APPENDIX 4-4

Fire Risk Management and Emergency Response Plan

FIRE RISK MANAGEMENT & EMERGENCY RESPONSE PLAN

Killoshulan Renewable Energy Ltd. BESS Safety Report

Risk Mitigation, Fire Protection, and Safety Management Systems for the Battery Energy Storage Infrastructure.

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1 EXECUTIVE SUMMARY

This report outlines the fire risk management and emergency response plan for a proposed 50MWh battery energy storage system (BESS) on an 10 No. turbine wind farm in County Kilkenny. Based on tested and approved battery technology, predictive modelling and a desktop hazard mitigation analysis (HMA), the identified threats including fire, toxic cloud, and explosion risks can be safely managed.

The proposed 0.40-hectare BESS compound will contain 10 modular liquid cooled container units built to meet global safety benchmarks, including UL9540A and NFPA-855. Operations will be overseen by intelligent battery management systems providing real time monitoring to detect and catch thermal events early.

The proposed 50 MWh BESS facility represents a highly stable, modern utility asset. The probability of a thermal incident is statistically very small, and the physical consequences of an isolated cell failure are benign, non-propagating, and safely managed within the enclosure boundaries. The project presents no significant risk to local infrastructure, first responders, or the surrounding community.

The probabilistic analysis in this report gives a clear, data driven assurance that a thermal incident at this facility is an exceptionally rare statistical anomaly. Nevertheless to manage risks, the safety strategy introduces critical infrastructure to protect emergency responders, and the surrounding environment. Static water storage tanks will provide the abundance of water necessary to control thermal runaway and prevent fire spread during an extended incident. To safeguard the local environment from contaminated runoff, specialised site bunding and a dedicated retention tank will capture firefighting water so it can be sampled, treated, or safely removed by hazardous waste contractors. The report also incorporates clear site access routes and explicit evacuation protocols tailored for local fire and rescue services. While the operator holds ultimate responsibility for site safety, these integrated design features will dramatically reduce risks, safeguard emergency services, protect the environment, and minimize operational downtime after an incident.

2 INTRODUCTION

The proposed Killoshulan Renewable Energy Project (the Proposed Project) comprises of 10 no. wind turbines, and associated infrastructure, the Battery Energy Storage System (BESS) compound and associated works, and the proposed underground cabling route that will 'loop-in' the an existing substation at Ballyragget to the 110kV overhead transmission line.

D.M. Flaherty & associates fire consultants have been instructed by MKO on behalf of Killoshulan Renewable Energy Limited to carry out a fire risk management and response plan for the proposed construction of a battery energy storage system (BESS) facility within the townland of Killoshulan Co. Kilkenny. The purpose of this report is to support the planning application for the proposed project which involves the construction of the afore mentioned BESS facility, a windfarm, and sub-station. The scope of this report is associated to the proposed BESS facility only and will specifically address the fire and explosion threats which have been identified at the design stage. This report will also provide guidance in relation to mitigation measures which should be implemented to address the specific hazards and threats identified.

The proposed BESS is within a total site area of 2 hectares and will involve the construction of all relevant equipment and infrastructure for the provision of a 50MWh BESS facility. The site, works and equipment will consist of the installation of electrical inverters, electrical transformers, containerised battery storage modules, access tracks, associated electrical infrastructure, security gates and site fencing and all associated ancillary infrastructure.

D.M. Flaherty & Associates Fire Consultants have carried out a desktop fire predictive modelling of the threats of the proposed BESS facility. As part of this desktop review, a hazard mitigation modelling (HMA) analysis was carried out. The findings of this HMA are presented in detail in Section 7 of this report. It is put forward that, if the mitigation measures which are proposed in this report are implemented, the fire, toxic cloud and explosion threats which are considered relevant to this proposed facility are adequately controlled and mitigated.

The content of this report is relevant only to the design and planning phase of this project. This fire risk and response plan should be not be used to inform the construction phase and any building control requirements for this project. It will be the responsibility of the client and/or person/body corporate responsible for the BESS facility to ensure

that this report is fully reviewed prior to commencement of construction to ensure that all relevant changes to legislation, guidance, design standards, industry knowledge and product technologies have been addressed, accounted for and updated accordingly.

3 PROJECT DESCRIPTION

The Site is located within a rural setting in northwest Co. Kilkenny, approximately 4.6 kilometres (km) to the west of the village of Freshford. The town of Urlingford is located approximately 5.5km west and Kilkenny City at approximately 16km southeast of the site. The site comprises a mix of agri-pastoral land and Coillte forestry. The M8 Motorway runs north-south approximately 12km to the west. The R693 regional road runs southeast- southwest on the southern boundary of the site. Existing access is via the R693 road to the south and the L1805, L18055 and the L18056 local roads to the north of the site. The site location context is shown in Figure 1. The Site falls within the townlands of Killoshulan, Foyle South, Frankford or Ballykieran, Barna and Spahill, County Kilkenny.



Figure 1 – Site and BESS Location

4 DESCRIPTION OF THE BESS PROJECT

The proposed BESS project will consist of 10 No. battery storage containers, with each container having a capacity of 5MWh. Each container is fully integrated with embedded a power conversion in 12.2m (W) x 2.4m (D) x 2.58m (H) and 10 No. medium voltage transformers will be positioned on concrete plinth foundations (figure 2). The proposed BESS will connect with a 110kV substation building, auxiliary electrical equipment storage, an unbound internal track, a lightning mast, lighting columns, and CCTV cameras.

To provide access between the proposed BESS and the surrounding proposed project infrastructure, existing access tracks will be upgraded, and new access tracks will be constructed. The compound will be enclosed with a 2.6m high palisade fence with vehicular gates providing access to the compound area during the operational phase.

The BESS system is a modular, grid-scale battery energy storage system. Unlike traditional DC blocks, it is an AC-based system that integrates battery pods and the power conversion system (inverter) in the same enclosure. The capacity of each container is 5MWh. The system is designed to meet key fire safety standards, including UL9540 and UL9540A, NFPA-855, NFPA68 and NFPA69.



Figure 2 – MV Transformer

The enclosures include a comprehensive fire protection system with isolated containment zones, integrated fire suppression, deflagration panels, environmental sensors, and active ventilation. These features are designed to prevent, detect, and contain thermal events, minimizing damage and downtime. The system has undergone full-scale fire tests to assess propagation, safe distances, gas emissions, and incident response times, going beyond minimum compliance. The enclosures have an IP55 rating, which means it is protected against dust ingress and low-pressure water jets from any direction, contributing to overall safety and durability.

External lighting is proposed to serve the compound which will be protected and secured with 2.6m high palisade fencing (Figure 3). Prior to installing the container enclosures, clearance of the site area, levelling off the ground surface and creation of a hard stand is proposed to be undertaken.

The BESS containers house the batteries, inverters, transformers, fire safety equipment and associated electrical components. The containers are to be spaced to allow airflow around the enclosures, feeding their climate control systems and provide fire spread separation. The battery storage compound will operate continuously, linked to the IPP Building within the substation adjacent to the BESS compound. It will be monitored in tandem with the overall development and there will be sporadic maintenance visits as required.



Figure 3 – Proposed BESS Compound Layout

5 BATTERY ENERGY SYSTEM (BESS)

A battery energy storage system comprises several integral components, each crucial for maintaining efficiency and safety. The illustration below (Figure 4) demonstrates how these parts are connected in the BESS. The Battery Management System (BMS) is a real-time monitoring system containing an electronic circuit apparatus which monitors the state of the battery ensuring battery safety, reliability, and stability. This includes a cell supervision circuit, a sub-battery management unit and master battery management.

The Power Conversion System (PCS) is an electrical or electro-mechanical device that converts electrical energy between DC and AC, essential for managing various loads. Most loads use AC but batteries, wind turbines and solar panels have a DC output. The PCS is bi-directional inverter/charger, compared with a photo voltaic inverter.

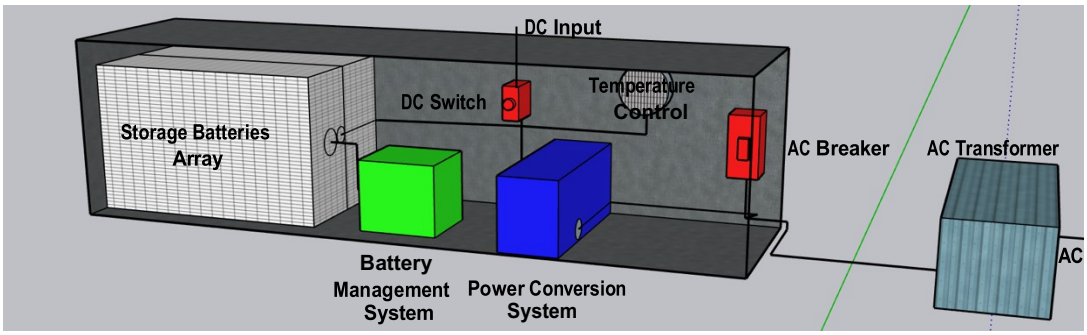


Figure 4 - Battery Storage Container

Environment Sensor & Temperature Control System detects any abnormal surrounding conditions of the BESS and alerts the environment control module. This includes door sensors, flooding sensors, smoke sensors and more.

The environment control module contains an air conditioner and an automatic control system providing an ideal temperature and humidity environment for batteries during charging and discharging. The fire suppression system is managed and control by this system to ensures the safety of the energy storage system designed to prevent electrical fires.

The BESS contains a DC switch between PCS and storage device and an AC breaker between PCS and AC transformer for safety. The wind turbine energy DC input or DC output load can be connected to the system after the DC switch. The transformer is a major external component that ensures the output of the BESS requirements on AC voltage.

6. STANDARDS and GUIDANCE

The fire safety measures identified for this installation will be developed using considerations from Irish guidance, international best practices and applicable international standards. The European Regulations (Regulation (EU) 2023/1542) for Battery Energy Storage Systems with lithium-ion batteries involves several key standards. These standards address safety, performance, and lifecycle management of lithium-ion batteries used in BESS, ensuring they are safe for normal operation and under expected fault conditions.

The Batteries Regulation (Regulation (EU) 2023/1542) requires that stationary BESS be safe during normal operation and use. It mandates demonstration of compliance with state-of-the-art testing methods developed by organisations such as the European Committee for Electrotechnical Standardisation (CENELEC) and the International Electrotechnical Commission (IEC) and other organisations with global recognition.

The BESS installation plan will be designed and installed to the recommendations from the following standards and best practice guides in Ireland and internationally:

- EN-IEC 62619 - Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications.
- EN IEC 63056 - Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems.
- IEC 62933-5-1 - Electrical energy storage (EES) systems - Part 5-1: Safety considerations for grid-integrated EES systems - General specification.
- IEC 62933-5-2 - Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid-integrated EES systems - Electrochemical-based systems.
- IEC 62485-5 – Safety requirements for secondary batteries and battery installations – Lithium-ion batteries for stationary applications.
- NFPA 855 – Standard for the Installation of Stationary Energy Storage Systems.
- NFPA 68 – Standard on Explosion Protection by Deflagration Venting.
- NFPA 69 – Standard on Explosion Prevention Systems.
- NFPA 2010 – Standard for Fixed Aerosol Fire-Extinguishing Systems.
- FM Global Property Loss Prevention Data Sheets 5-33.
- UL 9540 Standard for Energy/Storage and Equipment.
- UL 9540A Test Method for Battery Energy Storage Systems (BESS).
- CSA TS-800:24 Large-Scale Fire Test (LSFT) Procedure.

In response to the requirements of the standards and guidance documents, this plan outlines safety measures specifically for this proposed outdoor utility scale lithium ion battery energy storage systems. The battery system proposed for this site will have been testing at cell-level to UL 9540A to provide detailed information of the breakdown of the composition of vented gas from cells in thermal runaway, including flammable gases and vapours. Large scale fire testing will be carried out on the container enclosure system to CSA TS-800:24 Large-Scale Fire Test (LSFT) procedure**.** This technical specification provides a standardised method for evaluating fire hazards associated with energy storage systems.

7. FIRE RISK MANAGEMENT PLAN

7.1 Introduction

BESS are devices or groups of devices that enable energy from intermittent renewable energy sources (such as wind power) to be stored and then released when customers need power most. They are constructed of successive battery packs wired together to create modules that are connected within racks to create an energy storage array. The battery chemistries for this BESS installation has been decided at this point as a containerised system with lithium iron phosphate (LFP) battery technology.

The fire safety measures outlined in this report for this BESS installation have been developed using considerations from Irish guidance, international best practices and applicable international standards. The European Regulations (Regulation (EU) 2023/1542) for battery energy storage systems with lithium-ion batteries involves several key standards. These standards address safety, performance, and lifecycle management of lithium-ion batteries used in BESS, ensuring they are safe for normal operation and under expected fault conditions.

The BESS compound and the site in general will operate mostly unstaffed autonomous through an alarm receiving centre (ARC) monitoring the onsite control systems with supervisory control and data acquisition (SCADA) systems and 24/7 monitoring by a human operator or team, enabling comprehensive oversight and control without a constant on-site presence. Integrations with closed circuit TV (CCTV) will allow for live video feeds in which the monitoring centre will be able to verify alarms and detect false alarms, ensuring appropriate responses. Automated alerts can also be sent via text, email or App, keeping stakeholders informed of incidents in real-time.

This plan has been developed accordingly with the safety of the staff, public and emergency services in mind. It is based on trying to help reduce the risk as far as reasonably practicable, whilst recognising that ultimate responsibility for the safe design and running of these facilities rests with the operator.
This fire risk management plan is based upon a range of supporting materials including academic research, national and international standards, case studies, and industry guidance. The content of this plan is the result of analysis of that supporting material with subsequent professional judgement applied. Every Battery Energy Storage System installation is different and for this proposal bespoke solutions will be necessary.

7.2 BESS Threats

If a battery cell creates more heat than it can effectively dissipate it can result in a rapid uncontrolled release of heat energy, known as ‘thermal runaway,’ that can result in a fire, toxic plume or explosion. This can occur as a result of an internal short circuit due to manufacturing defects, ‘lithium plating’ (formation of metallic lithium on an anode surface within a battery cell), or mechanical damage. Other possible causes of thermal runaway are exposure to heat from an external source, overcharging, over-discharging, and failure or malfunction of the BMS.

BESS installations often use large numbers of flat ‘prismatic battery cells’ (rather than ‘cylindrical battery cells’) that are sandwiched together. These typically pose a greater risk of thermal runaway occurring than with cylindrical cells, however the protection strategies are the same.

Thermal runaway can lead to the ejection of a range of gases from battery casings, such as hydrogen (extremely flammable), carbon monoxide (toxic, asphyxiant, and flammable), and hydrogen fluoride gas (acutely toxic and corrosive).

When a battery cell vents or ruptures due to thermal runaway, immediate ignition of the emitted gases can occur (especially for batteries with a high level of charge). Alternatively, the gases may spread-out unignited, with the potential for a deflagration (very rapid combustion) or explosion if an external ignition source is encountered.

7.3 Proposed Risk Management Approach

A hazard mitigation analysis (HMA) approach will be employed for this proposed development. The installation be systematicly assessed to identify potential risks, evaluate their consequences, and develop strategies to reduce or eliminate long-term threats to people, property, and the environment. The scope of the HMA will be to establish the fire and explosion protection design criteria for the facility. The development of the HMA will be an iterative process. The HMA will be revised as the design progresses and technical design aspects are selected and finalised and based on dialogue among the stakeholders. The HMA will outline the protection/prevention design basis for achieving the fire hazard control objectives agreed upon by the stakeholders.

The systematic HMA approach, that will be employed, to minimise the risks at this BESS site will follow the Hierarchy of Controls Methodology (Figure 5). The hierarchy of controls is a methodology that ranks safeguards for managing workplace hazards from most to least effective, prioritising methods that eliminate or reduce the hazard at its source. The five levels, in order of effectiveness, are Elimination (remove the hazard), Substitution (replace it with something less hazardous), Engineering Controls (physical isolate people from the hazard), Administrative Controls (change work policies and procedures) and Personal Protective Equipment (PPE) (provide protective gear as a last resort). This methodology will endeavour to ensure there are robust control measures are put in place to:

- reduce the likelihood of threat event.
- mitigate the consequences of a fire event should a fire occur.

These controls measures are imperative to protecting maintenance and emergency response personnel and the environment.

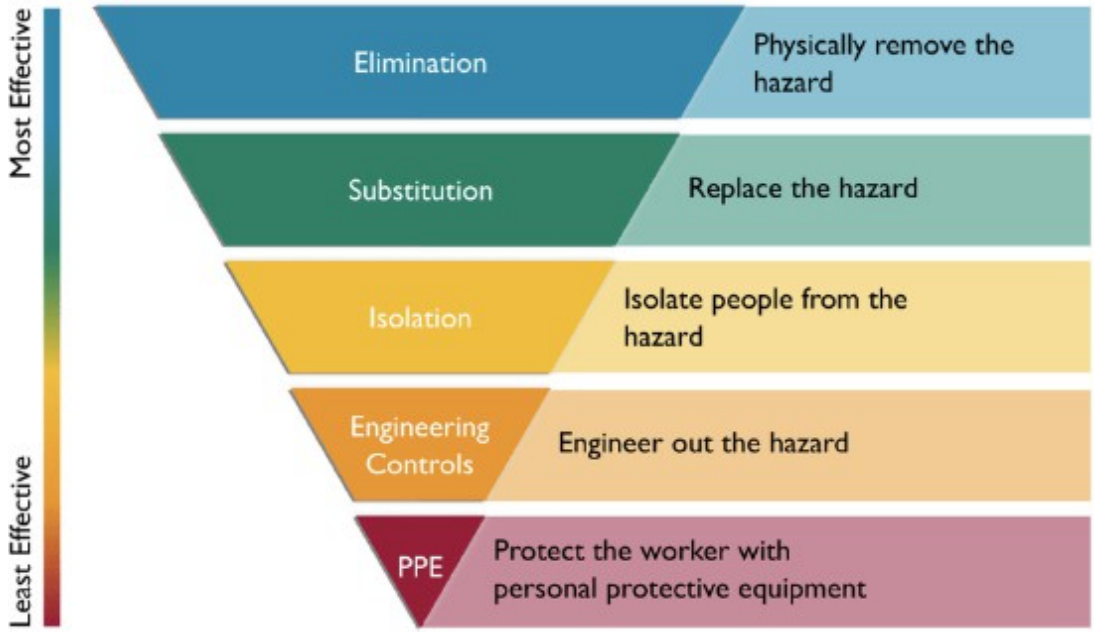


Figure 5 – Hierarchy of Controls

7.4 Elimination

The suppliers of the battery energy storage systems will be selected such that all levels including cell, module and BMS and the barriers designed within their equipment package are tested and certificated to reduce the fire risks. Testing of battery equipment to UL9540A standard (cell, module and unit) will be conducted by the equipment supplier. This will provide a critical input in understanding the volume of off-gases which are likely to be produced in a fire event and adequate steps to mitigate the impacts. Large scale testing of the BESS enclosure will also be carried out to CSA TS-800: 2024, Large-Scale Fire Test (LSFT) procedure. This involves intentionally initiating a fire in a BESS enclosure to evaluate how fire might spread to nearby systems. Unlike UL 9540A testing, which may only lead to the release of flammable gases without ignition, large-scale fire testing forces a fire condition in one BESS enclosure to assess if thermal runaway and fire propagation will occur in adjacent enclosures.

7.5 Substitution

Transformers are an integral component of BESS sites, with coil and core insulation facilitated by oil. To reduce the fire risk in the event of a spill, a non-mineral oil which is less flammable will be specified to be used as the insulating fluid.

As stated earlier, the decision has been made to use lithium iron phosphate (LFP) battery technology. Lithium Iron Phosphate batteries have a thermal ignition temperature of 270°C whereas Nickel Manganese Cobalt (NMC) batteries have a thermal ignition temperature of 210°C thereby being less thermally stable. Therefore, LFP batteries provide better resistance to a thermal runaway initiation. However off-gassing is more severe with LFP battery technology under fire or thermal runaway conditions.

7.6 Isolation

The design of the BESS enclosures itself will provide a passive barrier of protection to personnel. In addition, the exposure risks to personnel are further reduced/eliminated as the BESS site will operate largely unstaffed with monitoring done autonomously through the onsite control systems and 24/7 monitoring by a remotely.

7.7 Engineering Controls (Engineer Out the Hazard)

7.7.1 Introduction

All equipment/systems (BESS enclosures, power systems and inverter and transformers) are to be installed per the manufacturer's equipment specifications including spacing requirements for maintenance and safety clearances. The BESS enclosures are proposed to include various engineering controls ranging from passive barriers to active monitoring and detection systems. These measures will be employed to further reduce the likelihood and consequences of a fire at this BESS facility. These controls include:

7.7.2 Battery Management System (BMS)

A BMS will be installed to provide early detection of potential cell failure which could result in a thermal runaway event. The critical cell is identified, automatically disconnected and isolated before further degradation and ultimately a thermal runaway event can be initiated. The BMS will also provide cell and module over and under voltage protection, alert, and correction.

Computer controlled battery management systems (BMS) are a key element of BESS systems which manage the flow of energy to and from the BESS system and ensure that battery cells remain within their safe operating range for voltage, current, and temperature. Flammable electrolytes combined with high energy, contained in lithium-ion battery cells can lead to a fire or explosion from a single-point failure.

Cell level protection will be provided at each cell level which will be controlled by the BMS:

- Battery cells are to be fitted with current interrupting devices (CIDs) which allow for automatic isolation of individual cells during an external short.
- Overcharge safety devices (OSD) – are to be fitted which activate current interruption during over-charge.

Cells are to be outfitted with a safety function layer through ceramic coating which is designed to suppress thermal runaway within the cell.

7.7.3 Enclosure Panels

The BESS enclosure panels are proposed to provide 60 minutes fire resistance and therefore 120 minutes fire resistance between one BESS enclosure to another (back-to-back containers). The fire resistance and the physical separation of the container units will assist in reducing the cascading progression of an LFP threat. Installation of gas detectors is proposed in each enclosure for the early detection of off-gases/electrolyte-vapour such as H_2 and CO. The detectors will be monitored by the BMS with automatic shutdown capabilities.

7.7.4 Fire Detection & Alarm

It is proposed to provide a fire detection and alarms system to each BESS enclosure to include smoke detection, heat detection, sounders and strobe alert and one fire alarm panel (Control Indicating Equipment) per enclosure connected to a central BMS.

7.7.5 Aerosol Suppression

An aerosol extinguishing agent flooding system will be installed in each enclosure to extinguish an energised electrical fire in electrical components. This agent is intended for use on this classification of fire only and is not designed to prevent or combat thermal runaway. The choice of the type of suppression system will be informed by liaison with a competent system designer who can relate the system choice to the risk identified and the duration of its required activation. Such a choice must be evidence based.

7.7.6 Deflagration Panels

The BESS enclosures will be fitted with deflagration venting and explosion protection appropriate to the hazard. Designs will be developed by competent persons, with design suitability able to be evidenced. The deflagration panel(s) will be included which are designed to structurally fail at a lower pressure than the enclosure structure in the event of an overpressure situation. Any blast overpressure of gases will be directed upwards and away from personnel in the event of exhaust ventilation system failure. Deflagration ventilation will be installed in accordance

with NFPA 69 and NFPA 68. The sizing the vent area (A_v) involves several complex variables such as the enclosure strength (P_{red}), the venting characteristics C, which is a function of the fundamental burning velocity, density and other thermo-physical properties of the off-gases from UL 9540A tests.

The vent area is calculated using the formula,

$$A_v = C \cdot A_s / \sqrt{P_{red}}, \text{ where;}$$

A_s is the internal surface area of the enclosure and the maximum pressure, $P_{red,}$ that an ISO enclosure can withstand is typically 0.2 bar-g before structural failure.

7.7.7 Ventilation

A ventilation system will be included to vent an ESS enclosure after a combustible concentration reduction system (CCR system), based on an NFPA 69 deflagration study, is activated and signals the BMS of the presence of flammable gases. The continuous gas detection system will comply with the following:

1. The gas detection system will be designed to activate the CCR system on detection of flammable gases at no more than 10% of the lower flammability limit (LFL) of the gas mixture or of the individual components.
2. The CCR system will remain on to ensure the flammable gas does not accumulate and exceed 25% on average of the LFL of the total enclosure volume of the gas mixture. For hydrogen produced the maximum concentration must be limited to 1% of the total volume of the enclosure. An exhaust ventilation rate based on the area of not less than 5.1 l/sec/m^2.
3. The CCR system and its components will be considered a critical safety system and will be provided with a minimum of 24 hours of standby power.
4. The gas detection system and CCR system will annunciate at a supervising station.

The CCR system should take priority over a suppression system. The activation of a suppression system must not hinder the CCR system operation or delay its performance. To ensure this, a “no impact” analysis with supporting performance data should be performed.

7.7.8 Space Separation

Separation of BESS container units is an effective means of preventing a fire event from escalating through radiated fire spread to adjacent BESS containers, buildings and equipment. Separation distances are proposed which exceed or match standards and best practice (See Appendix A for site diagram).

- >30m separation distance (minimum) from the BESS site boundary and occupied building per NFPA 855.
- >10m separation from combustible vegetation.
- 0.9m BESS container distance separation in compliance with 0.9m guidance from NFPA 855.
- BESS systems will be at least 15 metres from building HVAC air inlets.
- 6.0m fire break between groups of equipment where possible
- >10 m separation between the water tank and BESS nearest enclosure.

It may be acceptable to reduce some of the above risk control measures where, as in this case, large-scale testing, such as testing to UL9540A or equivalent for this type of battery technology and it has been demonstrated that adjusted mitigation measures are adequate and acceptable.

7.7.9 Ingress protection (IP)

The IP rating of the BESS enclosures are specified to at least a rating of IP55. This provides protection to the internal equipment from water jet sprays in any direction and against solid, the entry of dust and other elements that can damage internal components and circuitry. Cooling BESS containers with water spray will be a fundamental tactic used by the fire and rescue services to mitigate against thermal runaway and fire spread to opposing container through thermal radiation.

7.8 Administrative Controls

Internal procedures and training, stakeholder engagement and emergency response planning will be utilised to manage the residual risks which remain after the designed engineering controls. This will include the following:

- Early engagement with the Fire and Rescue Service forms a critical input during the development and early design phase of BESS sites. The process begins with consultation with local authority fire brigade during the initial site design which can provide further guidance to the development engineering works for the BESS site. The finalised designs and site layout cater to the equipment of the local authority fire service with provisions for site access, adequate turning circles and fire water capacity.
- An Emergency Response Plan (ERP) will be developed for the BESS site in alignment with current Irish civil response procedures using the national incident command and control structure. The ERP will be informed by site-specific risks and detail the level of response required following activities such as the consultation with the Fire and Rescue Service and other emergency services, the recommendations of the plume analysis and any other risk or impact assessments conducted. All personnel deployed to the site will be adequately trained and act as tactical liaisons. Site-specific risk information will be available at the site entrance(s) to aid in response efforts.
- A series of risk assessments with the BESS equipment suppliers will be completed. These risk assessments contain many of the engineering controls detailed in this document and a will be presented using the 'Bowtie' Methodology. This process gives a graphical method for analysing and managing hazards across the site and to ensure a level of standardisation among different equipment suppliers. This will be a crucial part of the Safety Statement process.

7.9 Fire Water Supply

Static water storage tanks, with a combined capacity of at least 500,000 litres shall be provided in the compound to assist fire fighters in a fire event. The provision of firewater stored on site shall be subject to consultation with Kilkenny Fire Service. Refer to section 9.7 and Appendix A of this report for water storage design details.

7.10 Personal Protective Equipment (PPE)

All personnel on site whether during construction, commissioning or during operation will have the minimum personal protection equipment requirement necessary to be on site. In addition, there will be adequate signage detailing the required PPE for each site area and equipment. The operation or maintenance of specific equipment may have different safety requirements. There are different levels of PPE that will be checked and maintained. All personnel who wear levels of protection above and beyond their normal everyday attire will be trained in that PPE. All training of PPE will be conducted by a competent person and documented. Some PPE will have a requirement to be maintained and the wearer will be familiar with the limitations of such equipment. Wearers of PPE will be aware of individual equipment operational requirements and hazards as well as out of service dates. All personnel on site will have and don the following minimum PPE:

- Safety glasses with side shields (no dark glasses are permitted except those approved for welding or cutting)
- Face shields for cutting & grinding
- Approved safety toe shoes
- Approved hearing protection (as specified)
- Approved hardhat & gloves
- Long sleeve shirt & long pants

All PPE will be required to be worn at all times. Any PPE that is compromised or no longer considered viable for protection will be discarded and replaced. Any PPE that comes in contact with hazardous material will be properly decontaminated and inspected for functionality before being returned to service.

8. PREDICTIVE MODELLING

8.1 Introduction

Predictive modelling is employed to support the establishment of a robust fire risk assessment. In this section of the report quantitative event tree analysis (ETA) is coupled with localised ALOHA (Areal Locations of Hazardous

Atmospheres) predictive hazard modelling. The probabilistic analysis gives a comforting reassurance that a fire at this facility is an incredibly rare. While probabilistic models define the mathematical frequency of an incident involving thermal runaway they do not quantify the spatial consequences. ALOHA bridges this gap by simulating the real-world, physical footprint of the resulting rare threats (Toxic Plumes, Vapor Cloud Explosions, and Jet Fires) based on site specific atmospheric and chemical source inputs. By mapping scenario probabilities directly against ALOHA's calculated "Levels of Concern" (LOC) boundaries, the facility design moves from abstract risk metrics to validated physical engineering controls. This dual approach provides with empirical evidence that the radiant heat, overpressure blast waves, and toxic concentrations from an isolated failure will safely attenuate to negligible thresholds well within the facility's property line.

8.2 Threat Probabilities

A global quantitative fire likelihood assessment published in the Journal of Energy Storage (Science Direct, 30 June, 2025) calculated fire frequencies across multi-year global capacities of BESS installations. When averaging historical data against registered MWh globally, the study calculated an average baseline risk of 0.015% fire incidents per MWh per year**.** A 0.06% to 0.10% annual fire incident probability per container is supported by an independent safety review titled "Observations on Fire Safety in Past and Future Battery Energy Storage Systems," compiled by the Saugerties Conservation Advisory Commission. The report derives this statistic by evaluating 38 utility scale battery energy storage system failure incidents across the United States from 2012 through to 2026 and calculating the frequency against total operational installations. Both studies align proving that individual battery cells have exceptionally low failure baselines as sited by the American Clean Power Association.

An event tree analysis as shown in figure 6, was conducted by The Electric Power Research Institute (EPRI) detailing the probabilities of threats following thermal runaway. The probabilities are supported through research by EPRI, The Institute for Sustainable Industries and Liveable Cities (Probabilistic Risk Assessment of Grid Scale Lithium-Ion Battery Energy Storage System Fire Hazards), DNV GL's BESS Fire Safety Research and NFPA 855.

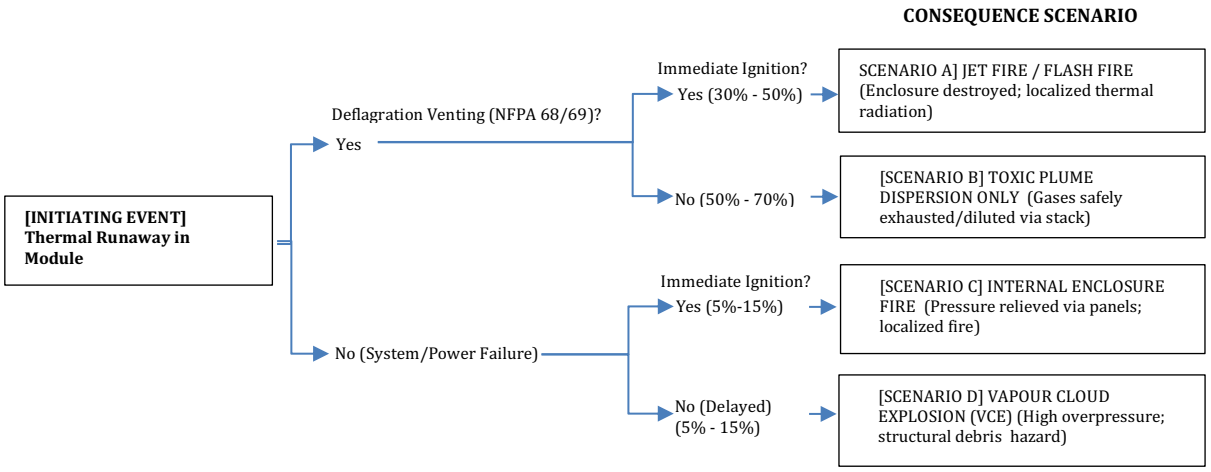


Figure 6 – Event Trees Analysis

Using an individual container failure rate of 0.06% to 0.1% per container-year, a 10-container BESS asset yields a total site initiating frequency of 0.6% to 1.0% per year**.** The statistical frequency of each threat can be calculated using the event tree probabilities above and are presented in Table 1. The frequency of occurrence in years for each threat scenario gives a clear reality check on how rare such events are, ranging from 1 in 100 years and upwards.

Table 1 – Threat Statistical Frequencies

Event / Scenario Path	Single Container Annual Risk	Facility-Wide Annual Risk (10 Containers)	Facility Return Period (Statistical Frequency)
Initiating Event: Thermal Runaway	0.06% – 0.10%	0.60% – 1.00%	1 in 100 to 1 in 166 years

Scenario A: Jet Fire / Flash Fire	0.018% – 0.05%	0.18% – 0.50%	1 in 200 to 1 in 555 years
Scenario B: Toxic Plume Only	0.030% – 0.07%	0.30% – 0.70%	1 in 142 to 1 in 333 years
Scenario C: Internal Enclosure Fire	0.003% – 0.015%	0.03% – 0.15%	1 in 666 to 1 in 3,333 years
Scenario D: Vapour Cloud Explosion (VCE)	0.003% – 0.015%	0.03% – 0.15%	1 in 666 to 1 in 3,333 years

Of course the frequency of occurrence for each threat scenario are predicated by the extensive degree of risk mitigation in the design and technologies employed for the BESS system.

8.3 Modelling Scenarios

Irrespective of the probabilities and frequencies of threats, this section considers the worst case consequence modelling for the proposed 5MWh (No. 10) of lithium iron phosphate battery energy storage system facility using ALOHA (Areal Locations of Hazardous Atmospheres) predictive modelling. Modern LFP battery architectures offer enhanced thermal stability, but cell-level thermal runaway can, although extremely rare, still generate highly flammable, pressurised, and acutely toxic off-gases. To rigorously evaluate the risk of cascading failures and structural damage, three independent, unmitigated hazard pathways are simulated:

- toxic gas dispersion (Hydrogen Fluoride),
- vapor cloud explosion (VCE overpressure), and
- directional thermal radiation (jet fire).

The primary objective of this analysis is to evaluate the worst case scenario risks, however rare, associated with this proposed installation to other infrastructure on site and to neighbouring properties. The resulting threat zone footprints can be used to establish definitive baselines for required engineering controls, including firewalls, automated venting systems, and emergency response exclusion boundaries in accordance with NFPA 855 compliance framework standards.

The hazard consequences are evaluated using ALOHA software, developed by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA). The details of the ALOHA scenarios and modelling are presented in appendix B.

8.4 Modelling Analysis

The probabilistic analysis gives a clear, data-driven assurance that a thermal incident at this facility is an exceptionally rare statistical anomaly. Furthermore, in the unlikely event of an isolated cell-level failure, the system's passive containment is engineered to fully suppress the risk internally well before it can pose a threat.

The ALOHA modelling clearly indicates that advanced active mitigation including a BMS, gas detection, ventilation, suppression and space separation is not merely a regulatory checkbox, but a structural necessity. It has been demonstrated the successful transforming of serious site wide threat events into a highly localised manageable industrial incident. The ALOHA consequence modelling indicates that a combined mitigation strategy utilising early intervention BMS, automated suppression and ventilation and space separation effectively contains a potential escalation of a threat. As a result of reduction of the peak release rate and limiting thermal radiation, this approach confines hazards and threats within the compound area and preventing domino effect failures.

9 EMERGENCY RESPONSE PLAN

9.1 Introduction

Emergency Management is about managing risks to infrastructure, communities and the environment. The emergency management cycle consists of four phases, Prevention/Mitigation, Preparedness, Response and Recovery. These phases form a continuous, integrated framework to reduce vulnerability to hazards, prevent emergencies, prepare for them, respond to them when they occur, and recover to normal operations.



Figure 7 – Emergency Management Cycle

The breakdown of each phase is shown in figure 7 and is as follows:

- Prevention/Mitigation

  This phase involves efforts to alter operations to reduce the risk of an emergency occurring or lessen its potential impact. Examples detection systems or investing in early warning systems.

- Preparedness:

  Before an emergency happens, plans and procedures are created and refined through training and simulations. This includes educating staff and ensuring necessary equipment is available.

- Response:

  During an emergency, the pre-established plans are put into action to protect lives and property. Effective, quick action is critical during this phase.

- Recovery:
  This phase focuses on restoring infrastructure, systems, and normal operations to their pre-emergency state. It involves repairing damage and resuming operations.

This continuous cycle helps organisations build resilience and cope with emergency situation, in an efficient, effective and more informed way. The prevention/mitigation phase is addressed through the systematic fire risk management hierarchy of controls methodology approach that was outlined earlier to minimise the fire risk at the site.

The other three phases will be managed through a comprehensive Emergency Response Plan (ERP). The ERP for this site can be summarised as a document detailing immediate and ongoing actions to manage an emergency incident, ensuring safety, minimising damage, and maintaining operations. It outlines specific steps for various scenarios like fires, defines roles and responsibilities for personnel, specifies emergency contacts, and establishes procedures for actions to be taken immediately, evacuation, communication, and post-incident review. Regular training and updates are crucial to the effectiveness of an ERP.

This plan specifically outlines an Emergency Response Plan detailing the procedures to be followed and actions to be taken by the Operator of this site in the event of a fire involving an outdoor stationary Battery Energy Storage System (BESS). It establishes key responsibilities of the system operator and provides guidance for coordination with emergency services. This report will apply to all site personnel, contractors, and fire service personnel at the BESS facility. It specifically addresses fire events involving lithium-ion or other electrochemical energy storage systems located in outdoor enclosures.

This site contemplates the use of lithium-ion (Li-ion) batteries for the BESS installation. The key Hazards from a Lithium-ion BESS fire are:

- Toxic gases: Hydrogen fluoride (HF), carbon monoxide (CO), hydrocarbons, and fine particulates.
- Flammable vapour clouds: Potential for deflagration/explosion if vapours accumulate.
- Corrosive aerosols: Acidic condensates may damage eyes, skin, and airways.
- Stored Energy: Stored energy within the batteries can be a chemical hazard. When a fire is extinguished, there is still stranded energy within the unaffected cells that can lead to electrical shock.

These hazards vary based on the battery technology used and the operating conditions.

Emergency services pre-incident planning is a key component of a successful emergency response plan. The operator of this site will endeavour to develop, with the emergency services, pre-incident plans for responding to fires, explosions, and other incidents associated with the BESS installations and provide key information to include:

- Awareness and understanding of procedures involved with the BESS facility operations and ERP.
- Knowledge of technology (battery type) and the related hazards and methods for responding to this type of BESS.
- Identifying the locations of all electrical disconnects.
- Understanding that there may be stored or stranded electrical energy in the BESS that cannot be discharged or isolated.
- Understanding procedures related to dealing with damaged BESS equipment.

Fires in electrochemical energy storage systems are often a result of thermal runaway, whereby the batteries create heat that cannot be dissipated, resulting in dynamic temperature increase.

9.2 Health and Safety Legislation

Workplaces in Ireland, are legally mandated to provide a Safety Statement, which is informed by thorough Risk Assessments and includes a detailed Risk Assessment Method Statement (RAMS) for specific high-risk activities. This operation will have a site-specific Safety Statement tailored to the organisation, outlining how health and safety will be managed, risks identified and how controls are implemented. A RAMS will further detail the precise procedures for carrying out hazardous tasks, ensuring compliance with the Safety, Health and Welfare at Work Act 2005. The key Documents and Requirements will include:

Safety Statement: This is a legal requirement for all employers in Ireland under the Safety, Health and Welfare at Work Act 2005. It will be a written, up-to-date, and site-specific document that reflects the actual management of health and safety within the organisation. It will act as a record of the operator's commitment to safeguarding the health and safety of employees and others affected by the work activities.

Risk Assessment: A comprehensive risk assessment will be a crucial part of the Safety Statement process, as it forms the basis of its content. The site operator is legally required to carry out a risk assessment for the workplace to identify hazards and assess associated risks. This assessment will identify potential dangers and the procedures necessary to control them, with the goal of reducing the risk of injury and illness and damage.

Risk Assessment Method Statement (RAMS) - For the high-risk activities, a RAMS will be provided. This document will outline how specific tasks with potential hazards will be performed safely. It will include identifying hazards and risks, implementing control measures, and regularly reviewing these measures.
These documents will work together such that the findings from the risk assessment will directly contribute to the content of the site's Safety Statement, explaining how risks are controlled.

Both the Risk Assessment and RAMS will be treated as live working documents that are reviewed and updated as conditions change or when new information becomes available.

As part of the site's safety statement there will be a requirement to clearly outline the roles and responsibilities for persons responsible for emergency management, noting the primary and secondary contact persons for liaison with the emergency services. Well-defined emergency fire management and procedures are crucial for an effective response during a fire incident. All roles pertaining to emergency management will be clearly understood by all and posted onsite in an area visible to workers, with contact details provided. The success or failure of all emergency plans depends upon effective training, continual review of this response plan, and execution of the response.

A review of this emergency response plan will be conducted and documented at minimum on an annual basis. The plan shall also be reviewed and amended whenever there is a change in facility design, construction, operation, or maintenance that affects emergency response planning. When outside resources are changed or modified the plan shall be reviewed and updated to reflect the changes that may affect this plan.

9.3 Roles and Responsibilities

Overall responsibility for the Emergency Response Plan (ERP) lies with the Wind Farm's appointed Emergency Response Coordinator. The Emergency Response Coordinator or their designee will be responsible for program implementation, including designating evacuation routes and employee assembly points, coordinating severe weather activities, communicating emergency response procedures to site personnel, contracting with emergency response organisations, and contractor coordination.

Specific management personnel will assume leadership roles for emergency responses. The Emergency Response Coordinator/Site Manager will assist in the implementation of this plan by knowing and communicating evacuation routes to workers during emergency evacuation and reporting the status of the evacuation to Kilkenny Fire and Rescue Service. The Emergency Response Coordinator is responsible for seeing that this plan is implemented and will appoint the necessary resources to enforce the plan, assure everyone is familiar with this plan and act as a liaison with the fire and rescue service.

All facility personnel/contractors will have the responsibility to immediately report emergency situations to the Emergency Response Coordinator or designee on duty. There will be no delay to report emergency events that require attendance by the fire and rescue services. The Emergency Response Coordinator or designee will notify the control centre / system owner / grid operator as per the Site Emergency Plan. The following principles will be addressed in the Emergency Response Plan:

1. Effective identification and management of hazards and risks specific to the siting, infrastructure, layout, and operations at the facility.
2. Impact on surrounding communities, buildings, and infrastructure.
3. Siting of renewable energy infrastructure so as to eliminate or reduce hazards to emergency responders.
4. Safe access for emergency services in and around the facility, including to energy storage infrastructure and firefighting infrastructure.
5. Provision of adequate water supply and firefighting infrastructure to allow safe and effective emergency response.
6. Vegetation sited and managed so as to avoid increased wild fire and grass fire risk.
7. Prevention of fire ignition on-site.
8. Prevention of fire spread between site infrastructure (battery containers/enclosures).
9. Prevention of external fire impacting and igniting site infrastructure.
10. Provision of accurate and current information for the emergency services during emergencies.
11. Effective emergency planning and management, specific to the site, infrastructure and operations demonstrating a full understanding of hazards, risks, and consequences.

9.4 Preparation and Planning for Emergencies

Pre-planning for emergencies is a crucial element of this Emergency Response plan. The following steps will be taken in planning for emergency situations at the site:

1. The Fire and Rescue Service and other emergency services will receive a copy of this plan and will have participated in on-site familiarisation meetings.
2. All emergency access points to the site shall be identified.
3. An emergency response information notice board shall be maintained at the Operation's Building and readily visible and accessible to all personnel, identifying key contacts for emergencies, a list of personnel certified in First Aid/CPR, and other notices as outlined in this document or as deemed appropriate by the Emergency Response Coordinator.
4. Provision shall be made for non-English speaking workers on site.
5. All road exits are established and posted on the emergency information notice board.
6. Evacuation route diagrams have been documented and posted on the emergency information notice board.
7. Logs of on-site personnel for tracking headcounts during emergencies will be maintained.
8. All buildings and property surrounded by fencing will be marked by signage that identifies specific hazards (Danger, Caution, Warning signal words).
9. Site personnel receive instruction to keep exit routes from the site clear and to maintain ready access to portable fire equipment.
10. Battery Safety Data Sheets (MSDS) shall be provided by manufacturers.

9.5 Emergency Access

The proposed BESS project is located within a rural setting within the townlands of Killoshulan, Foyle South, Frankford or Ballykieran, Barna and Spahill, County Kilkenny, approximately 4.6km west of Freshford town and 5.5km east of Urlingford town. Kilkenny City is approximately 16km southeast of the site via the L1810 and the R-693 roads. To prevent unauthorized access, the BESS compound will be secured within a 2.6m perimeter fence and monitored remotely by CCTV.

In the event of an emergency call out, the predetermined attendance (PDA) for The Fire and Rescue Services is for 2 pumps for industrial incidents. This requires the attendance from Freshford (KK13) and Urlingford (KK14) fire brigades with 1 Pump (class B appliance) from both stations. If the incident escalates and additional resources are required, Kilkenny (KK11) fire station is next on the PDA for attendance at this site. The time for attendance for Freshford and Urlingford appliances is approximately 20 to 25 minutes which includes a response time of 5 minutes for fire fighters to mobilise to their respective stations. Emergency assess to the site will be available through the north and south as shown in figure 8 below.

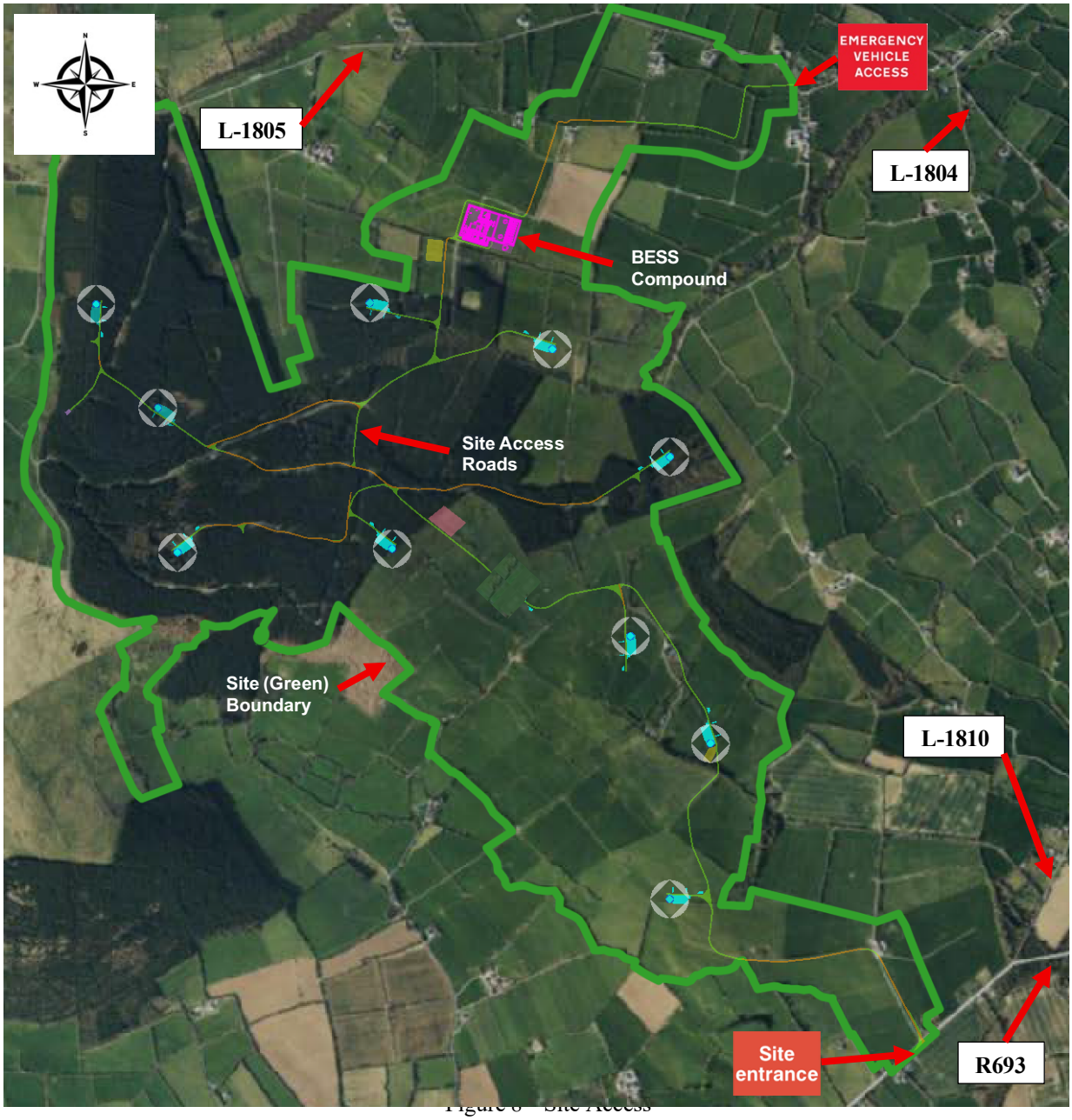


Figure 8 – Site Access

Access will include the following:

- Two separate access points to the site to account for wind conditions/direction.
- Roads and hard standing will be capable of accommodating fire service appliances at 18.5 tonnes and other vehicles in all weather conditions. As such there will be no extremes of grade.
- Roads with passing places suitable for fire service appliances and vehicles.
- The road network on site will enable unobstructed access to all areas of the facility.
- Turning circles, hammer heads, etc. sized to the requirements to B5 of the Building Regulations.

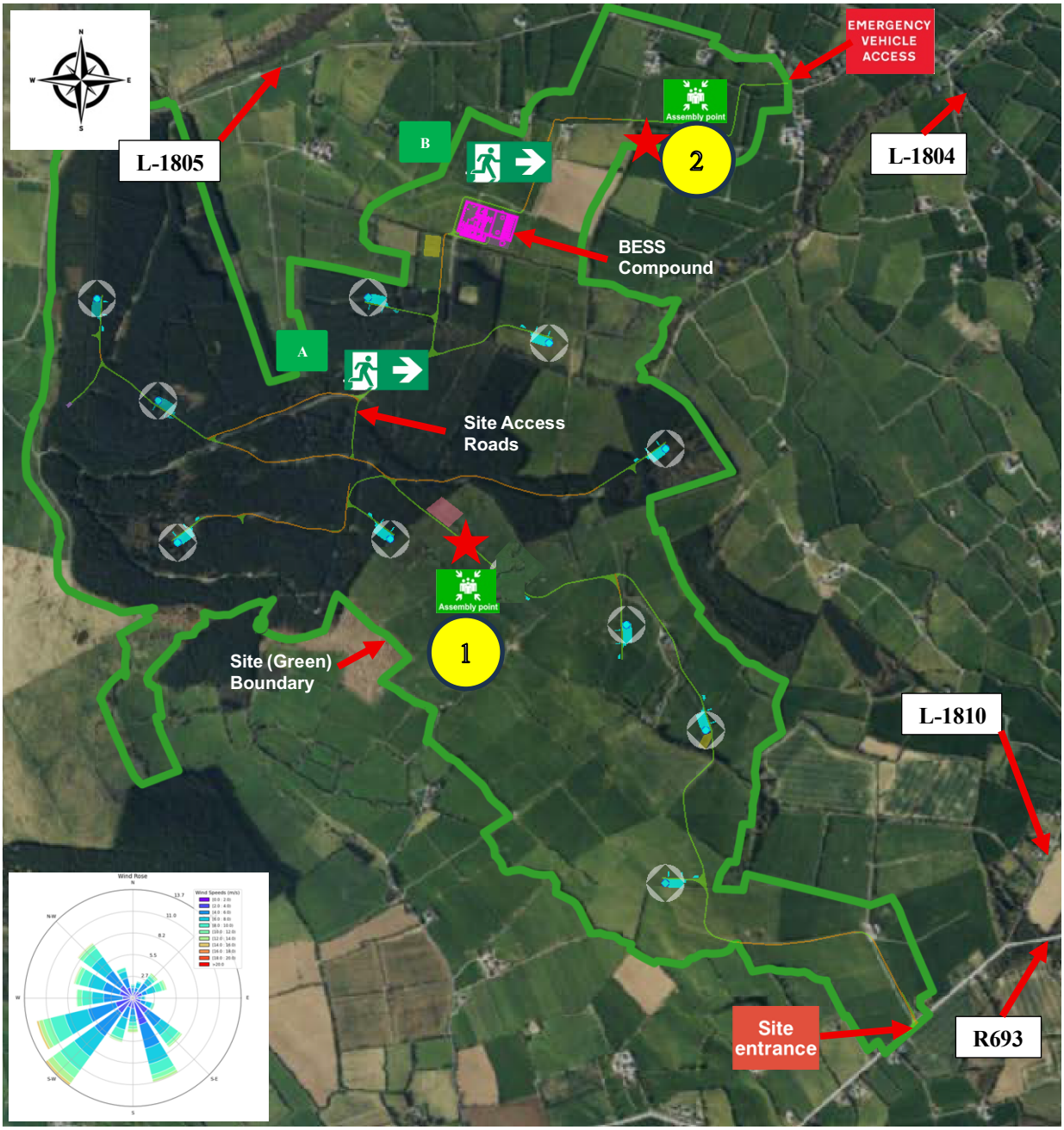


Figure 9 – Emergency Routes and Assembly Points

9.6 Emergency Evacuation

External and internal audible and visual (e.g., strobe lights) alarm systems will be established that reflect specific on site hazard analyses. Personnel will be trained on the significance of different alarms and the corresponding actions as outlined elsewhere in Emergency Response (ER) Plan. Descriptions of each alarm and corresponding actions will be clearly posted on the emergency information notice board.

Warning systems and alarms will be tested at least every three months or more frequently per manufacturer specifications and legal requirements. Tests will be documented. All site personnel, as well as those offsite who are likely to hear or see an alarm, will be made aware of tests so as not to cause undue concern. Audible and visual warning devices, as well as addressable identification at control and indicating equipment (fire alarm panels) will be linked to:

1. Battery Management Systems (when a thermal runaway event is identified)
2. Detection and suppression system activation for early warning and timely evacuation in the event of an emergency.

Depending upon the nature of the emergency, weather and/or site conditions, roadways and exit routes as designated on the site map will be used for routes of evacuation.

An evacuation sheet shall be posted and orally communicated to site personnel. The evacuation procedures will be discussed at periodic safety meetings in addition to being covered during new employee orientation. Two evacuation routes 1 and 2, to be provided as shown in figure 9 above.

The prevailing wind direction is also indicated in figure 9 and Appendix D with a Windrose issued by the SEAI from the site at 20m elevation in Co. Kilkenny

The location of the Assembly Points 1 and 2 are based on the prevailing wind direction and the proximity to exits routes A and B. An additional emergency access and egress route (ER) is proposed on the north of the site shown in figure 8. This will enable first responders access to the north of the BESS compound if wind conditions dictate such. Personnel will to be aware of the two exit routes at any point on the site (apart from limited dead end roads to wind turbine locations) and be familiar with the evacuation routes and assembly points posted in the location indicated on the site map. An Information Box (IB) will be positioned at the Fire Services access points. The purpose of the IBs will be to provide critical information for first responders such as the Emergency Response Plan, to include water supplies for firefighting, drainage plans highlighting any pollution control devices, penstocks etc.

In the event of an evacuation, all personnel will meet at the designated Assembly Point 1 for further information. If the primary Assembly Point 1 point is inaccessible or hazardous, personnel will gather at the secondary Assembly Point 2 and inform the emergency coordinator (if not present) by radio or telephone. Emergency telephone will be installed at both assembly point to aid evacuation and communication.

The emergency response coordinator will inform personnel of a diversion to the secondary Assembly Point 2 by such mean as are available, to include radio or loud hailer. If personnel are unable to make it to the designated Assembly Points, they will seek shelter wherever possible and contact the emergency response coordinator for further instructions. Accountability of personnel shall be of the upmost importance and be conducted in a timely manner. Access points and routes will be kept unobstructed at all times so the emergency services will not be hindered in their operations when responding to emergencies within the site.

9.7 Fire Water

For Li-ion battery fires, water is the preferred suppression agent due to its immediate cooling capacity, availability, and ease of onsite storage and transport. Firefighting foams are not considered to be effective because they lack the ability to cool and can conduct electricity. Foams may also contribute to thermal runaway issues by insulating the burning materials and exacerbating heat rise. Dry chemical powders used in firefighting may extinguish visible flame but, similar to foams, do not provide cooling to heated battery equipment. Thermal runaway inside the battery may continue potentially causing reignition.

Energy storage systems present a unique challenge for firefighters. Unlike a typical electrical or gas utility, a BESS does not have a single point of disconnect. There are disconnects that will deenergise select parts of the system, but batteries remain energised. The following hazards might be encountered when fighting fires in BESSs:

1) Shock or arcing hazard due to the presence of water during suppression activities
2) Related electrical enclosures might not resist water intrusion from the high pressure stream of a fire hose
3) Batteries damaged in the fire might not resist water intrusion
4) Damaged conductors might not resist water intrusion
5) Shock hazard due to direct contact with energized components
6) No means of complete electrical disconnect due to stranded energy

Due to these hazards, care and consideration should be applied when considering fire suppression by means of water inundation within BESSs. The appropriate use of water as an extinguishing medium should be assessed whether water reacts with the chemistries present or whether it is an appropriate extinguisher class.

The use of a substantial volume of firefighting water is currently recommended in many situations to extinguish fires resulting from incidents involving lithium ion batteries. FM Global DS 5-33 (Li-ion BESS): 2024 publication, provides loss prevention recommendations for outdoor enclosures, separation, and protection and while not prescribing a quantity for outdoor fire water flow. The FM guidance recommends planning toward 'robust water supplies' for extended exposure cooling.

Other international guidance recommends large water densities of the order of 1900 litres per minute for an outdoor (containerised/enclosures), BESS. This fire water flow reflects current standards, insurer data sheets and fire service guidance focused on cooling with defensive tactics rather than an interior attack.

Several industry and research sources note a firefighting tactic/strategy of allowing the involved BESS unit to burn while using large volumes of water to cool the shell of the unit/enclosure and protect adjacent BESS units and associated ancillary equipment.

A 1900 litres per minute flow is commonly used by utilities and fire services in pre plans as a minimum for outdoor defensive operations. The fire water requirement for this site is based on this flow requirement and using the appropriate firefighting tactics for this BESS installation. In addition to attacking or cooling the fire involved BESS container with the necessary flow of water, there can be a requirement to cool exposed BESS containers where radiated heat is a risk.

A hose stream capacity baseline of 1900 litres per minute (lpm) will be required to support exterior cooling and therefore 'defensive operations' employed by The Fire and Rescue Services. This flow requirement will be required for defensive cooling for one BESS container with a power rating of approximately 5MWh (Mega Watt hour) to cool and control thermal runaway. As the adjacent containers will be positioned with a minimum spacing of 6.5 metres, there will not be a requirement to cool adjacent BESS containers that are not involved in the fire outbreak. Separation distances of 6.5m is sufficient to reduce the radiant heat flux, to eliminate the risk of fire spread, from an ignition source (enclosure with thermal runaway) to a receiver, which in this case will be an opposing BESS container unit.

Based on 1900 lpm flow rates, separation distances and an extended period of intervention by The Fire Services of 4 hours, a static storage requirement of 500,000 litres of water will be provided on site in two separated above ground static storage tanks of capacity of 250,000L (see calculation in Appendix E). The two static storage tanks will be hydraulically connected to allow take off of all water supply from either tank outlet. An area around both static storage tanks will include a suitably designed hard standing area at 18.5 tonnes for fire appliances as applied to the access routes. The tanks are positioned on the north and south sides of the BESS compound to take into account alternative wind conditions during the fire outbreak.

The static storage tank outlets will be a maximum distance of 3.0 m from the hard standing to facilitate connection of hard suction pipes. The inlets to the tanks from the water main will be a minimum of 100 mm diameter terminating in a float valve or similar. Pipes will be metal where exposed. The static storage tanks will be monitored for water level. A low level alarm probe will be fitted at a high level position, typically at 90% contents of the tank.

Signage in accordance with BS 3251: 1976 will be provided to indicate the location of the static storage tanks. The signage will be located and sized to ensure they are clearly visible from the access route. Signage will indicate "FIRE FIGHTING WATER SUPPLY" and the capacity of the tanks 250,000 litres".

9.8 Fire Water Contamination and Toxicity

Firewater from a lithium ion BESS fire will pick up toxic and corrosive by products such as hydrofluoric acid, heavy metals, electrolytes, plastics, etc. This contamination occurs quickly, even in early runoff. Contaminated water cannot be reused in firefighting streams for health and safety reasons with increased firefighter exposure risks and possible damage to pumps, hoses and nozzles**.** In addition, reapplying contaminated water to hot batteries containers may aerosolize toxic compounds**,** worsening inhalation hazards. The practice on this site will be to comply with industry best practice and to treat all firewater as hazardous waste requiring capture and disposal after a fire incident.

The fire water retention design for this BESS compound will capture, contain, and hold contaminated runoff from the worst credible fire scenarios while keeping it away from drains, groundwater, and off site receptors. After the fire, the retained water will be sampled, treated, or removed by licensed hazardous waste contractors**.** The objectives of the fire water containment are to:

- Contain all firewater and contaminated rainfall from a worst case BESS fire without uncontrolled release.
- Bund the compound so a single fire incident does not cause firewater to escape the boundary of the proposed BESS compound.
- Provide positive isolation of surface water drains (automatic/manual penstocks), defaulting to "closed on alarm."
- Be chemically compatible with expected contaminants (HF, metals, electrolytes, plastics by products) and allow safe sampling, treatment, and removal.

The sizing of the fire water retention capacity is calculated in Appendix F by the addition of the fire flow driven volume and the concurrent rainfall on the catchment. The highest 26 year period of rain fall over a 24 hour period for the area was sourced from Met Eireann's historical data. The hardstand/roof area for the BESS compound is calculated to be 3,700m^2 with a runoff coefficient of 1. A 15% freeboard to prevent the possibility of overtopping with the most adverse wind exposure case is not applied as the runoff water will be contained in a sealed tank(s).

Dedicated Firewater Retention Tank(s) below ground, will be provided above ground to provide the most effective and suitable measure for retaining firewater. The tanks will be rendered impermeable by the use of an appropriate liner and integrity tested. All integrity testing of the tanks will be completed by a suitably qualified competent person and be in line with the Environmental Protection Agency's (EPA) guidance.

All the BESS compound drainage systems will divert automatically to the firewater retention tanks on activation of the site fire detection and alarm system. If storm water management is being used for the dual purpose with firewater retention, then the outlet will be fitted with an automatic valve linked to the fire detection system. Automatic shut-off valves will be tested and maintained as per the site's Safety Statement and Maintenance Procedures. The fire water retention tanks will be kept clean, and free of debris.

The bunding of this compound will include a composite capping system in the form of a geomembrane such as a linear low density polyethylene (LLDPE) liner overlain with suitable cover soils (well compacted clays free of contaminants and organic materials). This will provide an impermeable cap to the underlying soils thus bunding the compound and will allow for the surface water drainage system around the perimeter of the compound to collect any potential fire water and direct the flow to the fire water retention tank. The primary purpose of a bund is to contain the fire water when cooling is being provided to a container unit.

9.9 Pre-Fire Event Readiness

Before an emergency happens, plans and procedures are created and refined through training and simulations and therefore preparedness. This includes communication, training/educating staff/contractors and ensuring necessary equipment is available.

9.9.1 Communications

Timely and efficient communications are essential to deal with an emergency response situation. All staff and contractors on site shall be provided with handheld radios/phone to enable effective communication. Emergency transmissions will be clearly announced using signal words such as 'urgent' or 'mayday.' These signal words give priority to the radio transmitter to proceed with their message. If emergency radio/phone communications are

interrupted or unclear, employees will proceed to the Assembly Points. All hand held intrinsically safe radios/phones will be recharged daily with back up batteries ready for use.

9.9.2 Safety Training

Initial training for all site personnel/contractors on the Emergency Response Plan (ERP) will be undertaken upon the commencement of employment or contract. Refresher training of the ERP to site personnel shall be conducted at least annually. Documentation of ERP training will be maintained and documented in the site fire safety register. Emergency evacuation drills will be held at a minimum on a quarterly basis and shall be documented in the fire safety register. At least on an annual basis, the fire and rescue services and other emergency response personnel will be invited to participate and assist with critique of evacuation drills. Table top exercises will be employed to train personnel with procedures for different emergency scenarios that could be encountered at the site. The site Emergency Response Coordinator and designates will be trained in their specific duties in an emergency situation.

Operator/maintenance personnel will receive supplier/manufacturer approved training on the specific characteristics of the energy storage system. All personnel will be training in the wearing and use of PPE. All training of PPE will be conducted by a competent person and documented in the fire safety register.

9.9.3 Emergency Electrical BESS Shut Down

In the event of a BESS fire emergency, the installation will be shut down immediately to prevent injury, or equipment damage. A comprehensive electrical shut down procedure will be provided ensuring power and isolation is cut to the BESS compound. This procedure will be executed immediately in the event of a suspected fire, alarm action or discoverer of a fire in the BESS compound.

9.9.4 Grass/Wildland

The site around equipment and infrastructure will be free of combustible vegetation with only a ground cover of maintained vegetation adjacent to the BESS compound. Flying embers from offsite fire may inundate the area during fire events. Where fire breaks are required, they will be inspected regularly prior to the fire season and kept vegetation free. Fire breaks will be at least six metres wide. This will also apply to access routes. Grass land fire fighting tools such as beaters, buckets, knapsack sprayers and pumps will on hand on site and ready to use.

9.9.5. Hot Works, Welding and Open Flame

The Emergency Response Coordinator will be nominated to authorise hot works. This person will have experience and training in the problems associated with hot work and be of suitable status to ensure compliance with procedures. Before any hot work starts, a hot work permit will be obtained from the Emergency Response Coordinator. The permit will not be issued without first considering the significance of any other permits to work in the vicinity. The permit will only be issued for a specific task that is to be undertaken in a clearly identified area. Hot work permits will not be issued for protracted periods and separate permits will be issued for work which extends from morning to afternoon periods.

9.10 Fire Event Responsibilities and Actions

In the event of a fire outbreak, it is essential to act quickly and calmly. The procedures for the assigned persons as outlined in the ERP must be followed immediately. If the BESS facility is staffed or unstaffed, the procedure for a suspected fire event will be similar. If fire or thermal runaway is suspected (visible smoke, hissing, popping sounds, or alarms) treat as a confirmed fire event**.** The following actions must be taken by the Emergency Response Coordinator and designates or Alarm Receiving Centre (ARC) for a fire or suspected fire, immediately:

9.10.1 Fire Event – Actions to be Taken Immediately

1. **Raise the Alarm:**

(a) Monitor fire detection, smoke, gas, and thermal alarms within the BESS.
(b) Activate site emergency alarm.
(c) Initiate the BESS site's "**EMERGENCY SHUTDOWN PROCEDURE**".
(d) Call the Emergency Services (112 or 999) Fire and Rescue Service immediately. See contact list in Appendix D .
(e) Use the E.T.H.A.N.E. acronym used by emergency services to report the incident.
E – Exact location: Provide the precise location of the incident on the site.
T – Type of Incident: Describe the nature of the incident, what is on fire etc.

H – Hazards: Identify the dangers involved including explosion or vapour cloud etc.
A – Access: Detail the best and safety routes on the site to the emergency on site.
N – Nature of Casualties: Report the estimated number of injured persons etc.
E – Emergency Services: List which emergency services are already in attendance and what additional resources are required.

(f) Notify the system owner / grid operator as per the Site Emergency Plan.
(g) Remote control (if applicable): The ARC will activate remotely fire suppression equipment. Push notifications will be used for systems with remote apps to be sent to devices of designated users, allowing them to view system events and potentially initiate actions remotely.

2. Ensure Personnel Safety

(h) Evacuate all staff and contractors and non-essential personnel to the designated assembly points (at least 100 m upwind of the BESS). Ensure the site assembly points are clear and not affected by the incident.
(i) Account for all staff, contractors, and visitors who were working in the site. If any personnel are unaccounted, a communication shall be made through out the facility in attempt to locate the person(s) missing. As the person(s) is equipped with a facility radio, an emergency transmission will be communicated in attempt to locate the person(s).
(j) Deny re-entry to the affected area until the all clear is given by emergency services when present.
(k) Account for all personnel using the site roll call sheet.
(l) Do **not** attempt to enter or suppress a fire inside a BESS enclosure.

3. Isolation and Hazard Reduction (if safe to do so)

(m) Use the emergency stop switch or disconnect at the main isolation point.
(n) Activate remote or local system shutdown.
(o) Isolate DC and AC electrical feeds via emergency disconnect switches
(p) Isolate and shut down HVAC systems immediately that could spread vapours into buildings or switchgear areas.
(q) Follow Lockout/Tagout (LOTO) procedures to prevent inadvertent reenergisation.
(r) Shut down auxiliary equipment in the fire affected area
(s) Operators are not to attempt suppression of BESS fires due to risk of thermal runaway, toxic gases, and electrical hazards.
(t) Do not attempt manual disconnection if flames or heavy smoke are present.
(u) Confirm isolation of high voltage systems with the utility provider.

4. Protect Surrounding Areas

(v) Remove flammable materials from the vicinity if safe to do so.
(w) Close containment doors, fire dampers, or ventilation louvres (if installed and remotely operable).

5. Operator Communication Responsibilities During the Incident

(x) Provide the responding Fire Services' Incident Commander with:
(y) Site layout drawings, including BESS layout diagrams, fire water tanks, access routes, disconnect switches, and hazardous material (e.g., stored fuel, chemicals nearby) storage.
(z) Status of isolation/disconnection.
(aa) Details of battery chemistry and manufacturer safety data sheets (SDS) for the batteries and associated chemicals.
(bb) Windsock location on site with wind direction and conditions indicated.
(cc) Details of the installed fire suppression systems.
(dd) Information on monitoring systems (gas detection, thermal imaging).
(ee) Maintain communication with the incident commander and supply ongoing technical input.
(ff) Prevent unauthorised access to the site perimeter.
(gg) Support utility providers in confirming grid isolation and safe restoration.

9.10.2 Fire Event – Tactical Firefighting

When the fire brigade is in attendance at the incident the priorities will be life safety, hazard containment, and controlled extinguishment. A dynamic risk assessment will be conducted by the Incident Commander after liaising with the Emergency Response Coordinator and designates, incident reccy, and consulting with pre incident plans. A defensive strategy is preferred to allow a controlled burn if fire is inside a sealed enclosure and the risks to the other exposed container(s) is low and controlled. This will be achieved by applying an external water spray or

mist for cooling the fire involved enclosure, electrical equipment, and exposure hazards. Thermal imaging cameras can be used to monitor heat radiation to adjacent units. Large volumes of water may be required to maintain external enclosure temperatures below critical thresholds for cooling, to prevent thermal runaway spreading to other container units.

The following tactical guidance will apply to a lithium ion BESS fire:

(a) Establish a safety perimeter around the affected enclosure (minimum 50m; adjust based on wind and smoke plume).
(b) Use binoculars to determine scene size up.
(c) Consider toxic gases (HF, CO, VOCs) and apply respiratory protection.
(d) Structural firefighting PPE (turnout gear) with self contained breathing apparatus (SCBA) is the norm for initial and defensive firefighting.
(e) SCBA is mandatory in or near the hot zone, due to HF and CO.
(f) Use portable gas detection to monitor hydrogen and CO concentrations.
(g) Avoid forcible ventilation unless necessary; venting may release toxic and explosive gases.
(h) Anticipate thermal runaway propagation to adjacent battery modules.
(i) Firefighting tactics in most cases will constitute a defensive strategy (cooling the effected unit, allowing a controlled burn).
(j) Rotate crews to manage heat stress during long duration cooling.

Gas tight suits are not normally required for firefighting, because of the reduction in mobility and heat tolerance**,** making hose handling and long duration cooling impractical. They are not flame resistant, so they present a hazard in high heat environments. In the recovery phase where there is no active firefighting, gas tight chemical suits with SCBA are appropriate under hazmat protocols. Such activities may include, entering confined areas or enclosures with high HF concentrations, handling debris, ruptured cells, or electrolyte spills and sampling and pumping contaminated firewater.

9.10.3 Fire Event – A Vapour Cloud

A Vapour Cloud from a BESS fire is one of the most dangerous aspects of a BESS incident. Lithium ion batteries undergoing thermal runaway release large volumes of flammable gases (hydrogen, carbon monoxide, hydrocarbons) mixed with toxic and corrosive vapours (HF, VOCs, particulates)**.** These clouds can be invisible and may accumulate in low or confined areas and can ignite or explode if within flammable limits and exposed to a spark or ignition source. In the case of a vapour cloud from a BESS fire the following additional measures will be taken by the fire and rescue services:

(a) The focus will be on containment, dispersion, and monitoring rather than "fighting" the vapour directly.
(b) Evacuate and keep all personnel upwind. Establish an exclusion zone at least 50m and expand if the wind is calm or gases are pooling.
(c) Do not enter vapour clouds as the cloud atmosphere may be within explosive range at the lower explosive limit.
(d) Use multi gas detectors (LEL, CO, H_2, HF) and thermal imaging**.**
(e) Establish continuous atmospheric monitoring around the BESS and downwind.
(f) Monitor the wind direction and reposition exclusion zones dynamically as necessary.
(g) Inform the Local Authority if the vapour cloud could potentially travel beyond the site.
(h) Natural ventilation is preferred**:** allow the vapours to dissipate with the wind. Use large volume water spray/fog streams (not solid streams) to knock down and dilute vapours, encouraging mixing and dispersion.
(i) Avoid actions that might force vapours toward ignition sources**.**
(j) Prohibit radios, vehicles, or cutting tools in the exclusion zone unless intrinsically safe.
(k) Use intrinsically safe lighting and communication equipment only.

9.10.4 Post Fire Event – Operators Actions to be Taken After Fire Incident

Even after fire knockdown, re-ignition is highly likely due to latent thermal runaway. A fire watch will be maintained for at least 24 hours with monitoring by thermal imaging. Hazards after a fire will be identified at the time of installation such that recommendations for personal protective equipment (PPE) are available for clean-up crews and hazardous materials (HAZMAT) teams. This may include respirators to protect personnel from toxic gas that continues to be generated from hot cells. The following action will be taken:

(a) Do not re-enter the BESS enclosure until cleared by The Fire Services.
(b) Assist in incident reporting with photos, sensor logs, and personnel statements.
(c) Arrange for safe removal and disposal of damaged battery modules through certified hazardous waste handlers. Care will be taken to ensure that damaged batteries containing energy have been safety de-energized in accordance with disposal procedures, if possible, before handling and disposal. If unable to completely de-energize batteries involved in a fire, care will be taken with handling or dismantling battery systems involved in fires as they may still contain hazardous energy levels.
(d) Coordinate with environmental and hazmat teams to sample air and water.
(e) Do not attempt to restart or re-energize the BESS until cleared by The Fire Service and the equipment suppliers/manufacturers.
(f) Arrange for inspection by the OEM, insurance representatives, and regulatory bodies.
(g) Initiate environmental remediation for contaminated fire water runoff.
(h) Document the incident and initiate a formal root cause investigation.
(i) Update training and emergency response procedures as needed.

10 SUMMARY

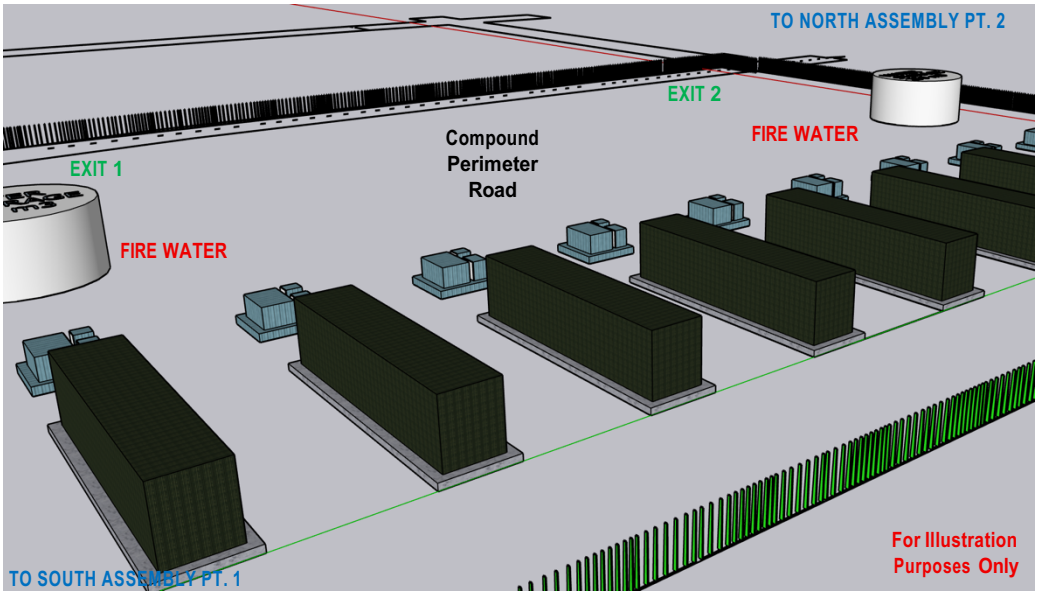
The aim of this Report is primarily to provide a concise outline of the analysis, assessments and procedures that will be carried out in the design, construction and commissioning of this proposed BESS installation to mitigate the risks from a fire, vapour cloud or explosion emergency. Such mitigation analysis in design, procedures and actions is necessary to protect the safety of site personnel, emergency service personnel, to protect the environment, to minimise damage and disruption, and to ensure a swift return to normal operations following a critical emergency. The approach taken is based on the systematic reduction of the risks as far as reasonably practicable, whilst recognising that ultimate responsibility for the safe design and running of these facilities rests with the site operator. This report outlines design factors that contribute to reducing the escalation in the severity of an incident, critical facilities for the Fire and Rescue Service, and safeguarding for the environment through fire water retention. The probabilistic analysis in this report gives a clear, data driven assurance that a thermal incident at this facility is an exceptionally rare statistical anomaly.

The provision of the large quantity of water in static storage tanks is key to the fire safety strategy for this remote site. Water in abundance is necessary to attempt to control thermal runaway and to prevent fire spread on the site over an extended incident period of 4 hours. Fire water retention is achieved using the BESS compound bunding and a fire water retention tank, which will allow in post fire situations the water to be sampled, treated, or removed by licensed hazardous waste contractors**.**

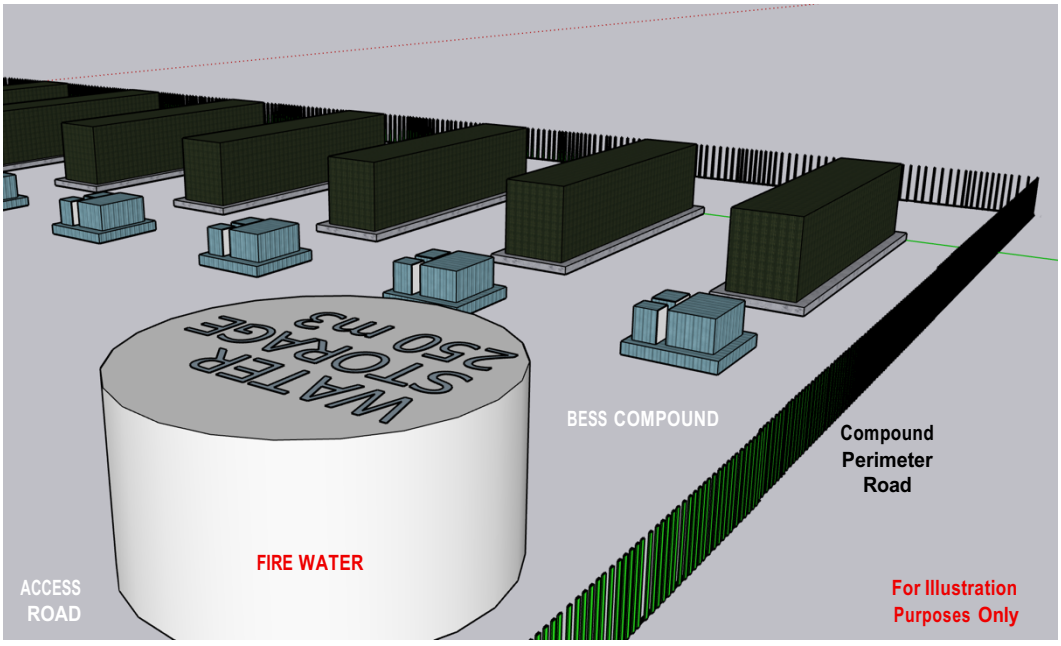
The report content directly relates to facilitating a safe and effective response, by the Operator and the Fire and Rescue Service, to a fire, explosion or vapour cloud release involving a BESS installation.

11 APPENDIX

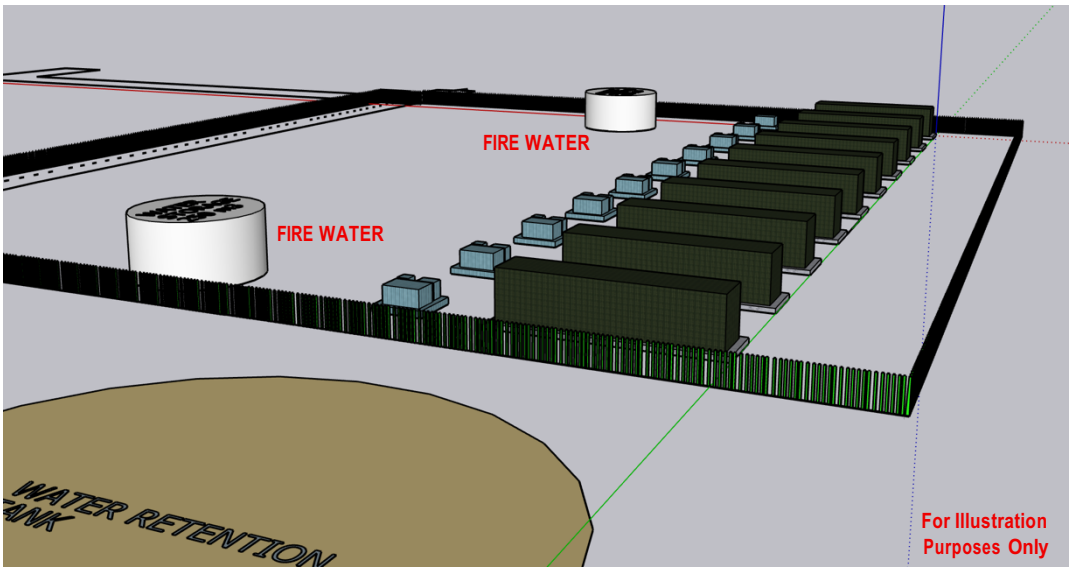
11. 1 APPENDIX A1 – BESS Layout Diagram



11.2 APPENDIX A2 – BESS Layout Diagram



11.3 APPENDIX A3 – BESS Layout Diagram



11.4 APPENDIX B – Predictive Modelling ALOHA Methodology

The hazard consequences are evaluated using the Areal Locations of Hazardous Atmospheres (ALOHA) software, developed by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA). ALOHA was selected to track the spatial footprint of gas dispersion, thermal radiation, and explosion overpressure waves resulting from localized chemical source terms. Because ALOHA evaluates chemical hazards in isolation, the cascading progression of an LFP failure was decoupled into three independent, unmitigated baseline scenarios, a non-flaming toxic gas plume, a delayed vapor cloud explosion (VCE), and an immediate flaming jet fire and repeated for mitigated scenarios.

11.4.1 Meteorological and Site Configurations

To ensure a conservative regulatory baseline, worst case atmospheric conditions were established to simulate minimal atmospheric mixing and maximum downwind plume concentration:

- Wind Speed & Direction: Set to a constant 4m/s blowing directly along the axis from the failing BESS enclosure toward adjacent lands.
- Measurement Height: 10 meters.
- Ground Roughness: Classified as urban or forest to account for the physical congestion and wind obstruction caused by dense arrangements of outdoor electrical equipment enclosures.
- Cloud Cover & Atmospheric Stability: Simulated at complete cover to force ALOHA into stability class D (extremely stable), representing night time or early morning dispersion dynamics.
- Ambient Air Temperature: Fixed at 15^0C with a relative humidity of 50%.
- Building Type: Configured as unsheltered / surroundings open to accurately evaluate unmitigated open air boundary risks.

11.4.2 Source Terms for Unmitigated BESS

Battery energy storage systems are not standard chemical storage vessels and therefore empirical source data is derived from standard LFP destructive testing literature and scaled down to a single 5MWh enclosure boundary.

1. Total Gas Generation Potential: LFP cell chemistries release an average of 120 Liters of vent off-gas per kWh of nominal battery capacity during unmitigated thermal runaway. For a 5,000kWh deployment, this yields a total potential gas volume of 5,000 kWh x 150 l/kWh = 750,000 Liters (750m^3).

2. Toxic Scenario Mass Rate (Hydrogen Fluoride): Under non-flaming conditions, Hydrogen Fluoride (HF) comprises approximately (1.5%) of the total off-gas mass profile due to the thermal breakdown of the lithium hexafluorophosphate $LiPF_6$ electrolyte salt and polyvinylidene fluoride (PVDF) binders. Assuming an unmitigated runaway event spanning a 60 minute peak decomposition cycle, the normalized continuous mass release rate input into ALOHA is 1.66kg/min of pure HF (based on a HF emission factor of 20mg/Wh**)** applied via a direct source entry at an exhaust height of 2 meters.

3. Explosion Scenario Mass (Hydrogen Proxy): For the Vapor Cloud Explosion (VCE) run, a delayed ignition scenario is assumed where the battery enclosure vents flammable gas into the surrounding yard without an immediate flame. LFP off-gas is highly enriched with Hydrogen (H_2) and Carbon Monoxide (CO), presenting a high laminar burning velocity. To model a worst case peak pressure wave, Hydrogen (H_2) is selected as the chemical proxy. The mass input is calculated based on the maximum volume of H_2 gas that can be released (750,000l x 0.3 = 250,000l (1/3 of released gas being H_2)) and its' associated mass at 18.5kg. This corresponds to peak release rate of 18.5kg/min of Hydrogen gas for a 1 minute release period.

4. Jet Fire Scenario Mass Rate (Flammable Proxy): If the off-gas ignites immediately upon contacting the atmosphere, it creates a turbulent torch fire. This was modelled using propane as the combustion proxy with a continuous peak mass burn rate of 1.25kg/sec. (10 minute duration) via a pressurise tank configuration at the 2 meter vent centre line height and is calculated as follows;

5. $$\text{Peak Release Rate} = \frac{750\text{kg of gas}}{600\text{seconds}} = 1.25\text{kg/sec}$$

11.4.3 Source Terms for a Mitigated BESS

When a Battery Energy Storage System (BESS) is fully mitigated with an active Battery Management System (BMS), early gas detection paired with deflagration ventilation, and a gas fire suppression system, the source strength calculations drop dramatically. Under these conditions, it is not necessary to model a catastrophic, unmitigated full enclosure thermal runaway. Instead, it is more appropriate to model a single module or single rack localized event that is successfully isolated and suppressed before propagating.

Mitigated Source Term Assumptions

1. BMS Isolation: Prevents electrical propagation across the entire string or enclosure, confining the thermal abuse to the initiating rack or module.
2. Gas Suppression (e.g., Novec 1230 or Stat-X): Knocks down open flames, preventing immediate ignition and cooling the surrounding cells to stop thermal propagation.
3. Gas Detection & Ventilation: Detects off-gases (like (CO) or (H_2)) at ppm levels before thermal runaway accelerates. The ventilation system purges the enclosure, preventing the gas concentration from reaching its Lower Explosive Limit (LEL), which drastically reduces Vapor Cloud Explosion (VCE) risks.

Instead of a full 5MWh container failing, it is typical to model the failure of a single 100 kWh to 250 kWh rack/module capacity as the maximum credible accident. Recalculated mitigated source inputs based on a 250 kWh maximum impact zone and using the same LFP off-gas profile but scaling the inventory down to a single isolated section, the total off-gas volume shrinks to provide a mitigated direct source. The source terms are listed in Table 1 below for the unmitigated and mitigated modelling scenarios.

ALOHA Run	Mitigated Proxy Chemical	Unmitigated Input (5MWh Container)	Mitigated Direct Source Input (250 kWh Rack)	Engineering Justification
Toxic Plume	Hydrogen Fluoride (HF)	1.66kg/min for 60 min	0.083kg/min for 60 min	Gas suppression slows down cell degradation; BMS isolates the cluster so only 0.083kg/min HF is generated.
Explosion (VCE)	Hydrogen (H_2)	18.5kg (Instantaneous)	0.92kg (Instantaneous)	Forced deflagration ventilation continually exhausts the gas. 0.92kg represents the residual gas pocket before fan clearing.
Jet Fire	Propane (C_3H_8)	1.25kg/sec (10 min duration)	0.0625kg/sec (10 min duration)	BMS isolation of the cluster including suppression

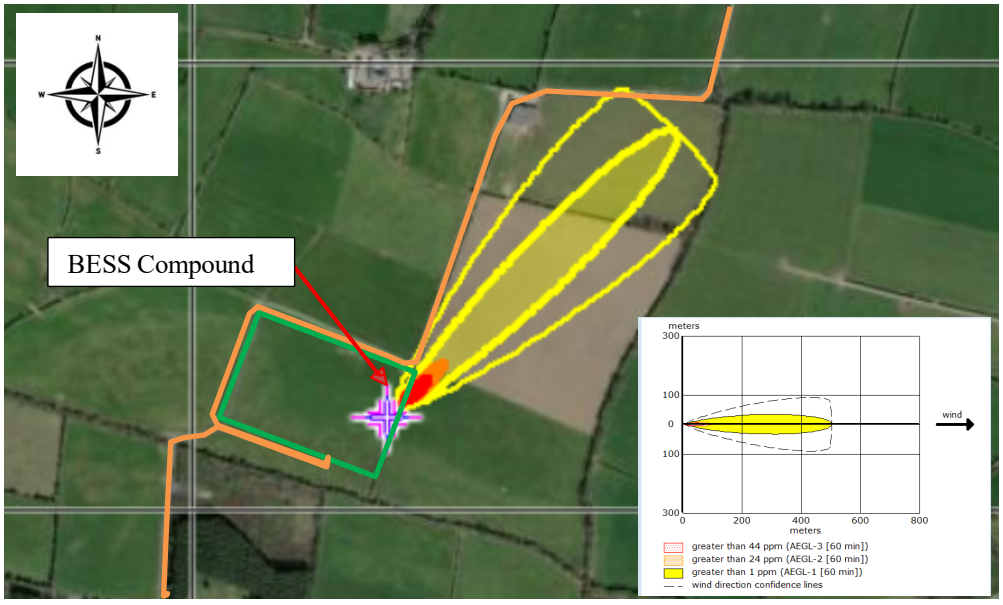
Table 1 – Summary of Source Terms All Threats (Unmitigated and Mitigated)

11.4.4 ALOHA Modelling Outputs

The predictive simulations conducted in ALOHA yielded distinct threat zone footprints for each isolated hazard pathway. The spatial boundaries for toxic gas dispersion, vapor cloud explosion (VCE) overpressure, and jet fire thermal radiation were measured along the downwind axis and directly evaluated at the critical compound perimeter to determine risk acceptability.

11.4.5 Toxic Gas Dispersion (Hydrogen Fluoride) Modelling Outputs

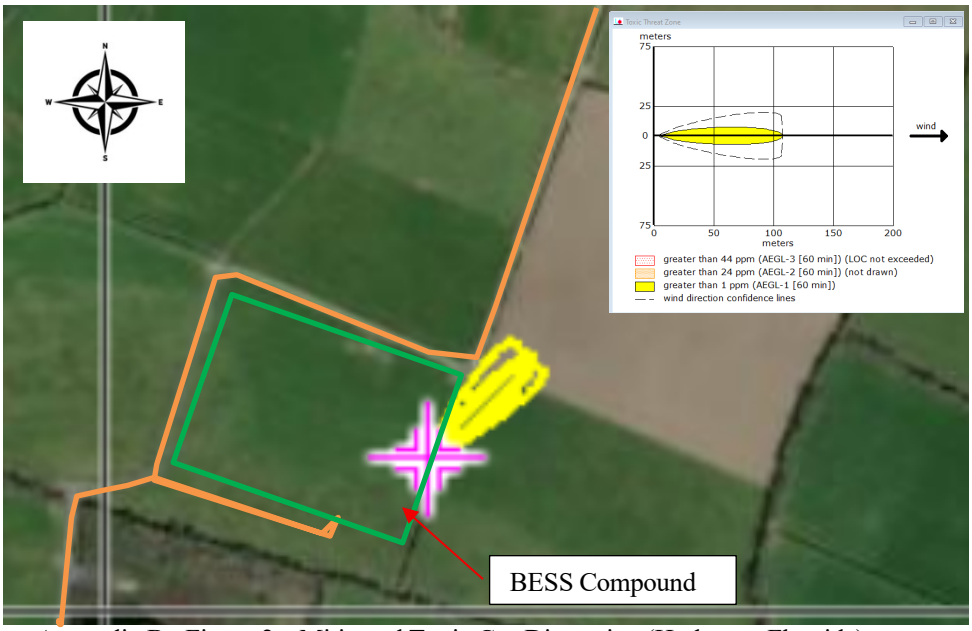
The non flaming atmospheric dispersion model for Hydrogen Fluoride (HF), simulated at a continuous release rate of 1.66kg/min under stable atmospheric conditions (Stability Class D), generated a narrow, low lying toxic plume that travels significantly downwind before dispersing below harmful limits. The plume is modelled to extend up to 450m for release area as shown in figure 1 Appendix B. Acute Exposure Guideline Levels (AEGLs) are divided into three tiers, AEGL-1, AEGL-2, and AEGL-3, which measure airborne chemical concentration threshold for emergency planning.



Appendix B - Figure 1 – Unmitigated Toxic Gas Dispersion (Hydrogen Fluoride)

- AEGL-1 Threat Zone (Yellow, 1ppm): The concentration of a substance in air above which the general population could experience mild, non-disabling, and temporary transient effects.
- AEGL-2 Threat Zone (Orange, 24ppm): The concentration above which the general population could experience irreversible or other serious, long-lasting adverse health effects, or an impaired ability to escape.
- AEGL-3: Threat Zone (Red, 44ppm): The concentration above which the general population could experience life threatening health effects or death.

In this scenario the toxic exposure levels do reach AEGL 2 and 3. AEGL 1 extends beyond the compound and finally disperse to below harmful levels.



Appendix B - Figure 2 – Mitigated Toxic Gas Dispersion (Hydrogen Fluoride)

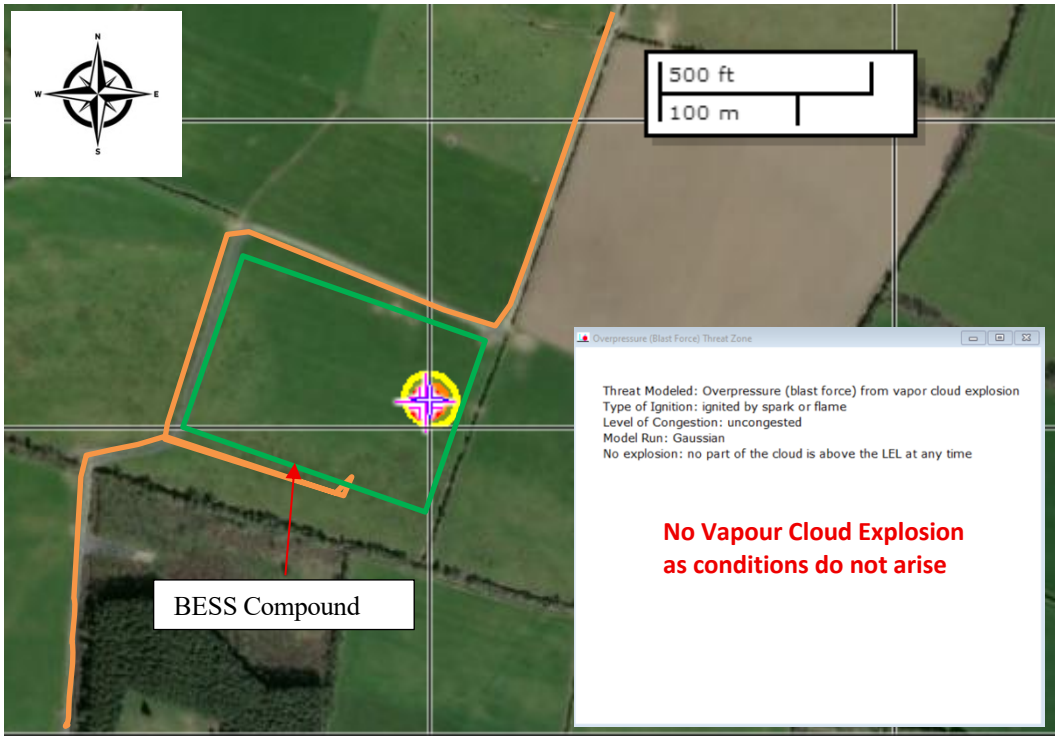
However, when the mitigated BESS installation is modelled with the source terms as listed in Table 1, the toxic plume is confined to just outside the BESS compound and the exposure levels do not exceed AEGL 1 (see figure Appendix B – figure 2 above). The mitigation through the BMS, gas suppression system and the off-gas detection clearly contributes to a significant reduction in the plume and the threat level.

11.4.6 Vapour Cloud Explosion Overpressure (Hydrogen) Modelling Outputs

The delayed ignition model of a near 18.5kg instantaneous release of hydrogen equivalent flammable off-gas within a congested layout produced a powerful localised blast wave with an unmitigated BESS enclosure. The overpressure is illustrated in Appendix B figure 3 below. The magnitude of the overpressure is 8.0psi as shown in the red zone at 38m and the orange zone to 3.5psi at 43m. This is the threshold for destruction of buildings and the potential loss of life. However, this threat is largely limited to the BESS compound.



Appendix B - Figure 3 – Unmitigated Vapour Cloud Explosion (Hydrogen)



Appendix B - Figure 4 – Mitigated Vapour Cloud Explosion (Hydrogen)

When the mitigated BESS enclosure VCE scenario is modelled with the source term of 0.92kg near instantaneous release of hydrogen equivalent flammable off-gas within a congested layout, the conditions for the occurrence of a vapour cloud explosion cannot be met. There is no part of the vapour cloud that is above the lower explosion limit (LEL) for hydrogen as indicated in the threat output in Appendix B figure 4.

11.4.7 Jet Fire (Propane) Modelling Outputs

The core focus is evaluating a high pressure flammable gas blowout resulting in a localized jet fire. The unmitigated scenario constitutes a thermal runaway propagates freely. Flammable gases (H_2), (CO), (CH_4) build up to critical pressures. An ignition source triggers a severe jet fire, threatening adjacent assets and personnel within a thermal radiation radius. With the mitigated scenario the integrating an advanced Battery Management System (BMS), automated clean agent fire suppression, and deflagration/gas ventilation restricts the thermal runaway to a single module. This reduces the jet fire hazard zone ensuring safety at the compound boundary.

Propane is used as the source chemical because it gives accurate, standard compliant thermal radiation footprint for a real BESS fire, and it successfully bypasses ALOHA's software limitations for jet fire using hydrogen. Propane is heavier than air. It mimics a low lying, horizontal "torch" or jet fire that stays close to the ground, accurately projecting thermal radiation toward your target receptors rather than losing it to vertical dispersion as hydrogen would. Therefore, propane as the proxy chemical is used as the source term input into ALOHA as a continuous direct release with immediate jet fire ignition. Propane as the chemical proxy provides an appropriate thermodynamic match to real world LFP battery off gas, balancing a high heat of combustion (≈ 46.4 MJ/kg) with a near ambient gas density that projects a realistic, ground level horizontal hazard plume.

To simulate a jet fire in ALOHA, the off gassing event is treated as a continuous release of a flammable gas mixture under pressure through a structural breach. The ALOHA jet fire modelling parameters are shown in the table 2 below.

Parameter	Input Value	Rationale
Representative Chemical	Propane proxy	Most suitable for Jet Fires
Model Option	Direct Vent / Gas Tank Rupture	Simulates pressurized jet release through an enclosure breach
Opening Diameter	0.10 meters	Simulates a localized structural failure or exhaust port failure
Internal Pressure	1.2 bar (unmitigated) / 0.1 bar (mitigated)	Pressure accumulation before enclosure or vent relief
Wind Speed	4m/s at 10 meters	Standard moderate wind risk profile
Ambient Temperature	15°C	Standard industrial baseline

Table 2 – Summary of Source Terms Jet Fire (Unmitigated and Mitigated)

11.4.7.1 Consequence Modelling Unmitigated Scenario Jet Fire Outputs

Without active interventions, a cell defect or localized thermal event cascades through modules and racks. High volume off-gassing pressurises the enclosure until a structural point fails, instantly igniting upon contact with hot cell debris. Flammable gas is expelled at a peak rate of 1.25kg/sec. (75kg/min). The jet fire flame length is calculated steady state flame length reaches 13 meters (Appendix B figure 5).

The Thermal Radiation Threat Zones:

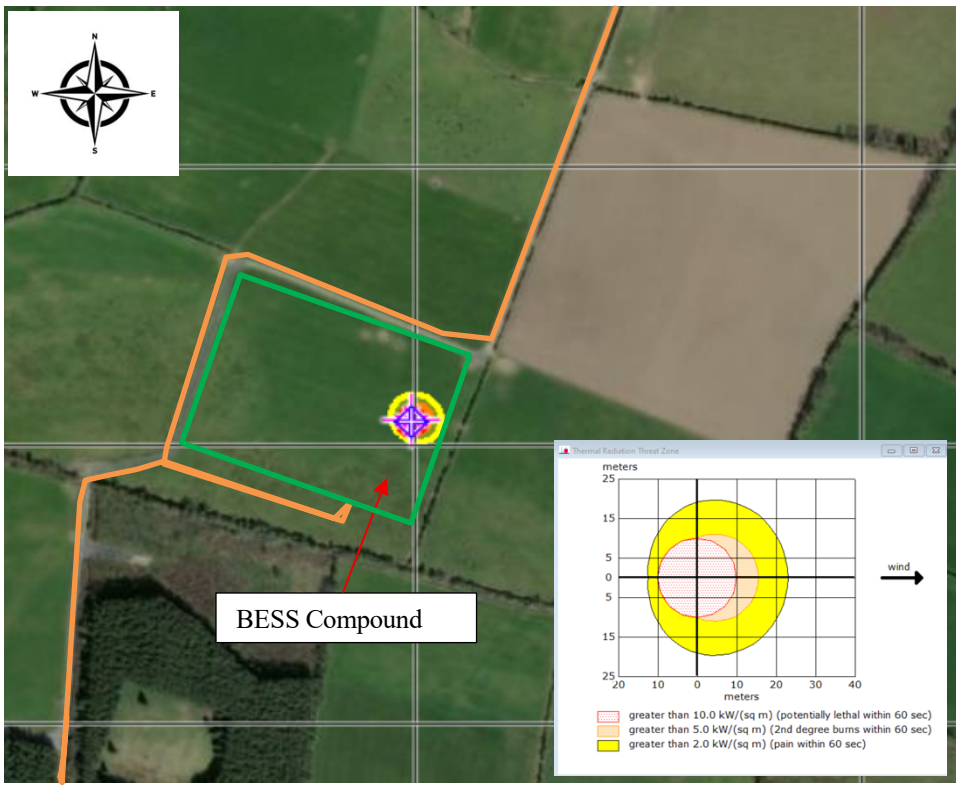
- Red Zone (10.0 kW/m^2): Extends 10 meters from the breach. Lethal to personnel within 60 seconds; causes immediate structural warping of uncooled steel.
- Orange Zone (5.0kW/m^2): Extends 16 meters. Causes second degree burns within 60 seconds; risks propagating fire to adjacent BESS units.
- Yellow Zone (2.0 kW/m^2): Extends 23 meters. Pain felt within 60 seconds; safe distance limit for unprotected personnel.

11.4.7.2 Consequence Modelling Mitigated Scenario Jet Fire Outputs

In the case of the mitigated scenario (BMS, Suppression and Ventilation), when safety systems are active, the event profile changes completely. The BMS Intervention detects early voltage and or temperature deviations. It electrically isolates the affected rack, preventing further electrical abuse or thermal propagation. Multi fan gas

ventilation activates via early gas detection (H_2)/(CO) sensors). This continuously exhausts flammable gases, keeping internal concentrations well below the lower explosive limit (LEL) and reducing pressure build up near 0 bar. Suppression deployment with a clean agent (such as Novec 1230 or Stat X aerosol) floods the enclosure, cooling the ambient air and chemically interrupting the fire cycle.

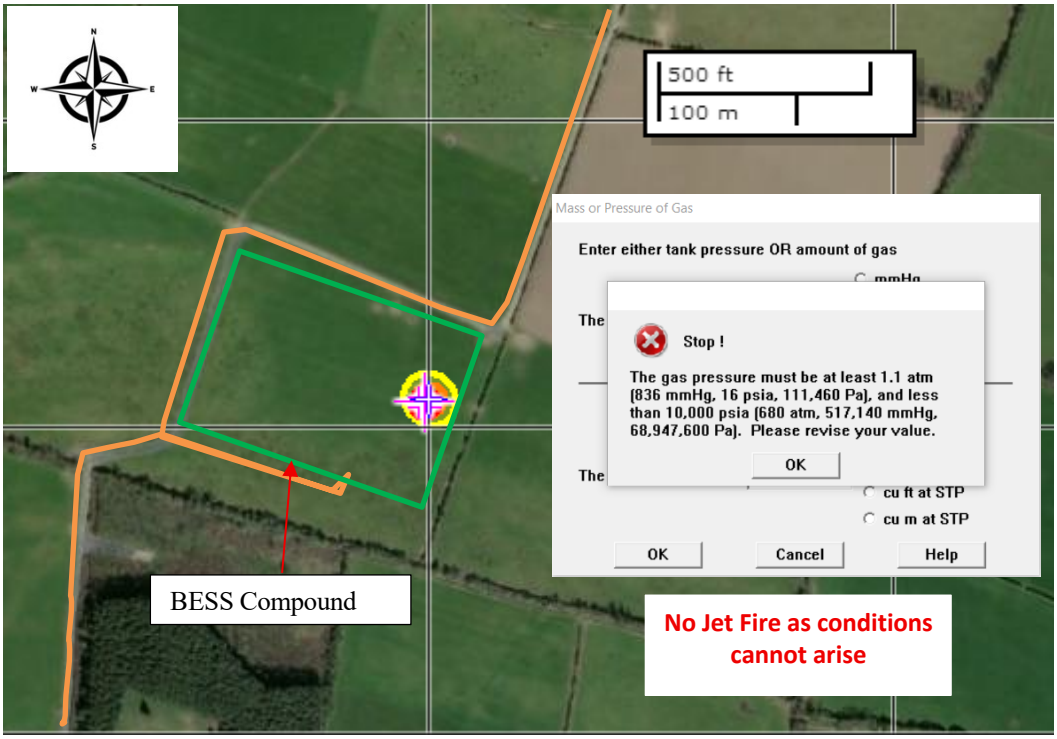
The mitigated gas release rate drops to less than 0.0625kg/s due to successful cooling, ventilation and suppression.



Appendix B - Figure 5 – Unmitigated Jet Fire (Propane)

While the unmitigated scenario with sustained peak mass release of 75kg/min. at an internal enclosure pressure of 1.25 bar) processed successfully within ALOHA, the low pressure mitigated scenario (0.1 bar overpressure through a 0.10 metre vent) is beyond ALOHA software limitations for practical reasons.

The mitigated scenario is based on the integrated engineering design as described earlier in this report. The system's multi layered safety approach actively disrupts the physical conditions required to form and sustain a pressurised jet fire. Specifically, the battery management system (BMS) provides protection by isolating thermal anomalies before gas generation begins, while the NFPA 855 compliant active ventilation system triggers at early gas detection thresholds (25% LEL) to forcefully exhaust off gasses and prevent fuel mass accumulation. Concurrently, the fire suppression system manages thermal propagation, helping to restrict potential failure to a localized, single rack that cannot produce the massive volume of gases needed for a continuous high capacity release. The installation of NFPA 68 compliant deflagration panels ensures that if any pressure does build up, it is immediately relieved at a low overpressure threshold of 0.1 to 0.2 bar. A high momentum jet fire requires a sustained internal absolute pressure exceeding the choked flow threshold through the vent (~1.1 bar absolute). Therefore, the physical conditions inside the container do not occur that would generate or sustain a jet fire scenario. This is indicated clearly in the modelling output in Appendix B, figure 6 below where the necessary gas pressure has not been reached.



Appendix B - Figure 6 – Mitigated Jet Fire (Propane)

11.4.8 Modelling Conclusions

ALOHA consequence modelling indicates that standard prescriptive boundaries can be assisted to prevent thermal runaway propagation across dense battery configurations. A combined mitigation strategy utilising early interventions effectively alters the event profile and subsequent threat levels. By significantly reducing the peak gas release rate and limiting thermal radiation, this defensive approach restricts hazards and explosive threats strictly to the immediate compound area. The modelling and data outputs demonstrates that a cascading, multi enclosure threat is entirely preventable when active controls function in unison. The modelling source inputs files are included for reference in Appendix C.

11.5 APPENDIX C – ALOHA Source Inputs

Text Summary

```
SITE DATA:
  Location: KILLOSHULAN CO KILKENNY, IRELAND
  Building Air Exchanges Per Hour: 0.63 (sheltered single storied)
  Time: September 7, 2026  1238 hours ST (using computer's clock)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.5° C
  Vapor Pressure at Ambient Temperature: 0.85 atm
  Ambient Saturation Concentration: 847,266 ppm or 84.7%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4 meters/second from SW at 3 meters
  Ground Roughness: urban or forest      Cloud Cover: 5 tenths
  Air Temperature: 15° C                 Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 1.665 kilograms/min     Source Height: 2 meters
  Release Duration: 60 minutes
  Release Rate: 1.67 kilograms/min
  Total Amount Released: 99.9 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red    : 72 meters --- (44 ppm = AEGL-3 [60 min])
  Orange: 99 meters --- (24 ppm = AEGL-2 [60 min])
  Yellow: 506 meters --- (1 ppm = AEGL-1 [60 min])
```

Appendix C – Unmitigated Toxic Gas Dispersion (Hydrogen Fluoride)

Text Summary

```
SITE DATA:
  Location: KILLOSHULAN CO KILKENNY, IRELAND
  Building Air Exchanges Per Hour: 0.63 (sheltered single storied)
  Time: September 7, 2026  1238 hours ST (using computer's clock)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.5° C
  Vapor Pressure at Ambient Temperature: 0.85 atm
  Ambient Saturation Concentration: 847,266 ppm or 84.7%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4 meters/second from SW at 3 meters
  Ground Roughness: urban or forest      Cloud Cover: 5 tenths
  Air Temperature: 15° C                 Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 0.083 kilograms/min     Source Height: 2 meters
  Release Duration: 60 minutes
  Release Rate: 83 grams/min
  Total Amount Released: 4.98 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: 19 meters --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because effects of near-field patchiness
     make dispersion predictions less reliable for short distances.
  Yellow: 108 meters --- (1 ppm = AEGL-1 [60 min])
```

Appendix C – Mitigated Toxic Gas Dispersion (Hydrogen Fluoride)

Text Summary

```
SITE DATA:
  Location: KILLOSHULAN CO KILKENNY, IRELAND
  Building Air Exchanges Per Hour: 0.63 (sheltered single storied)
  Time: September 7, 2026  1606 hours ST (using computer's clock)

CHEMICAL DATA:
  Chemical Name: HYDROGEN
  CAS Number: 1333-74-0                  Molecular Weight: 2.02 g/mol
  PAC-1: 65000 ppm   PAC-2: 230000 ppm   PAC-3: 400000 ppm
  LEL: 40000 ppm     UEL: 750000 ppm
  Ambient Boiling Point: -252.8° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4 meters/second from SW at 3 meters
  Ground Roughness: urban or forest      Cloud Cover: 5 tenths
  Air Temperature: 15° C                 Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 18.5 kilograms/min      Source Height: 0
  Release Duration: 1 minute
  Release Rate: 308 grams/sec
  Total Amount Released: 18.5 kilograms
  Note: This chemical may flash boil and/or result in two phase flow.
     Use both dispersion modules to investigate its potential behavior.

THREAT ZONE:
  Threat Modeled: Overpressure (blast force) from vapor cloud explosion
  Type of Ignition: ignited by spark or flame
  Level of Congestion: congested
  Model Run: Gaussian
  Red   : 38 meters --- (8.0 psi = destruction of buildings)
  Orange: 43 meters --- (3.5 psi = serious injury likely)
```

Appendix C – Unmitigated Vapour Cloud Explosion (Hydrogen)

Text Summary

```
SITE DATA:
  Location: KILLOSHULAN CO KILKENNY, IRELAND
  Building Air Exchanges Per Hour: 0.63 (sheltered single storied)
  Time: September 7, 2026  1606 hours ST (using computer's clock)

CHEMICAL DATA:
  Chemical Name: HYDROGEN
  CAS Number: 1333-74-0                  Molecular Weight: 2.02 g/mol
  PAC-1: 65000 ppm   PAC-2: 230000 ppm   PAC-3: 400000 ppm
  LEL: 40000 ppm     UEL: 750000 ppm
  Ambient Boiling Point: -252.8° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4 meters/second from SW at 3 meters
  Ground Roughness: urban or forest      Cloud Cover: 5 tenths
  Air Temperature: 15° C                 Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 0.92 kilograms/min      Source Height: 0
  Release Duration: 1 minute
  Release Rate: 15.3 grams/sec
  Total Amount Released: 920 grams
  Note: This chemical may flash boil and/or result in two phase flow.
     Use both dispersion modules to investigate its potential behavior.

THREAT ZONE:
  Threat Modeled: Overpressure (blast force) from vapor cloud explosion
  Type of Ignition: ignited by spark or flame
  Level of Congestion: congested
  Model Run: Gaussian
  No explosion: no part of the cloud is above the LEL at any time
```

Appendix C – Mitigated Vapour Cloud Explosion (Hydrogen)

Text Summary

```
SITE DATA:
  Location: KILLOSHULAN CO KILKENNY, IRELAND
  Building Air Exchanges Per Hour: 0.63 (sheltered single storied)
  Time: September 7, 2026  1606 hours ST (using computer's clock)

CHEMICAL DATA:
  Chemical Name: PROPANE
  CAS Number: 74-98-6                    Molecular Weight: 44.10 g/mol
  AEGL-1 (60 min): 5500 ppm   AEGL-2 (60 min): 17000 ppm   AEGL-3 (60 min): 33000 ppm
  IDLH: 2100 ppm     LEL: 21000 ppm      UEL: 95000 ppm
  Ambient Boiling Point: -42.0° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4 meters/second from SW at 3 meters
  Ground Roughness: urban or forest      Cloud Cover: 5 tenths
  Air Temperature: 15° C                 Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

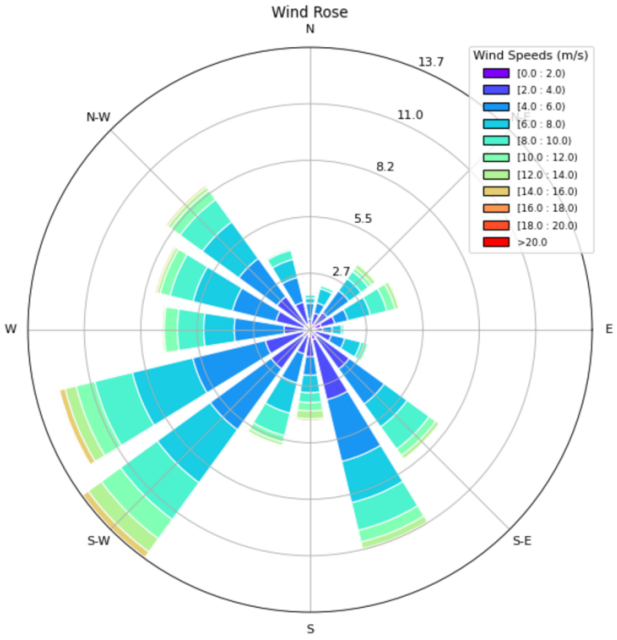
SOURCE STRENGTH:
  Leak from hole in horizontal cylindrical tank
  Flammable chemical is burning as it escapes from tank
  Tank Diameter: 2.4 meters              Tank Length: 12 meters
  Tank Volume: 54.3 cubic meters
  Tank contains gas only                 Internal Temperature: 15° C
  Chemical Mass in Tank: 117 kilograms
  Internal Press: 1.13 atmospheres
  Circular Opening Diameter: 10 centimeters
  Flame Length: 13 meters                Burn Duration: 20 seconds
  Burn Rate: 1.05 kilograms/sec
  Total Amount Burned: 12.4 kilograms

THREAT ZONE:
  Threat Modeled: Thermal radiation from jet fire
  Red    : 10 meters --- (10.0 kW/(sq m) = potentially lethal within 60 sec)
  Orange: 16 meters --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)
  Yellow: 23 meters --- (2.0 kW/(sq m) = pain within 60 sec)
```

Appendix C – Unmitigated Jet Fire (Hydrogen)

11.6 APPENDIX D – Prevailing Wind

The prevailing wind direction is predicted for the site with a Windrose issued by Sustainable Energy Authority of Ireland (SEAI) from the site at latitude 52.737771 and longitude -7.4997712 at 20m.



Windrose for Prevailing Wind Direction

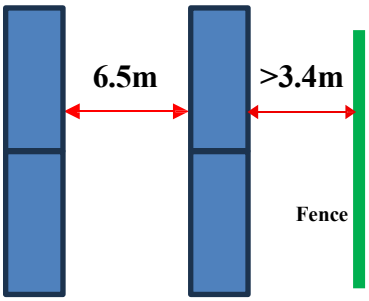
11.7 APPENDIX E – Fire Water Flows

The quantity/flow of firefighting water is determined by the formula below which is based on international best practice, where a BESS enclosure is involved in a fire outbreak and a separating distance has been provided to adjacent containers:

Flow = 1900 × $\mathbf{C_f}$ involved + 250 × $\mathbf{C_{ex}}$ exposures
$\mathbf{C_f}$ **– involved**: likely to be involved (fire) enclosures (initial unit(s)).
$\mathbf{C_{ex}}$ **– exposures**: immediately adjacent enclosures or critical equipment needing cooling.
Duration (hours). Plan 4 h as a baseline for lithium ion enclosure events (reignition/long cooling tails are common).
Total Volume (litres)
Volume = Flow (litres/minute) × 60 × Duration (hours).

For the wind farm BESS installation, the total volume of water on site available for firefighting is calculated accordingly with the following assumptions:

(a) Separation distance between the opposing faces of the BESS containers is a minimum of 6.5 m.



Appendix E Figure 1- BESS Unit Separation Distances

(b) Each BESS container enclosure which are physically separated to limit the radiation heat flux to apposing enclosures.
(c) As a result of the separation distances, no immediately adjacent BESS enclosure will require cooling.
(d) Planning an extended period of firefighting at 4 hours duration.
(e) The required quantity of fire water on sited is calculated as follows:

(Fire container + Exposed container) x (Fire Duration in Min.)
Flow = ((1900 × 1) + (250 × 0 exposure)) x (4 x 60)) = **456,000 litres = 456 m^3**

11.8 APPENDIX F – Fire Water Retention

The sizing the fire water retention capacity is calculated by the addition of the fire flow driven volume and the concurrent rainfall on the catchment.

$V_{retention} = (Q_{fire} \times 60 \times t_{duration}) + (I_{rain} \times A_{impervious} \times C)$

Where:
Q_{fire} = planned firefighting flow (litres/min) for your worst credible BESS scenario (e.g., (1900 + 250) litres/min defensive cooling for 1 enclosure/unit involved and 1 enclosure/unit exposure).

$t_{duration}$ = 4 hours worst case for defensive BESS cooling, which will be validate from UL 9540A and CSA TS-800 results of the lithium ion battery chemistry.

i_{rain} = design rainfall during incident (highest 76 year period of rain fall over a 24 hour period for the area sourced from Met Eireann's historical data). The historical records show that the nearest weather station at Greenhill weather station, Co. Kilkenny (10 km from the site) from the 1st Mar. 2010 to the 30th of April 2026 that the highest rainfall over a 24 hour period occurred on the 5th and the 6st of Sept. 2010 at 88.7mm.

$A_{impervious}$ = contributing hard stand/roof area routed to containment at 3700 m^2 for this BESS compound.

C = The runoff coefficient will be assumed to be very efficient and equal to 1.0 for the hardstand).

Add a 15% freeboard to prevent the possibility of overtopping with the most adverse wind exposure case (if exposed). Not applicable in this case.

Therefore, the Killoshulan Wind Farm BESS fire water retention requirement is calculated to be: $V_{retention}$

$= ((Q_{fire} \times 60 \times t_{duration}) + (I_{rain} \times A_{impervious} \times C)) \times 1$

$V_{retention}$ = ((1900) x 60 x 4) + (0.0887 x 3700 x 1.0) x 1

$V_{retention}$ = (456,000 + 328) x 1 = **456,328 litres or 500 m^3**.

11.9 APPENDIX G – Emergency Contact List

 **Emergency Contact List** 	
Fire and Rescue Services	112 or 999
Ambulance Services	112 or 999
St. Luke's General Hospital	056 778 5000
Kilkenny, Garda Station	056 777 5000
ESB Networks	1 800 372 999

BESS Battery Manufacturer/Supplier	00 - XXXXXXX/087-XXXXXXX
Emergency Response Coordinator	00 - 1234567/085-1234567
Operational Regional Manager	00 - 2345678/087-2345678
Kilkenny County Council	056 779 4000

END OF REPORT