BST+T

CONSULTANCY SERVICES

Cleve Hill Solar Park – Review of interested party comments submitted on the Battery Safety Management Plan

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

BST&T's assessment of the BESS design safety features was reliant upon the accuracy of the information provided by CHSPL and CATL (the BESS technology provider).

BST&T also agreed to collate a report for Swale BC covering a range of BESS safety issues including significant safety concerns submitted by interested parties during the planning process.

Topics include: **battery failure causes, explosion concerns, fire risks, toxic emissions and environmental concerns, risk assessments & consequence modelling, BESS battery specifications, battery system safety features and testing, BESS enclosure safety features, and additional site safety features.**

The recommendations and conclusions from the original detailed report are set out below:

BSMP amendments undertaken in BSMP Revision B based on BST&T recommendations:

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.

These recommendations have been adopted in the BSMP, Revision B (December 2023).

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.
9. BST&T does not consider that any design changes are required and the BSMP is fit for purpose, and therefore no impediment to planning approval has been identified from the materials supplied for the safety review.

TABLE OF CONTENTS

Section safety topic list:

BESS safety report executive summary for Swale BC

BST&T has put together this report to provide additional insights into certification and safety requirements for the BESS system and site design for the Cleve Hill project for Swale BC and interested parties who have made submissions regarding safety concerns.

It should be noted that the latest BESS safety standards, certifications, risk assessments, testing requirements and safety guidelines are significantly shaped by lessons learned from real world BESS thermal runaway events and recent full scale burn tests conducted by a variety of BESS manufacturers and system integrators. The EPRI white paper on lessons learned from the Carnegie Road BESS incident concludes (**Appendix 1**): "*In hindsight, many contributing factors are apparent– none of which is fundamentally new to the fire protection discipline or particularly difficult to address with engineering controls. This report serves to increase awareness in the industry in applying known mitigations against hazards that are now recognized*." [1]

The significant year-on-year increase in global BESS developments means there has been an increase in the number of failure incidents. However, codes and standards are rapidly evolving to regulate systems more efficiently by establishing safer battery system designs and strategies for hazard mitigation and emergency response. BESS codes and standards are developed and evolved to minimize the severity of failure events and to limit their consequences.

After reviewing the BSMP, BESS system design and controls, test data, risk assessments and following consultation with KFRS, BST&T concludes that CHSPL has demonstrated a thorough commitment to incident prevention, mitigation, and response planning. Safety of site operatives and first responders is the paramount safety concern and the final site-specific risk analysis reviews, consequence modelling and drafting of emergency response plans and training drills should ensure incident risk impacts are minimised. The complete range of thermal runaway scenarios (fire, explosion, toxic emissions, environmental pollution) have been considered. Prevention and mitigation measures have been designed to ensure incident impacts would be minimised for site operatives, first responders and the local community.

A *credible* BESS safety risk is a combination of the severity of the consequence of BESS safety incident coupled with the probability of that event occurring. This report provides additional insights and analysis on key safety features and requirements for BESS system and site design.

Examples of credible cause and failure scenarios are listed below and are commonly included in Failure Modes and Effects Analysis (FMEA) and HAZID or HAZOP assessments:

- Manufacturing or site installation errors.
- Damage to battery cells from environmental factors (dust, humidity, saline environments, water / moisture ingress, lightning strikes etc.).
- Electrical faults (overcharge / deep discharge, electrical arcing).
- Aging and lithium dendrite formation.
- Mechanical impacts.
- External fire sources.
- Operating conditions outside the manufacturers recommended battery system operating temperature range.
- Human error / malicious intent (installation, maintenance, vandalism, cyber-attacks).

This report does not focus on site requirements and infrastructure for KFRS because Matt Deadman's letter (Appendix 1 to Swale BC Planning Committee Report) concerning the Cleve Hill Battery Safety Management Plan indicates satisfaction with the BSMP and confirms KFRS intention to continue working closely with CHSPL to produce the requisite Risk Assessments and Incident Response Plans. Matt Deadman is also the Lead Officer for Alternative Fuels and Energy Systems at the NFCC so possesses significant knowledge of BESS site safety issues. BST&T fully concur with the position of KFRS on the ten safety issues / comments submitted by interested parties.

Section 1 - BESS battery failure tutorial:

The Electric Power Research Institute (EPRI) research identified 4 common BESS incident root causes (listed below) [2] - comprehensive design and maintenance programs can address all root causes except cell manufacturing defects. Selecting Tier 1 battery and BESS Original Equipment Manufacturers (OEM) with comprehensively audited manufacturing, storage and transportation processes significantly reduces defect risks. Modular BESS systems with pre-installed battery systems such as the CATL EnerC+ system, should be monitored for abuse conditions experienced during transportation to site and Site Acceptance Testing (SAT) processes must be comprehensive to ensure the highest safety standards are observed:

- **Internal cell defect**. Manufacturing quality control issues introduce unintended distortions, debris, or other contaminants in the cell assembly or chemistry that either induce or, by fatigue, develop into an internal short circuit.
- **Faulty battery management system (BMS)**. Inadequate protection settings or unreliable software or hardware performance result in exceedance of nominal operating thresholds (such as voltage, temperature, or duration at a certain state of charge).
- **Insufficient electrical isolation**. Ground fault, short-circuit, or DC bus power quality that leads to electrical arcing within a module or string.
- **Environmental contamination**. Exposure to humidity, dust, or otherwise corrosive atmosphere that breaks down existing electrical isolation or insulation.

Fire & Explosion risk are proportional to battery capacity and key mitigation solutions are universal to both risks. Battery module and battery rack combustibles can add significant fuel to heat release rates and fire toxicity. Key mitigation measures include:

1. Ventilation (module, rack, BESS enclosure)
2. Passive barriers and spacing (module, rack)
3. Active thermal management (module cooling)
4. Suppression system (includes detection and sensor alerts and incident monitoring redundancy) can be enclosure level or module / rack level system. Any fire suppression system must be capable to operate effectively in conjunction with the BESS enclosure gas exhaust / ventilation system.

The Jensen Hughes Hazard Mitigation Analysis for the CATL EnerC+ BESS, summarises the four primary hazards provided by sustained cell to cell propagation of thermal runaway:

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.

Section 2 – Explosion Hazards

The explosion hazard for a BESS enclosure is defined by the quantity and composition of gases released during thermal runaway and the volume of free air available in the container. Smaller BESS enclosures which typically have low volumes of free air are at higher risks of deflagrations without ventilation with small numbers of cells capable to vent gas volumes above the Lower Explosive Limit (LEL) / Lower Flammable Limit (LFL). A brief explanatory outline is listed below:

- Gas composition defines burning velocity, flaming / explosive limit ranges, and overpressure levels which could be generated in an explosive event. Exposure of battery cells to higher levels of heat tends to generate higher volumes of gas.
- Typical gases generated during battery venting are: hydrogen, hydrocarbon gases, carbon monoxide and carbon dioxide.
- Typical vented flammable gases across chemistries have autoignition range of 400 - 800C.
- Quantity and composition of gases is driven by State of Charge (SOC), cell design (form factor), cell chemistry (composition of internal constituents), cell geometry, and battery failure mechanism i.e. how it failed.
- Enclosure volume and quantity of gas released heavily determines the type of deflagration event.
- Cells at a higher SOC release more flammable gas at higher pressure rates - ventilation systems must be capable to effectively exhaust gases at the highest rates of venting.
- Predictions of gas properties and volumes from chemistry or form factor is unwise. Testing on actual BESS cells and modules is the only way to accurately define gas production. UL 9540A testing defines maximum cell and module overpressures and burning velocity. Other fire data recorded at module level is Peak Heat Release Rate (PHRR), Heat Release Rate (HRR), Total Heat Release (THR), cell propagation rates, temperatures within modules, and deflagration event data i.e. debris or shrapnel (if observed). Cell propagation during thermal runaway is driven by heat generated through internal current flow, parallel circuits, damaged circuitry, and wiring + external heat from vented gases and flames.
- It is diligent for manufacturers to test BESS cells and modules @ 100% SOC and SOC @ depth of discharge (lowest operating level SOC) to observe differences in typical thermal runaway behaviours and impacts on gas production, venting overpressure and burn velocity.
- The distribution of gas is dictated by cell & module venting design, battery rack construction and BESS container venting / gas exhaust design.

Cell level potential deflagration cause: vent failure, cell case failure, overcharge scenarios. This typically leads to faster rates of cell propagation within the module, the venting system must be capable to efficiently remove gases and heat from the module to ease the rate of cell propagation.

Module ignition sources: cell temperatures, cell ejected hot particles, hot circuits, melted wiring, and electrical arcing.

Typical conditions required for deflagration / explosion from vented gas:

1. Air and gas mixture must be in a range between the defined lower flammable limit (LFL) & upper flammable limit (UFL) where no combustion is possible.

2. Vent gas is released into a confined space i.e. module, BESS enclosure and overpressure is created.
3. Vent gas becomes congested i.e. obstacles, blockages, gas pathways can lead to flame acceleration increasing confinement effects.

Consequences:

1. Deflagrations are likely to cause rapid rise in heat generation >1600C and can produce greater volumes of toxic gas.
2. BESS modules, racks & enclosure / container design must integrate efficient venting to avoid structural damage.
3. BESS designs should be validated to prevent / protect against partial volume deflagrations (ignition of small volume of gas in localised areas) which can produce significant overpressures.

NFPA 855 (2023) [3] defines basic operation Health & Safety (H&S) protocols for all BESS site designs which should be incorporated into emergency response plans:

- Potential debris impact radius is defined as 100 ft / 30.5 m i.e. this is a typical explosion risk safe exclusion zone radius as modelling and previous BESS incidents typically show 25 m to be maximum radius.
- Automatic building evacuation area is defined as 200 ft or 61 m from the affected BESS enclosure.

BST&T will summarise additional details of how explosion risks are mitigated later in this report, as specified in the BSMP a strategy of explosion prevention was selected for the BESS system incorporating alert, monitoring and control systems which exceed current safety standards and best practice guidelines set out in NFCC and NFPA documentation.

Section 3 – Fire Hazards

Fire hazards i.e. burning thermal runaway events in BESS systems, are driven by identical factors covered in the section on explosion risks above. Variations in burn out times are significantly influenced by failure scenarios, SOC and battery rack configurations and materials. Cell and module propagation times during thermal runaway is driven by heat generated through internal current flow, parallel circuits, damaged circuitry and wiring, additional battery module and BESS enclosure combustibles, and internal / external module heating from vented gases and flames.

UL 9540A test data for the CATL EnerC+ system only recorded a venting thermal runaway incident with propagation to 3 cells in the battery module from the heated initiation of a single cell. However, BST&T has reviewed extensive testing data of full-scale burn tests of modules and BESS systems integrating similar large format LFP cells which can provide a range of basic fire scenario data which is reasonable to compare to the EnerC+ BESS system. A brief explanatory outline is listed below:

- Similar large form prismatic LFP cells (depending on SOC and vent design) during thermal runaway typically burn for 20-45 seconds. Gas volume and velocity depends on thermal runaway initiation protocols, SOC and Wh energy of the cell. However, a range of similar LFP cells have produced 200-400 litres of gas per cell during thermal runaway scenarios. The electrolyte burns fairly efficiently mainly producing Carbon Dioxide (CO), Nitrogen and Carbon Monoxide together with lower levels of hydrogen and hydrocarbon gases (venting reactions produce higher levels of hydrogen / hydrocarbon gases).

- Timeframes for full battery cell propagation in high energy density LFP BESS modules range from 6-14 minutes.
- Timeframes for burn out of high energy density LFP BESS modules range from 20-40 minutes.
- Whilst the total combustion energy released during a full burn out thermal runaway of a battery module or battery rack is generally consistent across all tests. Peak Heat Release Rate (PHRR) which is the maximum fire intensity generated by thermal runaway in a battery module or battery rack can vary significantly during repeat testing using the same initiation protocols. This means that outlier thermal runaway burnout times can frequently be half the time (highest intensity) or double the time (lowest intensity) recorded for other tests in the data sets.
- Typically, PHRR occurs when propagation rate of cells is at peak level and decays to a smaller steady fire that is burning through other module combustible materials.
- PHRR timeframes produce the highest levels of toxic gas emissions.
- Burn out times for full battery racks and BESS enclosures can vary depending on module design, rack design, passive and active protection features, rack spacing etc.
- Full BESS enclosure burn tests (750KWh – 1.5 MWh) involving high energy density LFP prismatic cell modules have generally burnt out in a 2-8 hour test window. BESS enclosures involved in the full-scale tests integrated 2-4 battery racks.
- Full scale burn tests have been conducted to establish the efficacy of ‘let it burn’ fire & explosion protection strategies for firefighters (FRS). This strategy allows a BESS fire to burn out in a controlled manner without direct intervention from the FRS except to provide ‘boundary cooling’ of adjacent BESS enclosures or ESS equipment if required i.e. to stop fire spreading. Full scale burn tests are used to establish safe spacing distances with site specific consequence modelling factoring in worst case wind conditions.
- 6 metres spacing between BESS enclosures integrated on the Cleve Hill site provides significant protection against a BESS thermal runaway incident propagating to an adjacent BESS enclosure. BESS enclosures integrating similar LFP cells have demonstrated fire propagation does not occur to other BESS enclosures at distances ranging from 15cm – 100cm to adjacent or back-to-back BESS enclosures with spacing of 7-10 feet across from the next row of BESS enclosures.
- ‘Let it burn’ strategies can help alleviate the following significant safety issues (see advice from the **International Association of Fire Chiefs** - **Appendix 2**): **a**. remove battery module ‘reignition’ risks energy **b**. remove stranded energy decommissioning problem i.e. how to safely discharge energy from damaged battery modules **c**. all flammable gases are consumed in a full burn out removing explosion risks **d**. if the FRS do not use hose streams directly on battery systems, then polluted water run-off issues should be avoided (confirmed in testing and recent US LFP BESS fire incidents).

Section 4 - Toxic emission and environmental concerns (thermal runaway scenarios):

Interested parties have submitted concerns regarding potential toxic emissions or pollution incidents that could occur in a thermal runaway incident with BESS systems. Several major research programs / studies have been commissioned to compare BESS fire emission toxicity with a range of industrial or warehouse storage type fire emissions. Upcoming changes to UL 9540A testing will also integrate new test protocols to define toxicity of BESS battery systems. Until these studies are published and new test protocols are in place, we must analyse data from recent real world BESS incidents and a range of significant scale burn tests of LFP cells and modules used in BESS systems. These tests analyse toxic gas emissions / pollution and heavy metal particulates that maybe generated in a BESS thermal runaway incident.

Gas capture is a tricky process for both toxic and explosive gases. Equipment and test protocols have significantly improved in the last 2-3 years, but sensors are often overwhelmed in explosive gas testing and toxic gas testing at significant scale still poses many challenges to ensure data capture is accurate.

A number of European and North American approved third-party or government test laboratories are installing large scale smoke hoods capable to capture every type of battery gas & particle emitted during the thermal runaway process by multiple battery racks or even full BESS enclosures.

This equipment can measure total volume gas production (gas chromatography) and FTIR (Fourier Transform Infrared Spectroscopy) testing (PPM) for organic compounds (toxic gases) such as: Carbon Monoxide, Carbon Dioxide, Hydrogen, Sulphur Dioxide, Nitrogen Oxides, Hydrogen Fluoride, Hydrogen Cyanide, Hydrogen Chloride, Hydrocarbon gases (THC content), PAHs, etc.

The equipment also integrates particle capture by XRF (X-ray fluorescence) analysis checks for: Phosphorus, Aluminium, Nickel, Silicon, Calcium, etc.

Volumes of toxic gases and heavy metal particulates that can be emitted during thermal runaway are often partially contained within the BESS enclosure (modules, racks, interior structure of BESS enclosure) and not vented into the external environment. The EPRI white paper (**Appendix 3**) [4] "The Evolution of Battery Energy Storage Safety Codes and Standards (2023)" notes: '*While laboratory testing identifies toxic compounds that are released by burning Li ion batteries, these may be consumed internally, combusted, or may react to form other non- toxic compounds before being released to the environment. In recent events where batteries have burned in this fashion, fire services have announced that nearby air -quality monitoring has shown the air quality to be at safe levels*.'

Speculation from interested parties concerning the need for Hazardous Substances Consent (HSC) is a matter for the HSE and EA, however BST&T has not reviewed any significant scale testing for a range of current BESS battery systems (LFP and NMC chemistries) which would give any validity to the claims made during the Sunnica DCO hearings.

BST&T has reviewed a wide range of toxic emission data from similar LFP BESS systems which demonstrate that toxic emissions are unlikely to significantly impact the local community and pollution risks will be minimised. Allowing a BESS fire to fully consume a battery system ensures that a combustion plume will travel downwind, so it is important to understand how this disperses and impacts the environment and the local community i.e. potential requirement to shelter in place or evacuate dependent on how closely a BESS site is located to receptors. The BSMP commits to prioritising the drafting of rigorous ERPs together with all key emergency response stakeholders, environmental incident monitoring will be a key part of this planning and a wide range of incident strategy scenarios will be evaluated for the Cleve Hill site.

BST&T worked with CHSPL and Hoare Lea to ensure the 'Revised Air Quality Battery Failure Plume Assessment Report' incorporated very conservative inputs and worst-case assumptions for high energy density LFP BESS battery systems which significantly exceeded toxic emission levels from full scale BESS burn tests and real-world events.

Hoare Lea Plume modelling uses very conservative inputs: all 40 modules in simultaneous burning thermal runaway, two BESS enclosures burning at the same time, high HF production (far higher than witnessed in recent LFP large scale burn testing). The report concludes the nearest receptors 300 metres from the closest BESS enclosure in worst-case meteorological conditions are not in an area of exceedance of Acute Exposure Guideline Levels (AEGL) levels of Hydrogen Fluoride (HF). HF when exposed to moisture will form Hydrofluoric Acid (also frequently referred to as HF). It should be noted that shorter time frame BESS fires (high PHRR) will release greater concentrations of toxic gases compared to longer burn times with lower heat release rates.

BST&T has included details in this report of LFP BESS system fire data from 2023, a real world environmental incident report and a UK BESS emissions report based on significant range of LFP battery fire test data (cell to system level). These reports should provide additional assurance that toxic emissions from BESS thermal runaway incidents need to be closely monitored but are unlikely to have a significant impact on Cleve Hill respondents in a credible burning thermal runaway scenario.

BESS incident and test data information (2023):

1. New York State (NYS) has the strictest BESS safety requirements in the US and has commissioned a significant number of BESS projects. Three separate BESS incidents occurred during 2023 and the Governor of NYS set up a Working Group to investigate environmental concerns and record air monitoring data and soil /surface and water sampling for the closest off-site receptor locations:

https://www.governor.ny.gov/news/governor-hochul-announces-release-initial-findings-inter-agency-fire-safety-working-group

- Data assembled and analyzed by the Working Group includes an air monitoring report from the Office of Fire Prevention and Control, and soil and water sampling data received from the Department of Environmental Conservation. An independent third-party site inspection report consisting of air monitoring and surface sampling at school buildings in the vicinity of the June 27, 2023, fire at the Warwick site was also submitted.

- The Working Group includes representatives from the Division of Homeland Security and Emergency Services (DHSES) Office of Fire Prevention and Control (OFPC) New York State Energy Research and Development Authority (NYSERDA), New York State Department of Environmental Conservation (DEC), Department of Public Service (DPS), and the Department of State (DOS). The group was convened in August 2023 and has gathered data and worked diligently with project developers, equipment manufacturers, and government officials to learn as much as possible about the fires at the three battery system sites.

The data assembled and analysed by the Working Group includes:

- An air monitoring report from the OFPC, and soil and water sampling data received from DEC from the Chaumont site.
- On-site air monitoring results collected from the Warwick sites and relayed to the Working Group by local officials.
- On-site soil sampling results from the East Hampton site relayed to the Working Group by a project developer.
- An independent third-party site inspection report consisting of air monitoring and surface sampling at school buildings in the vicinity of the June 27, 2023, fire at the Warwick site.

Based on the information available to date, there is no evidence of significant off-site migration of contaminants associated with the fires. The final report will be released later in 2024.

2. BST&T is currently working on the Cottam Solar Project DCO hearing. The developer commissioned a report by Tetra Tech: *The Air Quality Impact Assessment of BESS fires* (**Appendix 4** – study based on LFP battery systems) [5], key details are listed below:

- Uniquely for a generic indicative report for a DCO hearing, Tetra Tech was given access to a wide range of battery toxic gas emission data provided by a major battery test facility system and consulted with BST&T to access wider LFP system test data. The generic BESS system integrates 52 x 280Ah LFP cells in a 46.59 KWh module, 8 modules are located in each battery rack.
- Closest respondents to BESS areas are 320 metres so plume modelling is relevant for Cleve Hill.
- Tetra Tech also worked closely with the UK Health & Security Agency (UKHSA) to define the key potential BESS toxic emissions that should be included in the report and plume modelling

methodologies that should be used '*Undertaking a detailed battery energy storage systems (BESS) fire impact assessment using AERMOD dispersion model software. The predicted pollutant levels of NO_2, benzene, HCI, and HF and particulate matter (PM10 and PM2.5) emissions will be assessed at sensitive receptors using UK Air Quality Standards*.'

- Three impact assessment scenarios were undertaken for the report based on both LFP battery test data and BESS site data: **Scenario 1** – Assessment of a fire plume at temperatures of 800°C and the associated gas volume generation under this temperature; **Scenario 2** – Assessment of a fire plume at temperatures of 1,000°C and the associated gas volume generation under this temperature; **Scenario 3** – A sensitivity study of pollutant impacts under a high wind weather condition – a wind speed of 38 miles per hour (17m/s).
- The report concluded: ***based on the latest LFP BESS fire test (made available in October 2023) that NO_2, HCL, PM10 and Benzene are not present in high enough volumes in fire gases to require inclusion in the assessment. As such, HCL, PM10 and Benzene have not been included in the assessment, and only NO_2 is included for completeness***.
- The report BESS Fire Impact Assessment Results conclusions state: ***The short-term predicted environmental concentrations of Nitrogen Dioxide (NO2) and Carbon Monoxide (CO) at the residential receptor locations from a BESS fire incident are all below the relevant air quality objectives for the protection of human health. All receptors will have a 'low' air pollution level on the DAQI based on the short-term NO2 pollution index. The predicted ground level 8-Hour mean and 15-min mean of Hydrogen Fluoride (HF) concentrations at the residential receptor locations are all below the relevant British occupational exposure limits. The short-term HF impact of a BESS fire at the receptors is sufficiently 'small'. The effect of a BESS fire on the receptors is insignificant. The predicted maximum short-term HF concentrations are below the AEGL-1 (Acute Exposure Guideline Level 1). In addition, the sensitivity study assessment results of HF impact under a windy condition demonstrate that the predicted HF concentrations are also below the AEGL-1.***

Section 5 - Risk assessments & modelling reports provided by CATL and CHSPL:

To provide further background information on BST&T's safety report conclusions more details and observations on risk assessments and reports are listed below. It should be noted that leading BESS specialist engineering companies and fire protection engineers (FPE / PE) are US based and CATL has engaged the services of acknowledged global experts to produce HMA and NFPA 69 compliance reports.

1. FMEA analysis conducted and HMA report written by Jensen Hughes who has significant expertise in the field of battery and BESS safety testing, prevention, and mitigation analysis (US Navy, Tesla, GM, NASA, etc.).
2. NFPA 69 (Explosion prevention) compliance assessment and modelling report was conducted by Nicholas Bartlett a leading US BESS Fire Protection Engineer / Subject Matter Expert.
3. NFPA 69 report CFD model review showed no "dead spots" or areas in which flammable gases might accumulate. The report concluded: "*The fan and make up air unit are capable of exhausting flammable gases throughout the container in a homogenous manner*."
4. The NFPA 69 CFD modelling used a credible worst case of three modules (312 cells / 305.49 KWh) simultaneously venting which primarily could occur in an overcharge scenario. There are multiple layers of BESS system controls / monitoring to prevent this happening and variations in cell voltages at high states of charge (SOC) are likely to determine that large numbers of cells do not vent simultaneously.
5. The BESS exhaust fan provides air flow of 6.8 cubic feet per minute / per square foot (6.8 times the minimum recommended volumetric flow). The report concludes: "*explosion control system provided complies with the letter and intent of the applicable requirements of NFPA 69 and NFPA 855. As such, the explosion risk is mitigated to a substantially low and manageable risk*."

6. CHSPL has committed to commissioning site specific modelling as a priority once planning is granted and construction / operations teams are appointed (BSMP Table 2, Step 4 - as per Jensen Hughes HMA recommendations).

Section 6 - CATL EnerC+ BESS system confirmed specifications:

1. Prismatic LFP (Lithium Iron Phosphate) Battery Cell 979.2 Wh
2. Module 101.83 KWh (104 cells 52S2P) – IP 67 with liquid cooling
3. BESS system 5 x battery racks containing 8 modules = 4043.47KWh (4.043 MWh)
4. BESS site contains 96 x BESS enclosures.

In addition to meeting all requisite BESS safety certifications and standards BST&T has highlighted additional safety and risk mitigation measures undertaken by CHSPL (listed below).

Section 7 - Battery system safety features and Site Acceptance Testing (SAT) protocols demonstrating best practice and understanding of safety risks:

As specified in the BSMP:

1. Each battery module shall be fitted with a shock sensor to provide clear visible indication if the battery module has been exposed to any extreme impacts during the transportation period and include a muti-sensor data loggers capable of logging temperature & humidity, where possible the use of airconditioned containers shall be used to maintain the ambient temperature during transport.
2. Where battery modules are to be delivered in multiple quantities (e.g., the initial delivery of the modules to site) each container in which the modules are housed shall have installed at least four muti-sensor data loggers capable of logging temperature & humidity where possible the use of airconditioned containers shall be used to maintain the ambient temperature during transport. BST&T considers this to be a vital element of system safety, US Navy research shows that significant abuse to new battery cells and systems can occur during transportation and storage.
3. Prior to acceptance of a new / replacement battery module, CHSPL shall ensure that Site Acceptance Tests (SAT) will follow BS EN IEC 62933-5-2 standards and protocols, or equivalent before the module / cell is accepted for use.
4. Battery modules integrate liquid cooling systems with automated fail-safe operation. Liquid cooling systems generally provide higher levels of safety and better long-term performance. Air cooled BESS systems have been involved in most global BESS thermal runaway incidents. Air cooled systems leave battery systems more susceptible to a wider range of abuse factors that can result in thermal runaway scenarios. Higher operating temperatures with air cooled modules increase the difficulty to identify and detect potential thermal runaway threats.
5. In addition to the standard CATL battery system monitoring and control functions additional 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.
6. System data analytics integrated into EMS / BMS systems and controls reduces Thermal Runaway risks. Data Analytics can also be used to predict accurate End-of-Life timeframes and provide operator maintenance alerts.
7. The site's cybersecurity will form a fundamental part of the system design and architecture as there is an increasing focus in this area from national and international regulatory bodies. The development will reduce risk in accordance with the Health and Safety Executive (HSE) Operational Guidance document OG86. The International standards such as IEC 62443, UL 1741, IEEE 1815, IEEE 1547.3, and the recently published UL 2941 will be consulted and guidance from national sources such as National Cybersecurity Centre will be used to inform the implementation and protection measures.

Section 8 - BESS enclosure safety features

As specified in the BSMP:

1. 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 (Table 2, Step 4 BSMP).
2. A dry pipe sprinkler system installed (connections 25 feet from BESS enclosures as per HMA recommendation). The HD Medium Velocity Water Spray Nozzles are open type (non-automatic) nozzles with rubber plug, designed for directional spray application at 12 bar pressure on battery racks. The system can operate in conjunction with the gas exhaust system should KFRS decide that direct battery system fire suppression is required.
3. Discharge of the aerosol fire suppression system (FSS) shall be limited to only true “electrical” fault fires and will not trigger in the event of a thermal runaway ensuring the gas exhaust system remains in operation. 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.
4. The CATL EnerC+ Enclosure integrates smoke, gas and heat detection products which comply with NFPA 855 (2023), Standard for the Installation of Stationary Energy Storage Systems. CHSPL will also install carbon monoxide sensors in compliance with NFCC guidelines which BST&T considers to be best practice.
5. 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. Recent research in the US has shown that many BESS enclosures integrate malfunctioning or incorrectly installed fire protection equipment. BST&T considers CHSPL installation and commissioning commitment to be best practice and a vital safety compliance check.
6. Each BESS enclosure includes audible and visual notification devices in the event of a fault or alarm condition, this is a key safety feature for incident first responders.
7. Each BESS enclosure 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 signaling solution in the event of an emergency scenario, the system can also provide automatic signally to the local fire department which shall be offered and provided at their discretion. The detection systems meet all requirements identified in the Jensen Hughes HMA report.

Section 9 - Additional site safety features and commitments:

1. 5 metre bund to protect against flooding
2. 6 metre spacing between BESS enclosures, provides additional propagation protection against fire or explosion thermal runaway scenarios.
3. 3 metre spacing to other ESS equipment.
4. CHSPL will undertake additional site-specific risk analysis reviews once the contractor is appointed, these include site specific consequence modelling for first responders (fire & explosion risk analysis), HAZOP / Hazid operations peer review, Fire Protection System sign off, etc. This is best practice and conforms to Jensen Hughes HMA recommendations.
5. The impact of pollution entering the local watercourse has been mitigated by the site’s drainage design. Fire water can then be monitored and tested at each penstock outlet during and after the management of a fire event, and based on its results shall either be: **a.** Treated onsite, or **b**. pumped into tankers to be disposed of offsite.

BST&T conclusions:

1. BST&T is satisfied that BESS system and site design meets requisite safety standards, guidelines, and acknowledged best practice as set out in the BSMP.
2. KFRS remain satisfied with the proposals detailed in the Cleve Hill BSMP (December 2023, revision B) and has also responded to comments submitted by interested parties.
3. Site-specific risk analysis and safety reviews (BSMP Table 2, Step 4) will be commissioned once the contractor is appointed will provide a final layer of BESS safety analysis ensuring all elements of Jensen Hughes HMA recommendations are fully met.

References:

1) EPRI White Paper, CARNEGIE ROAD ENERGY STORAGE SYSTEM FAILURE RESPONSE, RECOVERY, AND REBUILD LESSONS LEARNED, (2023)

2) EPRI Technical Update Report, Lessons Learned: Lithium Ion Battery Storage Fire Prevention and Mitigation, (2021)

3) NFPA 855, STANDARD FOR THE INSTALLATION OF STATIONARY ENERGY STORAGE SYSTEMS (2023)

4) EPRI White Paper, The Evolution of BESS Safety Codes and Standards, (2023)

5) Zhiyuan Yang, Air Quality Impact Assessment of Battery Energy Storage Systems (BESS) Fire, (2023)