EnerC+ UL 9540A (2019), 4th Edition: Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems. The EnerC+ system was compliant with all test requirements at Unit Level testing, cell and module level data was used to compile the NFPA 69 Compliance report.
4. CATL Interface of BESS Specification document (in depth analysis of system components).
5. Hazid / Hazop developer risk analysis for BESS fire or explosion scenarios.

Key standards that are met by the CATL EnerC+ BESS system selected for CHSP which are in line with expectations for BESS systems supplied by Tier one manufacturers include:

1. UL 9540 certification (full enclosure certification to be obtained in Q1 2024)
2. UL 1973 certification
3. BS EN IEC 62619 certification
4. NFPA 855 conformance
5. NFPA 69 conformance (explosion prevention)
6. UN 38.3 certification

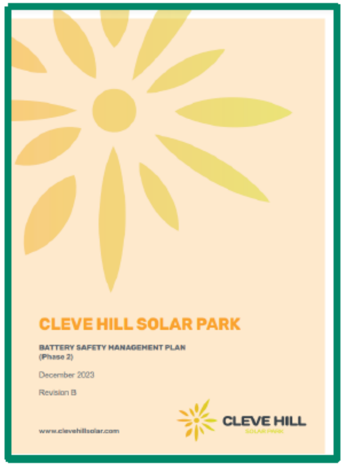
Approval of revised Battery Safety Management Plan and Air Quality report Executive Summary

The following amendments have been suggested to CHSPL and incorporated in Revision B of the BSMP:

1. Expansion of decommissioning content
2. Clarification to Fire Suppression content and check that system conforms to HMA recommendations
3. Inclusion of commitments to Cybersecurity standards and best practice
4. Additions to Emergency Response Planning detail
5. Exclusion zone radius increased to comply with the latest NFPA 855 (2023) recommendations
6. Clarification to include data analytics into Energy Management System (EMS) / Battery Management System (BMS) systems and controls
7. Confirmation that Factory Acceptance Testing (FAT) and Site Acceptance Testing (SAT) for BESS equipment will be to BS EN IEC 62933-5-2 standards or equivalent
8. Confirmation that UN 38.3 certification is required for replacement battery systems or components
9. Commitment to integrate multi-sensors to provide alerts for any potential battery abuse that takes place during BESS system transportation
10. Revised Air Quality Battery Failure Plume Assessment Report to ensure conservative modelling inputs

Summary of key safety measures and hazard mitigation incorporated in the CHSPL BESS and considered best practice:

1. Discharge of the aerosol fire suppression system shall be limited to only true "electrical" fault fires shall not trigger in the event of a Thermal runaway, this shall be managed by the fire alarms control logic and be validated by additional analytics provided by the BMS and EMS, this final system design shall be validated by an appointed British Approvals for Fire Equipment (BAFE) accredited specialist to ensure its compliance to the standards named. The Fire suppression system includes a manual and emergency deactivation button located externally to the BESS enclosure to allow manual deactivation in an emergency and deactivation by engineers when entering or opening the container to perform inspections and/or maintenance activities.
2. Data analytics and comprehensive programmable logic controllers (PLC) integration of key monitoring and detection functions into EMS / BMS, this provides significant early warning safety alerts and system shut down capabilities and allows for greater protection against false discharge of fire suppression systems



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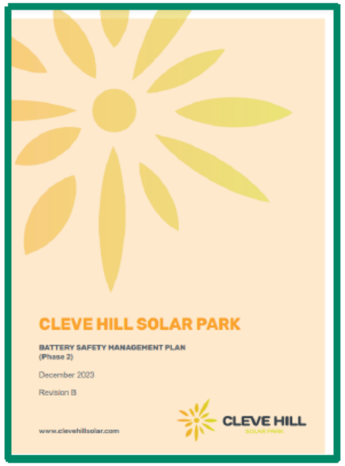
Approval of revised Battery Safety Management Plan and Air Quality report Executive Summary

Summary of key safety measures and hazard mitigation incorporated in the CHSPL BESS and considered best practice *(continued)*:

3. BESS fire protection products conform to both NFPA and BS EN standards
4. Carbon Monoxide detectors are integrated to provide additional safety alerts for first responders
5. Adoption of 6 metre spacing which exceeds NFPA 855 (2023) recommendation between BESS enclosures because full scale free burn testing had not been conducted to establish heat flux levels (not stipulated in any standard)
6. Compliance with all requests made by Kent Fire & Rescue Service (KFRS) and KFRS approval of revised BSMP
7. The revised Air Quality Battery Failure Plume Assessment Report analysed free burn test data from similar LFP BESS systems and concluded that levels of Hydrogen Fluoride (HF) used in the modelling were conservative i.e. at greater emission levels than recorded in other plume studies.
8. The revised Air Quality Battery Failure Plume Assessment Report considers production of Nitrogen Oxides, Hydrogen Chloride and Hydrogen Cyanide and concludes that levels are likely to be significantly lower than HF so are not included in the Plume Assessment. This conclusion tallies with previous LFP BESS system Plume Analysis reports previously reviewed where emissions of all three gases has totalled <25% of HF volume. There should be a high level of confidence that emission data listed for local respondents and the report Conclusions are both conservative and credible.
9. The NFPA 69 Compliance Report compliments the Air Quality Report to confirm that in gas venting thermal runaway scenarios defined by NFPA 855 (2023) the gas exhaust system will maintain explosive gases below 25% of the lower flammable limit minimising explosive risks. This minimises risks for first responders and reduces peak levels of any toxic gas emissions.



2.3.1.1 Listing Codes and Standards

The following codes and standards were considered in this hazard mitigation analysis. Specifically, failure modes identified in NFPA 855 were considered in the analysis. Fire protection requirements for Energy Storage Systems documented in NFPA 855 were used to inform the evaluation of the battery system. Table 2-2 provides an overview of the codes used for this evaluation and their relationship to other codes and requirements.

Table 2-2: Best Practice Codes and Standards

Code or Standard	*Commentary / Compliance*
2021 IFC – International Fire Code, Electrical Energy Storage Systems Chapter 1207	Chapter 12 – Energy Systems is applicable to the SBB system.
NFPA 855, "Standard for the Installation of Stationary Energy Storage Systems," (2023 Edition)	NFPA 855 matches the *applicable* failure modes required by the IFC.

Table 2-3: Definition and Purpose of UL 9540A Test Levels

Type	*Definition*	*Test Purpose*
Cell	The basic functional electrochemical unit containing an assembly of electrodes, electrolytes, separators, containers, and terminals.	Establish an effective method for forcing a cell into thermal runaway in a repeatable manner.
Module	A subassembly that is a component of a BESS that consists of a group of cells or electrochemical capacitors connected either in series and/or parallel configuration (sometimes referred to as a block) with or without devices and monitoring circuitry.	Assess the module's ability to contain thermal runaway.
Unit	A frame, rack, or enclosure that consists of a functional BESS that includes components and subassemblies such as cells, modules, battery management systems, ventilation devices, and other ancillary equipment.	Assess the ability of the unit to contain thermal runaway to the initiating unit and prevent a fire from spreading to adjacent target units.
Installation	BESS installed for use.	Assess the effectiveness of firefighting measures on the BESS level.

CATL EnerC+ BESS system key standards & testing

1. Jensen Hughes provide specialist BESS design risk analysis and reporting; the Hazard Mitigation Analysis (HMA) follows NFPA 855 (2023) guidelines. BST&T considers this to be a very thorough safety audit.
2. Jensen Hughes highlighted 8 major safety recommendations which this report compares against safety and testing documentation provide by CHSPL.
3. The CATL EnerC+ is tested and listed to UL 9540 (gold standard).
4. The CATL EnerC+ has completed UL 9540A 4th Edition (2019) to Unit level, complying with the latest UL test protocols and requirements.
5. The CATL EnerC+ gas exhaust system conforms to NFPA 69 standard of ventilating the BESS enclosure of any explosive gases produced during thermal runaway. NFPA 69 standard requires efficient ventilation of the BESS enclosure to ensure explosive gas levels remain under 25% of the Lower Flammable Limit (LFL).
6. The CATL EnerC+ Enclosure integrates smoke, gas and heat detection products which comply with NFPA 855 (2023). CHSPL will also install carbon monoxide sensors in compliance with NFCC guidelines which is to be considered best practice.

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Jensen Hughes methodology for Hazard Mitigation Analysis

2.4 HMA FAILURE MODES, CONSEQUENCES, AND RECOMMENDATIONS

The HMA aids in identifying and mitigating hazards created with the BESS technology. This section addresses the failure modes identified NFPA 855 which is in general agreement with industry best practice.

The failure modes listed in the NFPA 855 Standard for the Installation of Stationary Energy Storage Systems Section 4.4.2 (and echoed in this report Sections 2.4.1 through 2.4.3) were evaluated. Only single failure modes are considered for each mode. The evaluation includes a written description of the failure mode, the barriers in place to prevent the event, and the consequence of the event. This written evaluation is supported by a generic bowtie evaluation. It should be noted that this is a consequence-based analysis, and the likelihood of the event is not considered. The following are the failure modes listed in the 2023 edition of NFPA 855:

- A thermal runaway or mechanical failure condition in a single ESS unit
- Failure of an energy storage management system or protection system that is not covered by the product listing failure modes and effects analysis (FMEA)
- Failure of a required protection system including, but not limited to, ventilation (HVAC), exhaust ventilation smoke detection, heat detection, fire detection, fire suppression, or gas detection

Thermal Runaway definition and scenarios for BESS systems

2.4.1 Thermal Runaway or Mechanical Failure in Single ESS Rack, Module, or Unit

2.4.1.1 *Description*

Thermal runaway is the condition when an electro-chemical cell increases its temperature through self-heating in an uncontrollable fashion. This phenomenon typically progresses to a point at which the cell's heat generation is higher than the rate it can dissipate, potentially leading to the release of flammable gas, fire, or explosion. Once thermal runaway has started in a cell, it cannot be stopped. Thermal runaway can produce a significant amount of volatile gas that causes increased pressure within the cell housing and eventually leads to forceful venting [13]. If there is sufficient oxygen and a competent ignition source, these cell vent gases may ignite and progresses when the cells heat generation is at a higher rate than it can dissipate, potentially leading to the release of flammable gas, fire, or explosion. Once thermal runaway has started in a cell, it cannot be stopped. ignite.

Thermal runaway can be caused by physical damage (puncture, crushing), electrical issues (deep discharge, overcharging), exposure to elevated ambient temperatures, and manufacturer defects (imperfections, contaminants).

Cells in thermal runaway can cause adjacent cells to also undergo thermal runaway in a phenomenon known as thermal runaway propagation. Cell may cause thermal runaway in adjacent cells through one of several heat transfer mechanisms: 1) conductive heat transfer via direct contact between cells 2) overcurrent caused by damaged circuitry 3) impingement of hot or flaming vent gases. Cells may also cause thermal runaway in adjacent cells due to the effects of the cell depressurization (thermally from the fireball or mechanically from the force), or due to the original cell swelling and deforming adjacent cells.

Sustained Cell-to-Cell thermal propagation can lead to four primary hazardous scenarios:

1. Rapid ignition of flammable gases, sustained propagation, and resultant full-scale fire.
2. Multiple cells venting flammable gases without sufficient temperature for ignition.
3. Multiple cells venting flammable gases but delayed ignition leading to a deflagration or explosion.
4. Multiple cells venting flammable gases without sufficient temperature for ignition until after flammable gas concentrations have exceeded the Upper Flammable Limit (UFL). This condition can create a hazard known as 'backdraft' or 'flashover' in which opening the container and introduction of fresh oxygen can cause a deflagration.

It should be noted that while the backdraft hazard is a complex phenomenon, it was identified as the cause of seriously injuring four firefighters in a BESS thermal propagation event in Surprise, AZ in 2019 and is considered a plausible hazard of this installation.

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Jensen Hughes Hazard Mitigation Analysis (HMA) recommendations

Table 2-12: Safety recommendations resulting from HMA.

No.	Title	Description
1	Emergency response plan – fire suppression	Explore how emergency response planning can be defined to provide cooling (e.g., utilize nearby fire hydrants) to the enclosures with a hose stream in case of thermal runaway. Generally, water is the preferred agent for suppressing lithium-ion battery fires.
2	System testing and documentation	Verify all automatic and manual shutdown protocols for the BMS, EMS, and PCS during commissioning testing. Document the safety features of the BMS, EMS, and PCS to ensure these systems comply with industry best practice.
3	Battery cooling system documentation	For the liquid cooling system, inspection, testing, and maintenance protocols (PM frequency) need to be documented and evaluated for best practices in the industry.
4	Explosion prevention	Verify adequate basis of design, compliance with NFPA 69, and function of gas detectors and mechanical exhaust system during installation/commissioning.
5	Fire protection system	Consider installing the Fire Department Connection (FDC) at least 25 feet away from the container and ensure it is clearly marked with signage. Analyze the proposed site conditions, include fire department response, fire department access road, distance from fire department connection to fire hydrant, and fire flow for the site to meet the demand
6	Site specific analysis	When end user is developing an energy storage site, a site specific analysis should be carried out (e.g., Site hazard mitigation analysis, dispersion modeling, emergency response)
7	Fire Department Connection Location	Consider installing the Fire Department Connection (FDC) at least 25 feet away from the container and ensure it is clearly marked with signage.
8	Smoke and Heat Detection Circuits	Verify that each smoke detector and heat detector has its own dedicated circuit.

2.5 CONCLUSIONS

A hazard mitigation analysis was performed for the CATL EnerC+ BESS to determine compliance with NFPA 855. The failure modes as per NFPA 855 Section 4.4.2 were used to conduct a consequence-based analysis, which determined how well the provided barriers to failure of the safety system would reduce the severity of the hazard. Likelihood of events were not assessed and only one failure was used. Recommendations to address issues were assessed and repeated in the following subsection.

- Jensen Hughes are a highly respected US based engineering company who specialise in fire protection and life safety analysis for BESS systems and BESS sites.
- The HMA is conducted using NFPA 855 (2023) guidelines
- CHSPL will ensure compliance with all HMA safety recommendations.
- BST&T's review of the BSMP and risk analysis data provided by CHSPL concludes that all pre-construction recommendations have been satisfied

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Executive Summary

Jensen Hughes has completed a Hazard Mitigation Analysis of CATL EnerC+ 306 container. The Hazard Mitigation Analysis consists of:

a. A total of eight (8) recommendations listed in section 2.4.1 to address aspects of documentation and installation for safe operation including the following:
   - Emergency fire response plan – Fire suppression
   - System testing and documentation
   - Battery cooling system documentation
   - Explosion prevention
   - Fire protection system
   - Perimeter security
   - Emergency response plan – Coordination
   - Site specific analysis

b. For compliance with NFPA 855 requirements, a dispersion analysis may be recommended based on site specific installation.

This report, assembled with collaboration and design inputs provided from CATL, is a comprehensive product level review. Site level or installation level analysis may be required within certain jurisdictions outside of the scope of this report. The current EnerC+ design and its associated components are analyzed based on inputs and information provided from CATL. All identified non-compliance results are noted in this report.

This report was based solely upon and limited to the available information provided and/or presented in the submittal. Details and/or information not presented or provided on the documentation provided by the Client are not considered a part of this analysis.

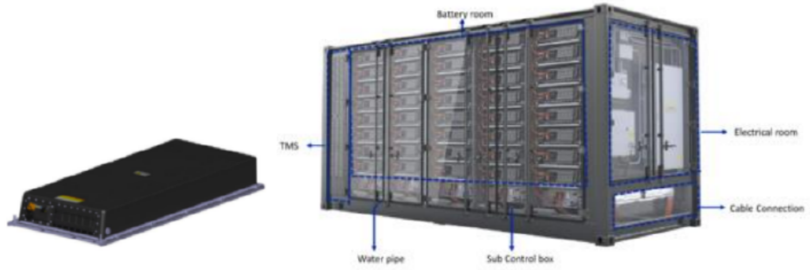

Figure 1: Module and Container Image

The system is monitored by a Battery Management System (BMS). The BMS monitors the battery voltage, current, and temperature. A liquid cooling system is built into the system to manage battery temperatures as determined by the BMS monitoring.

The container is protected with four (4) levels of fire suppression which stars with an alarm warning at the first level, then continues to the second level to utilize the mechanical ventilation system to prevent deflagration, the third level released aerosol to extinguish initial fire occurring in the container, and finally level four consists of water spraying to prevent the spread of fire.

This report analyses the most important recommendations from the HMA:

1. System testing and documentation
2. Battery Cooling System
3. Explosion Prevention
4. Fire Protection System
5. Site Specific Analysis
6. Emergency Response Plan provision

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Core BESS certifications & testing

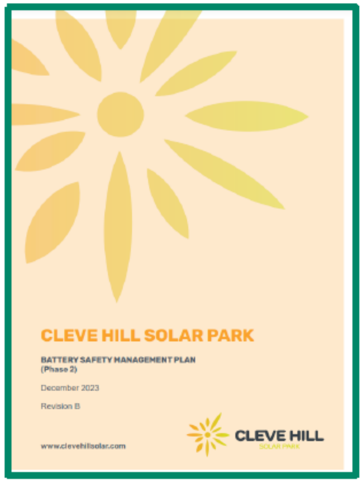
Cell: UL 1973, IEC 62619, UN 38.3 – conforms to key standards

Module: UL 1973, IEC 62619, UN 38.3 – conforms to key standards

Rack: UL 1973 – conforms to key standard

Testing: Compliant with UL 9540A unit level test protocols - UL9540A test method allows for an assessment of the flammability / thermal runaway hazard of the battery system. This testing is required to comply with NFPA 855 (2023) and to obtain UL 9540 system level listing.

BMS: UL 1973, UL 9540 – conforms to key standards and BMS integrates NFPA 855 recommended controls. CHSPL are also integrating data analytics and PLC integrated detection capability, BST&T considers this best practice.



Gas exhaust system: designed to NFPA 69 requirement for BESS
1. The gas detection system shall be designed to activate the mechanical exhaust system when the level of flammable gas detected in the container exceeds 25 percent of the Lower Flammable Limit (LFL).
2. The mechanical exhaust system must stay on until the flammable gas detected is below 25 % of the LFL.
3. The system shall be provided with a minimum of 2 hours of standby power.
4. If the gas detection system fails, the system shall annunciate a trouble signal at an approved central station, or remote station service in accordance with NFPA 72 or at an approved, constantly attended location.

Enclosure: CATL is certifying to UL 9540 and the expectation is that certification will be obtained in Q1 2024

BST&T Conclusion:
- EnerC+ is a tier one BESS system certified to the requisite standards
- CATL needs to provide the final UL 9540 certification of the BESS enclosure, this is expected to be obtained in Q1 2024. For the avoidance of doubt, this upcoming certification is part of a normal ongoing compliance process for a new BESS system and is not a legitimate reason to delay approval of the BSMP.

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2.4.3.2 Mechanical Exhaust System

Description

Failure of the mechanical exhaust system is designed to exhaust gas buildup. This system is activated upon detection of gas from hydrogen gas detection system. Under normal operating conditions mechanical exhaust system is not utilized.

Barriers

Exhaust ventilation system is designed and installed in accordance with NFPA 69.

Consequences

Buildup of flammable gas in container above the lower flammable limit to an explosive concentration can cause an explosion.

Recommendations

1. Verify adequate basis of design, compliance with NFPA 69, and function of gas detectors and mechanical exhaust system during installation/commissioning.

2.4.3.5 Gas Detection System

Description

The gas detection system is used to automatically activate the exhaust ventilation system to remove flammable gas buildup from a thermal runaway event. The documentation available for review indicates that the gas detection system is provided using a UL approved gas sensor which detects hydrogen. Since the gas emitted during a thermal runaway event is primarily hydrogen, it is recommended to use detectors that can detect hydrogen as hydrogen is a gas normally not present in normal conditions but is expected to be generated in high quantities during a thermal runaway event. Two hydrogen gas detectors planned for this design.

Barriers

Periodic inspection, testing, and maintenance of the gas detection system components in accordance with applicable standards, their listing, and manufacturer guidelines to reduce the potential of failure of the gas detection system.

Consequences

If the gas detection devices fail, activation of the ventilation system will not occur potentially resulting in a flammable atmosphere inside the enclosure. This would increase the potential of a deflagration to occur.

Recommendations

None.

BST&T considers that CATL and CHSPL fulfils all HMA recommendations for explosion prevention:

1. A Fire Protection Assessment for NFPA 69 Compliance Report for the EnerC+ BESS has been produced by TLB Fire Protection Engineering, Inc
2. A Computational Fluids Dynamics (CFD) model was utilized to demonstrate the system design successfully reduces the concentration of combustible gases in the container to less than 25 percent of the lower flammability limit (LFL) of the gas mixture recorded in UL 9540A testing.
3. The CFD model conservatively assumes three modules will go into thermal runaway concurrently, to validate gas exhaust performance. The model demonstrates that the average concentration of hydrogen within the BESS is maintained below 25% of the LFL for the duration of the thermal runaway as per the intent of the requirement in NFPA 855 (2023).
4. TLB Fire Protection Engineering, Inc. conclude that according to the information provided, the BESS explosion prevention measures meets the intent of NFPA 69 (2019) standards and the explosion control requirements of NFPA 855 (2023).
5. CHSPL will commission a site-specific explosion prevention review during installation which will validate the NFPA 69 Compliance conclusions, confirm detection system compliance and approve maintenance schedules.

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Cleve Hill Fire Suppression System (FSS)

2.4.3.6 Water-Based Suppression System

Description

A manual dry fire sprinkler system with sprinklers provided in design documentation. The a design density in.3 gpm/ft² based over the area of the room is required by 2023 edition of NFPA 855 provided for this enclosure

[18]. A fire department connection for the dry standpipe is required to be provided for local firefighters to attach a water supply connection to cool the container in case of a thermal runaway event.

Barriers

Fire department may not hook up water depending on system installation configuration and emergency response procedures. The fire department connection is directly adjacent to the battery room on the side of the container, and in an event scenario it may be unsafe for a fire fighter to connect a hose due to the fire and explosion hazard in the battery room. This is not a review of a site-specific solution so the site water supply, fire department access, and distances will need to be analyzed for each site. Periodic inspection, testing, and maintenance of the sprinkler system components in accordance with NFPA 25 and applicable standards to reduce the potential of failure of the fire sprinkler system.

Consequences

Failure of fire department attaching water supply may cause a fire in one battery rack to spread to adjacent racks, causing a greater release of flammable gas and additional potential for explosion and fire.

Recommendations

1. Consider installing the Fire Department Connection (FDC) at least 25 feet away from the container and ensure it is clearly marked with signage.
2. Analyze the proposed site conditions, include fire department response, fire department access road, distance from fire department connection to fire hydrant, and fire flow for the site to meet the demand.

BST&T considers that CHSPL fulfils all HMA Fire Suppression System recommendations:

1. KFRS Connections will be located at least 25 feet from enclosures and clearly signed for KFRS response.
2. CHSPL has liaised closely with KFRS to agree key site design requirements for First Responders. NFCC guidelines were used as the foundation of site design and both water provision and BESS enclosure spacing follows these guidelines.
3. Both sprinkler and aerosol FSS conforms to both NFPA and BS EN standards
4. Because aerosol discharge could increase the explosion risk during a thermal runaway scenario: discharge of the aerosol fire suppression system shall be limited to only true “electrical” fault fires shall not trigger in the event of a thermal runaway, this shall be managed by the fire alarms control logic and be validated by additional analytics provided by the BMS and EMS, this final system design shall be validated by an appointed British Approvals for Fire Equipment (BAFE) accredited specialist to ensure its compliance to the standards named. The FSS includes a manual and emergency deactivation button located externally to the BESS enclosure to allow manual deactivation in an emergency and deactivation by engineers when entering or opening the container to perform inspections and/or maintenance activities.

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2.4.3.4 Smoke and Heat Detection System

Description

Three (3) smoke detectors and two (2) heat detectors are provided according to the documentation available. The design documentation indicates that two (2) smoke detectors and two (2) heat detectors are installed in the battery compartment as well as one (1) smoke detector in the electrical compartment. The smoke and heat detectors are a part of the Fire Suppression System (FSS) and connected to the Fire Control Panel (FCP) which will activate the aerosol, ventilation and provide notification of an event (alarm).

Connection of the fire alarm system to a central monitoring station will be required as part of the site-specific evaluations.

Barriers

Periodic inspection, testing, and maintenance of the fire alarm system and components in accordance with NFPA 72 to reduce the potential for failure of the detection system is required. Three (3) smoke detectors and two (2) heat detectors are proposed. In case of a single or multiple detector failure it is expected that the remaining detectors will function properly, as the system will be constantly monitored and will report any troubles, faults, or supervisory alarms to the central monitoring station.

Consequences

In the event that a single smoke detector or heat detector does not activate, notification may not occur or will be delayed until a second smoke detector or heat detector is activated. Due to the constant monitoring, it is not expected that the fire detection system will fail, however it is still probable, which would prevent the notification system from activating.

Recommendations

1. Verify that each detector has its own dedicated circuit
2. Connection of the fire alarm system to a central monitoring station as part of the site-specific evaluations.

BST&T considers that as specified in the BSMP, CHSPL selected detection systems exceed Jensen Hughes Recommendations:

1. All fire detection systems shall all be installed and commissioned to BS EN 54, BS EN 9999, NFPA 885, NFPA 850. Final system design shall be validated by an appointed British Approvals for Fire Equipment (BAFE) accredited specialist to ensure its compliance to the standards named.
2. Each BESS also includes audible and visual notification devices in the event of a fault or alarm condition.
3. Each battery enclosures fire detection system shall be integrated into a dedicated site wide fire monitoring system to allow notification from a centralized location onsite. The site wide monitoring system shall be securely monitored via a dedicated platform and provide automatic remote notification to a certified alarm receiving centre via a dual path signalling solution in the event of an emergency scenario, the system can also provide automatic signally to the local fire departed which shall be offered and provided at their discretion.
4. The site wide monitoring system shall also provide automatic controls to disconnect an affected battery enclosure from its designated Power Conversion System and nearby equipment from the High-Voltage network in the event of an alarm being triggered. Hardwired normally closed safety loops are also to be installed between each battery enclosure and its designated Power Conversion System to provide local disconnection from the High-Voltage network as a second layer of redundancy if a communications fault between the systems was to occur simultaneously.

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2.4.3.7 Manual Firefighting Response

Description

Manual firefighting response by the local fire department is likely going to be a "defensive approach" that focuses on preventing the propagation to neighboring containers and should be outlined in an emergency response plan. The emergency response plan is typically developed with the site operator and in communication with the responding fire department during the permitting stage and finalized after project completion. The enclosure is equipped with an emergency stop that can be used during an incident.

Manual firefighting response is initiated by the central station, triggered by the activation of smoke, heat, or gas detection system. Connection of the fire alarm system to a central monitoring station will be required as part of the site-specific evaluations.

Barriers

- Emergency response plan
- Training and site familiarity
- Proper inspection, testing, and maintenance of firefighting equipment

Consequences

Failure of the manual firefighting response could lead to propagation of a thermal runaway event, total loss of the BESS, and/or possible explosion(s). Lack of an adequate emergency response plan, training and site familiarity may result in harm to emergency responders.

BST&T considers that BSMP comprehensively sets out requirements for Emergency Response Planning, training and site familiarity and inspection, testing and maintenance of equipment. CHSPL will appoint a Construction Emergency Response Team (CERT) which will fully liaise with KFRS to ensure firefighting requirements are met.

The CERT shall be responsible for:

a. Completing the developments construction Emergency Response Plan, including but not limited to

i. Review and further develop the responsibility matrix (RACI) for decision making and protocols for incident response – shared across the facility and response teams.

ii. Review the EMS, BMS and Fire alert / alarm systems and further detail the functions, capabilities and control hierarchy.

iii. Review and further detail the Standard Operating Procedures (SOPS) with specific emphasis on safe shutdown and isolation procedures, emergency response procedures and decommissioning procedures. Review and further detail the developments system monitoring data analytics for real time support in an emergency event.

b. Liaising with the local emergency services and making them aware of the detailed project programme, identify key milestones such as the battery delivery dates, installation commencement, commissioning commencement and any other periods of construction which may pose a higher risk of fire hazards being present.

c. Maintaining regular meetings and periodic reviews of the construction progress ensuring fire safety is maintained.

d. Provide continual updates to the local emergency services and notify them of any changes to key construction milestones, new hazards, or changes to the Emergency Response Plan.

e. Perform real life scenario-based testing to evaluate the effectiveness of the Emergency Response Plan.

f. Ensure the recommendation of the air quality assessment (Plume Analysis) as summarised in section 8.3 and 8.4 of the BSMP document are enforced.

g. Ensure the protocols, guidelines, and standards of the BSMP are followed.

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2.4.3.1 Ventilation (Battery Liquid Cooling)

Description

This failure mode is perhaps better described as failure of the battery cooling system. For the CATL EnerC+ system, thermal management of the battery modules is provided via a liquid cooling system under the bottom of battery that is designed to maintain the battery cells within their operating limits. In the event that a thermal management system fails, the battery cells may be exposed to elevated temperatures (i.e., above the operating temperature range). When this occurs, the cell is not able to dissipate heat efficiently, which, in turn, leads to increased internal temperatures. If the internal temperature rises out of the tolerance of the separator on the cell, the separator can degrade. Aging and long term degradation of the separator is often a precursor to a thermal runaway event.

Failure of the liquid battery cooling system may occur due to the following causes.

+ The coolant pump fails to operate due to a faulty temperature sensor, a blown fuse or other failure mode associated with the pump.
+ A leak occurs in the system, causing drainage of the coolant.

Barriers

Barriers addressing the failure of the liquid battery cooling system includes:

+ The BMS monitors cell temperatures relative to the manufacturer's specifications including module temperature detection and thermal management. The BMS is designed to detect and correct abnormal conditions, as well as electrically disconnect the battery if the module temperature falls outside these thresholds.
+ Proper inspection, testing, and maintenance of the liquid cooling system. This includes checking/maintaining the coolant levels within the system and its components, inspection of the coolant quality, and ensuring piping integrity.

Consequences

Failure of the liquid cooling system shuts down the operations of the CATL EnerC+ ESS (i.e., the unit trips). It is important to note that the critical cell failure temperatures are typically around 130°C, a level that is unlikely to be reached in the installation environment. Therefore, a loss of coolant should not immediately trigger a thermal runaway. Coolant leakage could cause a short circuit in battery modules or auxiliary equipment resulting in an overheat condition potentially leading to a thermal runaway. The consequences of a thermal runaway event are described in Section 2.4.1.3.

Recommendations

1. Verify all automatic and manual shutdown protocols for the BMS, EMS, and PCS during commissioning testing.
2. Document the safety features of the BMS, EMS, and PCS to ensure these systems comply with industry best practice.

If an EMS failure occurs, the worst-case consequence is a thermal runaway. Hence, the same recommendations as provided in Section 2.4.1.4 apply.

BST&T considers that the BSMP complies with all Ventilation recommendations in the HMA, namely:

1. During operation routine maintenance shall be undertaken of the battery facility. Maintenance shall be conducted in accordance with the manufacturer's guidelines, current relevant standards and industry best practices and as a minimum shall include the tasks as detailed in Table 4 (Standard Routine Maintenance)
2. System data analytics will be integrated into EMS / BMS systems and controls which reduces Thermal Runaway risks. Data Analytics can also be used to predict accurate End-of-Life timeframes and provide operator maintenance alerts.
3. Site Acceptance Testing (SAT) for BESS equipment will be to BS EN IEC 62933-5-2 standards or equivalent.
4. The Construction Emergency Response Team (CERT) will review the EMS, BMS, PCS and Fire alert / alarm systems and further detail the functions, capabilities and control hierarchy.
5. The monitoring system provides automatic controls to disconnect an affected battery enclosure from its designated Power Conversion System (PCS) and nearby equipment from the High-Voltage network in the event of an alarm being triggered. Hardwired normally closed safety loops are also to be installed between each battery enclosure and its designated PCS to provide local disconnection from the High-Voltage network as a second layer of redundancy if a communications fault between the systems was to occur simultaneously.
6. CATL's Battery Management System (BMS) is designed to monitor key electrical, mechanical, and environmental parameters to ensure the system operates within its designed thresholds. The BMS controls the battery systems, electrical systems and thermal management systems and is interlinked to the systems fire detections and fire suppression systems. The BMS provides early warning notification, fault notifications and disconnection of the battery system in the event of a parameter being exceeded. CHSPL will also PLC integrate detection and alert mechanisms to provide additional safeguards to the BESS system. The BMS samples and records parameters every second and can provide a sub-second disconnection of the system in the event of a fault or parameter exceedance.

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2.4.2 Failure of an Energy Storage Management System (ESMS)

2.4.2.1 Description

The ESMS is defined in NFPA 855 as: "a system that monitors, controls, and optimizes the performance and safety of an energy storage system" (NFPA 855 Section 3.3.8). This definition therefore implies that, at a minimum, the ESMS encompasses the combined performance of the system BMS and EMS. Therefore, this section addresses potential failures in these subsystems.

Each failure can be addressed based on overall function expectations. The EMS includes the module-level, rack-level and unit-level BMS that monitor and balance cell voltages, currents, and temperatures within the manufacturer's specifications and the EMS that monitors and manages the feed and load. Section 9.2.3 of the NFPA 855 2023 Edition requires the energy storage management system to disconnect electrical connections to the ESS or otherwise place it in a safe condition if potentially hazardous temperatures or other conditions such as short circuits, over voltage or under voltage are detected.

+ The Battery Management System (BMS) may fail to provide monitoring and/or control at the cell/module level, resulting in inability to shut down, report adverse conditions, properly monitor, balance or protect the system resulting in adverse conditions.
+ The Energy Management System (EMS) may fail at the rack or system level which results in adverse conditions to the system.

2.4.2.2 Barriers

Barriers to failure of the Energy Storage Management System include:

+ NFPA 855 2023 edition invokes UL 1973 [17]. In the event that the EMS or BMS is relied upon for maintaining the battery cells within their safe operating region, UL 1973 requires that "the Energy management system (EMS) shall maintain cells within the specified cell voltage region from over-charge and over-discharge of the cell voltage, and it shall maintain cells within the specified cell temperature region providing protection from overheating and under temperature operation. Additionally, it shall maintain batteries within the specified battery current region from over charge of current and prevent high-rate discharge exceeding the cell specification. The batteries utilized in the EnerC+ are UL 1973 certified.
+ Generally, the ESMS can remotely shut down the EnerC+ via a control system integral to the container. The EnerC+ can also be shut down locally via emergency stop. In the event of fault detected condition (e.g., over voltage, over current, over temperature, communication, etc.), The high voltage DC circuit is cut off.

2.4.2.3 Consequences

Failure to shut down the system given potentially hazardous temperatures or other conditions such as short circuits, over or under voltage conditions are detected may result in damage to the battery cells. This damage could ultimately lead to thermal runaway event. The consequences of a thermal runaway event are described in Section 2.4.1.3.

2.4.2.4 *Recommendations*

1. Verify all functions of the BMS and automatic and manual shutdown protocols of the EMS during commissioning testing.

If an EMS failure occurs, the worst-case consequence is a thermal runaway. Hence, the same recommendations as provided in Section 2.4.1.4 apply.

BST&T considers that the BSMP complies with EMS / BMS (ESMS) failure recommendations:

- Key parameters considered for the importance of fire safety monitored by the BMS include but are not limited to:

a. Overall system voltage
b. System State of Health ("SOH")
c. System Stage of Charge ("SOC")
d. Single cell temperatures
e. Single cell voltage
f. Single cell temperature difference
g. Single cell voltage difference
h. Battery System Insulation Resistance
i. Enclosure ambient temperatures
j. Thermal Management System ("TMS") water temperatures

- The BMS provides levels of early warning notifications when parameters are nearing their designed limits, these notifications are automatically generated and shall be monitored by a centralised system so that operational teams can investigate, analyse and provide reactive maintenance to repair or replace defective parts appropriately.
- In the event of a parameter being exceeded the BMS automatically provides fault notification and immediate disconnection of the system from the high voltage AC supply, notifications are automatically generated and shall be monitored by a centralised system so that operational teams can investigate, analyse, and provide reactive maintenance to repair or replace defective parts appropriately.
- The BSMP outlines a risk assessment conducted by CHSPL identified 9 critical steps across six key project stages as listed in Table 2. Step 6, Commissioning Verification process ensures the implemented EMS / BMS (ESMS) control measures are functioning effectively.
- Site Acceptance Tests (SAT) will follow BS EN IEC 62933-5-2 standards and protocols, or equivalent.

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2.4.2 Failure of an Energy Storage Management System (ESMS)

2.4.2.1 Description

The ESMS is defined in NFPA 855 as: "a system that monitors, controls, and optimizes the performance and safety of an energy storage system" (NFPA 855 Section 3.3.8). This definition therefore implies that, at a minimum, the ESMS encompasses the combined performance of the system BMS and EMS. Therefore, this section addresses potential failures in these subsystems.

Each failure can be addressed based on overall function expectations. The EMS includes the module-level, rack-level and unit-level BMS that monitor and balance cell voltages, currents, and temperatures within the manufacturer's specifications and the EMS that monitors and manages the feed and load. Section 9.2.3 of the NFPA 855 2023 Edition requires the energy storage management system to disconnect electrical connections to the ESS or otherwise place it in a safe condition if potentially hazardous temperatures or other conditions such as short circuits, over voltage or under voltage are detected.

+ The Battery Management System (BMS) may fail to provide monitoring and/or control at the cell/module level, resulting in inability to shut down, report adverse conditions, properly monitor, balance or protect the system resulting in adverse conditions.
+ The Energy Management System (EMS) may fail at the rack or system level which results in adverse conditions to the system.

2.4.2.2 Barriers

Barriers to failure of the Energy Storage Management System include:

+ NFPA 855 2023 edition invokes UL 1973 [17]. In the event that the EMS or BMS is relied upon for maintaining the battery cells within their safe operating region, UL 1973 requires that "the Energy management system (EMS) shall maintain cells within the specified cell voltage region from over-charge and over-discharge of the cell voltage, and it shall maintain cells within the specified cell temperature region providing protection from overheating and under temperature operation. Additionally, it shall maintain batteries within the specified battery current region from over charge of current and prevent high-rate discharge exceeding the cell specification. The batteries utilized in the EnerC+ are UL 1973 certified.
+ Generally, the ESMS can remotely shut down the EnerC+ via a control system integral to the container. The EnerC+ can also be shut down locally via emergency stop. In the event of fault detected condition (e.g., over voltage, over current, over temperature, communication, etc.), The high voltage DC circuit is cut off.

2.4.2.3 Consequences

Failure to shut down the system given potentially hazardous temperatures or other conditions such as short circuits, over or under voltage conditions are detected may result in damage to the battery cells. This damage could ultimately lead to thermal runaway event. The consequences of a thermal runaway event are described in Section 2.4.1.3.

2.4.2.4 *Recommendations*

1. Verify all functions of the BMS and automatic and manual shutdown protocols of the EMS during commissioning testing.

If an EMS failure occurs, the worst-case consequence is a thermal runaway. Hence, the same recommendations as provided in Section 2.4.1.4 apply.

BST&T considers that the BSMP complies with EMS / BMS (ESMS) failure recommendations (continued):

- Key parameters considered for the importance of fire safety which generate automatic disconnection of the system by the BMS include but are not limited to;

a. A Communication fault,
b. SOC under/over limit,
c. System Current over limit,
d. Single cell voltage over/under limit,
e. Rack voltage difference over/under limit,
f. Single cell temperature over/under limit,
g. Rack temperature difference over/under limit,
h. Insulation fault under limit,
i. Auxiliary power fault,
j. Lightning protection device fault,
k. Fire system fault,
l. TMS water temperature over/under limit,
m. TMS fault,
n. Emergency stop button engaged,
o. Emergency stop button fault.

- System data analytics will be integrated into EMS / BMS systems and controls which reduces Thermal Runaway risks. Data Analytics can also be used to predict accurate End-of-Life timeframes and provide operator maintenance alerts.

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EnerC+ design safety conclusions

Assumptions: This report summarises BST&T's assessment of the BESS design safety features and relies on the accuracy of the information provided by CATL and CHSPL. CHSPL has been very cooperative in providing the data that BST&T has requested, some data received from CHSPL that has been used in the production of this BSMP and safety review has been omitted from this report based on requirements that it remains confidential.

Battery system: CATL's EnerC+ system is tested and certified to UL 1973, IEC 62619 and UN 38.3; BST&T considers this meets the highest industry expectations.

Thermal Management System (TMS): BST&T considers the TMS is in line with typical industry standards for BESS cooling applications and the key features of the cooling system design align with the characteristics of the battery cells. Liquid cooling provides higher levels of safety and performance for BESS systems and CHSPL has PLC integrated additional alerts and data analytics into the BMS to ensure comprehensive safety controls.

Battery Management Systems (BMS) and controls: BST&T considers CATL's BMS architecture aligns with the current industry expectations. CHSPL will also PLC integrate detection and alert mechanisms to provide additional safeguards to the BESS system and integrate data analytics which will provide for the highest level of Thermal Runaway incident prevention.

Explosion Prevention System: BST&T considers that the gas exhaust system is designed to NFPA 69 requirements for BESS. Additionally, discharge of the aerosol fire suppression system shall be limited to only true "electrical" fault fires shall not trigger in the event of a thermal runaway ensuring the gas exhaust system remains in operation. The dry pipe water sprinkler can operate in conjunction with the gas exhaust system which could further reduce the risks of a deflagration event occurring.

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PAUL GREGORY – BATTERY TESTING AND SAFETY CV

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BATTERY BACKGROUND	I'm a specialist battery safety and testing consultant whose areas of expertise include: BESS safety & mitigation strategies, battery system validation & abuse testing, BESS explosion test planning, battery system risk assessment & training, operations & battery systems safety audits, suppression system & explosion protection test planning, BESS incident ERP drafting / planning. My project focus since 2015 has been within renewable energy sectors leading to an interest and specialization in lithium battery technologies. Projects have covered all aspects of the safety spectrum: risk analysis, FDS modelling, scale testing mitigation strategies, passive protection measures and effective bespoke special hazard suppression solutions. Battery and safety product roadmap experience includes full scale battery abuse testing and certification, design of battery abuse test facilities, identifying and validating BESS safety equipment, test planning / review for fire & explosion tests for a variety of battery application suppression systems. Unique multi-application experience of working in a variety of high energy density lithium battery (both primary and secondary) technologies and applications. I have a detailed understanding of new battery technologies, application performance requirements and key safety and mitigation factors. Previous project partners and clients: **| EaglePicher | Northvolt | ESPEC | EnerSys | NEC Energy Solutions | LG Chem | Trina Solar | Gridserve | ABB | APi Group | Hiller | Collins Aerospace | Kidde | TUV SUD | Johnson Controls | FAA | IATA | Esterline / Armtec | General Motors | STIF | Scottish Power | Honeywell | Nexceris | Johnson Controls | AECOM | DNV | Gexcon | Metis Engineering | Accure Battery Intelligence | IGP | Low Carbon**
SKILLS & ATTRIBUTES	**BESS Emergency Response Planning (ERP) & Analysis | Battery technology application & safety research | BESS UL 9540A test data analysis | BESS site design planning | BESS hazard mitigation analysis | BESS design risk assessment | Thermal Runaway & explosive gas detection testing | Strategic planning | Product management | Battery system testing, certification & validation | Project management of multi-disciplinary teams | Market research & product development | BESS Explosion test planning | Operational strategy | Lithium battery technologies (primary and secondary) | BESS fire & explosion safety audits | Lithium battery application hazard mitigation & fire suppression testing and analysis | Lithium battery passive protection product development | Lithium battery safety & training services | BESS safety planning peer review consultant | Detailed knowledge of LIB safety codes and testing requirements (NFPA 855, UL 9540A, UL 1973, UL 9540, IFC, IEC, SAE, etc.) |**

BESS PROJECTS

BESS planning projects: BESS safety consultant working directly with a variety of clients on grid scale project planning teams (fire safety, air quality, drainage, environment & sustainability). Consultancy services include drafting and peer reviews of BESS fire safety management plans, DCO hearing BESS safety content provision, BESS site design safety analysis & guidance, BESS safety standard & code compliance, Battery system design safety analysis, fire protection system design reviews, BESS explosion prevention system audits & review, BESS fire & explosion test data analysis, BESS site first responder facility provision, BESS incident & emergency response planning with local Fire & Rescue Services.

Lithium-ion Battery (LIB) Working Group, Review Board Member - Lead for test planning and data review (2022, BESS and EVs): Lead test consultant for a global fire protection & suppression company's large scale battery abuse and suppression testing program. Reviewing ongoing program of performance tests for water and aqueous suppression agents on a wide range of battery systems and chemistries.

Basingstoke & Deane Borough Council – safety consultant to review and evaluate BESS system and site design (2024): Ongoing project for a scheme that has received planning permission to peer review BESS system design, certifications, and test data. The review will also include site design conformance to NFCC and NFPA 855 guidelines and ensure first responder requirements are fully accommodated.

UL & ISO, Stationary Energy Storage Systems Working Group member: Member of the BESS first responder working group who are working to devise and implement international ISO safety protocols and signage for BESS emergency incident response.

Consultant for BESS system validation and certification (UL 9540A & 3rd Party): Lead consultant on key safety code and regulation compliance for BESS system validation and certification (UL 1973, UL 9540, UL 9540A, NFPA 855) for a major European battery manufacturer. Consultant for planning BESS large scale 3rd party fire & explosion testing in conjunction with thermal runaway detection and suppression testing evaluation program.

Battery Production facilities risk assessment and suppression system evaluation testing: Lead for US project team tasked with comprehensive risk assessment of a major US battery production facilities. Member of working group to establish rigorous test program of suppression system / suppression agent evaluation testing.

Consultant for Solar & BESS systems for utility scale energy / EV charging: Lead battery safety consultant for a variety of ongoing UK projects, advising on battery safety standards, fire & explosion risk analysis, fire protection system & mitigation analysis / validation, global fire code compliance, BESS site design risk analysis and Emergency Response Plan (ERP) drafting. Responsible for peer reviewing all battery and fire safety performance test results and advising on additional mitigation or retrofit / remedial actions (if required).

Consultant for BESS system safety evaluation: Lead battery safety consultant responsible for risk assessing the client's partner Battery OEM BESS system and drafting Emergency Response Plans (ERP). This involves comprehensive risk assessments of battery systems and analysis of UL /3rd Party large scale abuse testing to determine if further safety testing should be conducted by the battery

OEM. Establishment of new independent testing protocols to further identify fire and explosive risks which could impact on BESS site design parameters e.g. suppression system design selection, BESS enclosure spacing, BESS electronic control capabilities, gas exhaust design review, HVAC capabilities, etc.

BESS explosion test planning & evaluation consultant: Lead test planning consultant for BESS explosion prevention & explosion protection systems. Currently designing 3rd party test programs for a variety of gas venting and deflagration protection solutions.

Lithium battery fire suppression agent development (2016-2019), North America: Application risk research, strategic planning, regulatory certification & compliance testing, establishing a large-scale battery fire test facility, suppression system hardware development, lithium battery pack risk assessment, Thermal runaway detection and prevention, LIB application suppression system / mitigation solution performance testing, leading battery application working groups to cover all areas of risk assessment, mitigation, passive protection & suppression solutions.