SUNNICA ENERGY FARM

EN010106

Volume 7

7.6 Outline Battery Fire Safety Management Plan

APFP Regulation 5(2)(q)

Planning Act 2008

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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Sunnica Energy Farm

7.6 Outline Battery Fire Safety Management Plan

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Table of contents

Table of Tables

Figures

1 Technical Terms and Definitions

1.1.1 The following technical terms and definitions have been used in the document and will form the basis of understanding.

Table 1: Technical Terms and Definitions

Term	Definition
AHJ	Authority Having Jurisdiction will be the statutory body responsible for approval of the project and will be confirmed in the final Battery Fire Safety Management Plan.
Battery System	Refers to the components inside the BESS enclosure (cells, modules, electronic boards, cables, etc.).
BESS	Battery Energy Storage System.
Cell	Refers to the Li-ion unit that provides a source of electrical energy by direct conversion of chemical energy.
CFRS	Cambridge Fire and Rescue Service.
BESS Enclosure	Refers to the enclosed structure surrounding the BESS.
DNV GL	Det Norske Veritas Germanischer Lloyd (DNV GL) is a technical consultancy.
Electronic Boards	Refers to the electronic boards implemented in the battery system.
EMC	Electromagnetic Compatibility.
EMS	Energy Management System
Fire Suppression System	Active fire prevention system placed inside the battery enclosure.
FM Global	Factory Mutual (FM) Global is an American mutual insurance company specialising in loss prevention for large corporations in the Highly Protected Risk property insurance market sector.
FPA	The Fire Protection Association (FPA) is the UK's national fire safety organisation who work to identify the dangers of fire and help their clients reduce fire-related risks.
Heating and Cooling System	System which regulates temperature and humidity within the BESS enclosure.
HSE	Health and Safety Executive (HSE) is a UK government agency responsible for the encouragement, regulation and enforcement of workplace health, safety and welfare including research into occupational risks.
Module	Compact module that integrates several Li-ion cells.
NFPA	The National Fire Protection Association (NFPA) is an international non-profit organisation devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards.
Off-Gassing	The event in which the batter cell case vents due to a rise in internal pressure.
Rack	Composed of several modules in series, including their management system.
RiscAuthority	RiscAuthority is a research scheme supported by a significant group of UK insurers that conducts research in support of the development and dissemination of best practice on the protection of property and business.
Scheme	A nationally significant infrastructure project comprising a ground mounted solar photovoltaic generating station with a gross electrical capacity of over 50 megawatts and associated development. The details of the Scheme are described in **Chapter 3** of the Environmental Statement **[EN010106/APP/6.1]** and Schedule 1 of the draft DCO submitted with the Application. The Scheme will be known as "Sunnica Energy Farm".
SFRS	Suffolk Fire and Rescue Services.

2 Scheme Description

2.1.1 This report presents an Outline Battery Fire Safety Management Plan for the Scheme, a renewable energy project proposed by Sunnica Limited (Applicant). Electricity will be generated and stored at Sunnica East Sites A and B and Sunnica West Sites A and B across Cambridgeshire and Suffolk for distribution to the Burwell National Grid Substation via underground cables.

2.2 General Arrangement

2.2.1 The Scheme will consist of the following components:

a. Solar photovoltaic (PV) modules installed on mounting structures;

b. Inverters, transformers and switchgear;

c. Onsite cabling (high voltage / low voltage);

d. Battery Energy Storage Systems (BESS's) on Sunnica East Sites A and B and Sunnica West Site A;

e. Onsite Substations on Sunnica East Sites A and B and Sunnica West Site A;

f. Office / warehouse (Sunnica East Sites A and B);

g. Fencing and security measures;

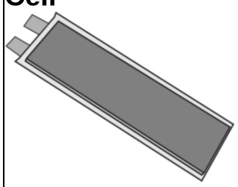
h. Internal access roads and car parking;

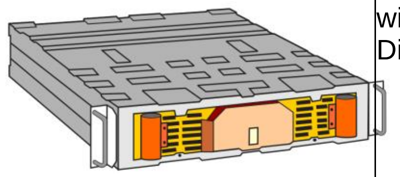
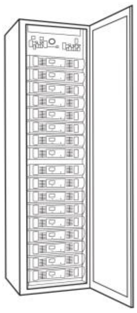
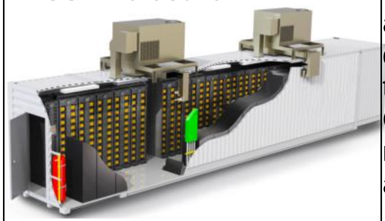
i. Landscaping including habitat creation areas; and

j. Construction laydown areas.

2.2.2 While it is known that the BESS's will consist of a compound and battery array, details of the design for the BESS elements, including their power and energy ratings, and their final enclosure dimensions and appearance, are currently in development and will be finalised following receipt of any Development Consent Order. Table 2 outlines the limits of the design parameters for the BESS which will allow flexibility and optimisation of the Scheme moving forward.

Table 2: BESS Design Parameters

Work No.	Scheme Component	Applicable Design Principle
2A, 2B, 2C	**Cell**  *Typical Pouch Cell (Ref. 2).*	The batteries selected for use on the Scheme will be from tier 1 manufacturers and will utilise lithium-ion chemistry. Each battery being procured and installed will be fully sealed by design and has no free electrolyte. The lithium-ion batteries will be either NMC (Nickel Manganese Cobalt) or Lithium Iron Phosphate ($LiFePO_4$) chemistry (Ref. 3).

Work No.	Scheme Component	Applicable Design Principle
2A, 2B, 2C	***Module***  *Typical Enclosed Module (Ref. 2).*	There are several cells which make up a module. Each cell will have a thermal barrier separating adjacent cells. Dimensions vary between manufacturers.
2A, 2B, 2C	**Rack**  *Typical Rack (Ref. 2).*	 *6 MW Leighton Buzzard (Ref. 4).* Modules will be stacked vertically within each rack. Each rack will be separated with thermal barriers on the sides. Single rows of racks will be open in the front and back whereas double row racks (i.e. back to back racks) will have thermal barriers at the back of the rack only.
2A, 2B, 2C	**BESS Enclosure**  *Mobile Energy Storage Contai (Ref. 5).*  *Breach Farm 10 MW BESS site in Derbyshire (Ref. 6).*  *BYD High Energy Density Site Solution (Ref. 7).*	The BESS enclosure will have multiple racks with direct access either from the ends or side of the enclosure depending on the manufacturer. The construction will be in the form of modified 20-foot / 40-foot ISO shipping containers OR modular premanufactured containers / enclosures. The maximum anticipated footprint will be 17 m (L) x 5 m (W) with a maximum height from ground level of 6 m.

Work No.	Scheme Component	Applicable Design Principle
2A, 2B, 2C	**BESS Compound**  *Fluence Energy 30MW Site in Australia (Ref. 8)*  *Zenobe Energy 29 MW Site in Aylesford, England (Ref. 9)*	There are three centralised areas consisting of BESS enclosures and battery stations as follows: Sunnica East Site A: 66,000 Sunnica East Site B: 162,000m^2 Sunnica West Site A: 83,000m^2
8A, 8B	**Operational Office / Warehouse Building**	The maximum anticipated size of the Operational Office and Warehouse Building for the different sites are as follows: Sunnica East Site A: 31 m(L) x 13 m(W) x 5 m(H) Sunnica East Site B: 35.5 m(L) x 25 m(W) x 8 m(H)
2A, 2B, 2C	**Indoor or Outdoor Battery Station**	A station comprising transformers, switchgear, power conversion system (PCS) or inverter, and other ancillary equipment. These will either be located outside or housed together in a container, with a maximum height of up to 6m.
3A, 3B, 3C	**Substation (adjacent to BESS)**	Electrical infrastructure consisting of transformers, switchgear, metering equipment and a substation control building or container as follows: Sunnica East Site A: 85 m (L) x 55 m (W) x 10 m (H) Sunnica East Site B: 85 m (L) x 130 m (W) x 10 m (H) Sunnica West Site A: 85 m (L) x 130 m (W) x 10 m (H) The maximum anticipated size of the substation control building or container will be 25 m (L) x 8 m (W) x 6 m (H).
2A, 2B, 2C	**Fire Water Storage Tanks**	Fire water storage tanks dedicated for firefighting operations only. The additional fire water storage tank will ensure availability and resiliency in the event of a single water storage tank not being available in the case of maintenance and / or impairment.

Work No.	Scheme Component	Applicable Design Principle
	 	

2.3 The Planning Process

2.3.1 The Scheme is classified as a Nationally Significant Infrastructure Project (NSIP) because its proposed generating capacity is greater than 50 megawatts (MW). NSIP's are major developments which require consent to be granted by the relevant Secretary of State through a Development Consent Order (DCO) under the Planning Act 2008 (PA 2008).

2.3.2 Unlike local planning permissions, which are considered by local authorities, DCO applications are submitted to the Planning Inspectorate (PINS). This independent body administers the application process on behalf of the relevant Secretary of State. In this case, the relevant government department is the Department for Business, Energy & Industrial Strategy (BEIS).

2.3.3 DCO's are governed by a fixed, statutory process which requires consultations with persons with an interest in the land and certain bodies as prescribed under Section 42 of the PA 2008; the local community under Section 47 of the PA 2008; and to publicise the Scheme locally and nationally under Section 48 of the PA 2008 (Ref. 11).

2.3.4 At the time of writing this report, various consultations have been carried out with interested parties. A joint response to the statutory consultation was received from West Suffolk Council, Suffolk County Council, East Cambridgeshire District Council, and Cambridgeshire County Council (Ref. 12). The councils have expressed a concern that the risks associated with battery storage fires have not been fully explored and a request has been made to develop an Outline Battery Fire Safety Management Plan for the BESS and to be included as part of the DCO application for the Scheme. This document addresses this request.

2.3.5 Once the DCO is granted then this Outline Battery Fire Safety Management Plan will be secured through a requirement in Schedule 2 of the DCO. The requirement within the DCO will require a Battery Fire Safety Management Plan to be submitted to and approved by the relevant planning authorities prior to the commencement of the BESS. The Battery Fire Safety Management Plan must be in accordance with the Outline Battery Fire Safety Management Plan, which is this document.

2.4 Contributors and Consultees

2.4.1 Effective stakeholder engagement and consultation is a key requirement of the PA 2008. The following stakeholders have been identified with the aim of ensuring collective agreement and acceptance of the Outline Battery Fire Safety Management Plan :

a. **Sunnica Ltd** is the developer for the project. It is owned by PS Renewables, a leading Engineering, Procurement and Construction (EPC) company within the UK solar power sector, and Tribus Clean Energy Limited, a solar developer that is currently developing 250 MW of stand-alone BESS in Norfolk as part of a separate scheme.

b. **AECOM** is a multidisciplinary engineering consultancy appointed to advise on the environment and fire safety of this Scheme.

c. **Cambridge Fire and Rescue Service** (CFRS) is the statutory fire and rescue service for the combined authorities of Cambridgeshire and Peterborough although it has been agreed that consultation and engagement will be with the SFRS for the purpose of the Outline Battery Fire Safety Management Plan. CFRS have however been consulted as part of the statutory consultation in relation to the Preliminary Environmental Information Report.

d. **Suffolk Fire and Rescue Service** (SFRS) is the statutory fire and rescue service covering Suffolk. SFRS was consulted as part of the statutory consultation in relation to the Preliminary Environmental Information Report and this Outline Battery Fire Safety Management Plan.

e. **The Health and Safety Executive** (HSE) is a UK government agency responsible for the encouragement, regulation and enforcement of workplace health, safety and welfare, and for research into occupational risks in Great Britain. HSE has been closely studying battery safety for several years, using its bespoke battery testing facility to help customers understand how best to manage the risks faced by many industry sectors during battery manufacture, storage, transport and use. The HSE has been consulted over the Scheme.

f. **Smith Brothers Contracting Ltd** is an Engineering Procurement and Construction services company advising the Applicant on the delivery of technical advice for the grid connection and associated electrical equipment design required for this Scheme.

3 Purpose and Scope

3.1.1 The scope of this Outline Battery Fire Safety Management Plan covers the life safety and property protection fire safety requirements of the BESS at Sunnica East Site A, Sunnica East Site B and Sunnica West Site A.

3.1.2 The purpose of the Outline Battery Fire Safety Management Plan is to demonstrate that the location of BESS within the Scheme does not give rise to a significant increase in fire risk and that any risk that does exist can be addressed by ensuring that the Scheme is constructed, operated and decommissioned in accordance with an appropriate Outline Battery Fire Safety Management Plan. This Outline Battery Fire Safety Management Plan has been developed in collaboration with SFRS. CFRS deferred consultation on the Outline Battery Fire Safety Management Plan to SFRS. Table 3 summarises the statutory consultation response received from West Suffolk Council, East Cambridgeshire District Council, Suffolk County Council and Cambridgeshire County Council, together with the Applicants responses to those items.

3.1.3 Concerns have also been raised by local communities about the fire safety of historical BESS projects. This Outline Battery Fire Safety Management Plan will consider the experience gained from these projects and implement solutions where reasonably practical and effective for life safety and property protection.

Table 3: Statutory Consultation Requirements

Item	Requirement	Response
1	Procuring components and using construction techniques which comply with all relevant legislation.	Components and construction will comply with relevant legislation and the guidance outlined in Section 3. If any deviation from industry guidance is proposed during the Scheme, agreement with CFRS, SFRS and the HSE will be obtained prior to implementation.
2	Developing an emergency response plan with both counties' fire services, to minimise the impact of an incident during construction, operation, and decommissioning of the facility.	This document is the start of that process and it will be further developed as the project progresses. Refer to paragraph 4.1.1 of this document which states: "This Outline Battery Fire Safety Management Plan will be kept up-to-date by the Operations and Maintenance company that is awarded the contract for maintaining the Scheme and which will be contractually required to produce a revised version of the Battery Fire Safety Management Plan if relevant legislation / guidance is introduced that triggers a change to standards or codes used in the Battery Fire Safety Management Plan, or if there is a change to the Scheme (development or process) itself." The Battery Fire Safety Management Plan will include an emergency response plan during the detailed design stage of the Scheme.
3	Ensuring the BESS is located away from residential areas. Prevailing wind directions should be factored into the location	Consideration of the release of toxic gases, including prevailing wind direction, has been undertaken as part of the Major Accidents and Disasters section of **Chapter 16: Other**

Item	Requirement	Response
	of the BESS to minimise the impact of a fire involving lithium-ion batteries due to the toxic fumes produced.	**Environmental Topics** of the Environmental Statement **[EN010106/APP/6.1]** and the **Appendix 16D: Unplanned Atmospheric Emissions from Battery Energy Storage Systems (BESS)** of the Environmental Statement **[EN010106/APP/6.2]**. The report entitled 'Unplanned Atmospheric Emissions from Battery Energy Storage Systems (BESS)' **[EN010106/APP/6.2]** provides an overview of the nature of the risk and assesses how local meteorological conditions would dilute emissions between the proposed battery locations and potential sensitive receptors using dispersion modelling. The report concludes that in the unlikely event that a fire were to break out in a single cell or module, it is considered very unlikely given the control measures that the fire would spread to the rest of the BESS. Even should all the systems fail and a large scale fire break out within one of the BESS containers, then the resultant hydrogen fluoride concentration at the closest receptors would be below the level that Public Health England has identified as resulting in notable discomfort to members of the general population.
4	The emergency response plan should include details of the hazards associated with lithium-ion batteries, isolation of electrical sources to enable firefighting activities, measures to extinguish or cool batteries involved in fire, management of toxic or flammable gases, minimise the environmental impact of an incident, containment of fire water runoff, handling and responsibility for disposal of damaged batteries, establishment of regular onsite training exercises.	Details of known hazards are shown in Table 6 to Table 10 for the different phases of the Scheme. Risk Mitigation Methods are outlined in Section 6: • Isolation of electrical sources is covered under section 6 Risk Mitigation Methods RMM 10 and RMM 13. • Measures to extinguish and cool fires is covered under clause 6 Risk Mitigation Methods RMM 18, RMM 19 and RMM 21. • The environmental impact is considered within the Major Accidents and Disaster Assessment of the EIA and reported in the ES. • Methods to minimise the environmental impact and the containment of fire water runoff is covered under section 6 Risk Mitigation Method RMM 15. • Handling and responsibility for disposal of damaged batteries has been added into this Outline Battery Fire Safety Management Plan. • Regular onsite training exercises will be required in the Battery Fire Safety Management Plan.

Item	Requirement	Response
5	The emergency response plan should be maintained and regularly reviewed by the Applicant and any material changes notified to SFRS and CFRS.	Refer to item 2 above. The emergency response plan will be maintained and regularly reviewed within the Battery Fire Safety Management Plan.
6	Environmental impact should include the prevention of ground contamination, water course pollution, and the release of toxic gases.	Refer to item 4 above. Minimising environmental impact and containment of fire water runoff is covered under risk mitigation method RMM 15. The environment impacts associated with this has been considered within the **Chapter 9: Flood Risk, Drainage and Water Resources** and **Chapter 16: Other Environmental Topics** of the Environmental Statement **[EN010106/APP/6.1]**.
7	The BESS facilities should be designed to provide automatic fire detection and suppression systems are available, but the Service's preferred system would be a water drenching system as fires involving Lithium-ion batteries have the potential for thermal runaway. Other systems, such as inert gas, would be less effective in preventing reignition.	Automatic fire detection systems will be provided as per risk mitigation methods RMM 17, RMM 18 and RMM 19. A gas fire extinguishing system with enhanced extinguishing agent design concentration was originally proposed which is now upgraded to an automatic water-based system in response to the Fire and Rescue Services' preference. An automatic water mist system will be considered as an alternative option to an automatic sprinkler system, with the final choice to be agreed with the Fire and Rescue Services post-consent at detailed design stage. Water mist is known to scrub the surrounding air of toxins produced by fire and will provide cooling throughout the BESS enclosure including concealed spaces, such as modules within racks, which a conventional automatic sprinkler system would otherwise find difficult to penetrate with larger water droplets. The choice of automatic suppression (sprinklers or mist) will be agreed with the Fire and Rescue Services. The water supply for the automatic sprinkler or water mist system will be integrated into the design of each BESS enclosure and located either internally or externally adjacent to the BESS enclosure. Alternatively, the water supply and pumps will be located centrally in each of Sunnica East Site A, Sunnica East Site B and Sunnica West Site A with underground connections to each BESS container.
8	The BESS facilities should be designed to provide redundancy in the design to provide multiple layers of protection.	The electronic protection for the battery system is provided with multiple layers of redundancy. If battery abuse is detected, the battery module, rack or entire container will be isolated as fail safes and disconnected from grid. An automatic water-based suppression system will also be included.

Item	Requirement	Response
9	The BESS facilities should be designed to provide design measures to contain and restrict the spread of fire using fire-resistant materials, and adequate separation between elements of the BESS.	Thermal barriers or adequate fire separation will be provided in accordance with legislative code requirements and will be referenced in section 6, Risk Mitigation Method RMM 01.
10	The BESS facilities should be designed to provide adequate thermal barriers between switch gear and batteries.	Thermal barriers are covered under section 6, Risk Mitigation Method RMM 01.
11	The BESS facilities should be designed to provide adequate ventilation or an air conditioning system to control the temperature. Ventilation is important since batteries will continue to generate flammable gas if they are hot. Also, carbon monoxide will be generated until the batteries are completely cooled through to their core.	Heating and cooling of the BESS units is covered under section 6, Risk Mitigation Method RMM 23 where permanent mechanical ventilation will be provided with an air flow monitoring system to prevent concentration of hazardous gases.
12	The BESS facilities should be designed to provide a very early warning fire detection system, such as aspirating smoke detection.	An aspirating smoke detection system will be provided as set out in section 6, Risk Mitigation Method RMM 19.
13	The BESS facilities should be designed to provide carbon monoxide (CO) detection within the BESS containers.	A carbon monoxide detection system will be provided as set out in section 6, Risk Mitigation Method RMM 19.
14	The BESS facilities should be designed to install sprinkler protection within BESS containers. The sprinkler system should be designed to adequately contain and extinguish a fire.	A dedicated automatic water-based system will be provided within each BESS container designed to contain a fire until fire and rescue services arrive.
15	The BESS facilities should be designed to ensure that sufficient water is available for manual firefighting. An external fire hydrant should be in close proximity of the BESS containers. The water supply should be able to provide a minimum of 1,900 l/min for at least 2 hours. Further hydrants should be strategically located across the development. These should be tested and regularly serviced by the operator.	Sufficient water storage will be provided for all firefighting systems (manual and automatic). In terms of the water supply requirement of 1900 l/min flow for 120 minutes, this is taken from American standard NFPA 13 and is based on high hazard storage occupancies within urban areas; this American standard isn't directly applicable to this UK project. The same minimum water supply requirement taken from British standard BS 9990 is 1500 l/min flow for 45 minutes. To align the requirement with the UK market, it is proposed to use a flow of 1500 l/min for a duration of 120 minutes. This has been discussed and agreed with SFRS. In terms of fire hydrant provision, due to the remote site location and lack of water supply infrastructure, Approved Document B (Ref. 12) allows for the use of natural water source or

Item	Requirement	Response
		the provision of a full holding capacity tank for firefighting operations. Where a natural water supply is used, then the seasonal availability of natural water supplies for each site applicable will be investigated and verified at detailed design stage. Natural water supplies will only be dedicated for use by fire hydrants and no other firefighting systems. If a natural water source is not available on site, a full holding capacity tank will then be used for fire and rescue services to relay water to the incident area and use the fire services own appliances for pumping operations.
16	A safe access route for fire appliances to manoeuvre within the site (including turning circles). An alternative access point and approach route should be provided and maintained to enable appliances to approach from an up-wind direction. Please note that SFRS requires a minimum carrying capacity for hardstanding for pumping/high reach appliances of 15/26 tonnes, not 12.5 tonnes as detailed in the Building Regulations 2000 Approved Document B, 2006 Edition, due to the specification of our appliances.	A safe access route and alternative access route will be provided for each of the Sites within the Scheme (details of access are provided in **Chapter 13: Transport and Access** of the Environmental Statement **[EN/010106/APP/6.1]**) and is detailed in clause 6 Risk Mitigation Method RMM 24. Where both access routes are located on the same road into a site, internal roads will be arranged to allow approach from an upwind direction (details of access are provided in **Chapter 13: Transport and Access** of the Environmental Statement **[EN/010106/APP/6.1]**).
17	The risk assessments refer to undesirable outcome to persons being burnt. There is a potential for death because of an explosion or toxic gas release. This outcome should be referenced throughout risk assessment.	Loss of life has been added to the risk assessment matrix where people in proximity are at risk, see Table 7 below.
18	The impact of the risk mitigation measures on the overall risk rating appear to be over generous.	The overall risk rating of the risk mitigation measures have been reviewed and amended accordingly for this planning stage. The risk mitigation methods will be revised in subsequent stages of design when the project specific design is developed. It is proposed that at detailed design stage, a Hazard Identification Study (HazID) and Hazard and Operability Study (HAZOP) workshop will be arranged with CFRS, SFRS and the Applicant to identify risks and review/agree risk rating for each hazard. This will be done in advance of submitting the Battery Safety Management Plan for approval.
19	Details of the BESS technology needs to be presented as part of the consultation and not developed post consent. This includes the total storage capacity and locations.	Details of the BESS technology has been provided in Table 1 for each element of the Scheme including cell, module, rack, BESS enclosure and BESS compound. The maximum parameters of the BESS have been provided, which provides a good understanding in terms of the built form. More detailed information of the BESS technology will be provided within the detailed Battery Fire Safety Management Plan as the project develops during detailed design.

Item	Requirement	Response
20	Management of, and mitigation measures, following a catastrophic failure and inadvertent release of toxic and flammable gases need to be included in the Outline Battery Fire Safety Management Plan. This should include the potential impact on site to staff and responders, off site to surrounding community, and environmental impact. These should form part of the risk assessment and detail the measures included in the risk mitigation measures to reduce the impact and risk.	Refer to item 3.
21	The Service would want the Applicant to observe the minimum of 6m separation between containers rather than the provision of 1-hour fire separation. This is due to the potential for thermal runaway that could last for several hours rendering the effectiveness of the barriers insufficient.	Thermal barriers or adequate fire separation will be provided in accordance with legislative code requirements available at detailed design stage and are referenced in section 6, risk mitigation method RMM 01. This will be provided within the detailed Battery Fire Safety Management Plan. Where legislative code requirements don’t cover the separation distances, common industry practice and guidelines will be considered and agreed by all parties prior to implementation. This approach has been agreed with SFRS.
22	The manufacturing, transporting, storing, installation and maintenance should be independently quality assured to ensure the highest standards are maintained.	Quality assurance will be to UK industry standards for all stages of the project in sections 5.3 to 5.8.
23	The Service continues to support the installation of a water drenching system rather than a gaseous suppression system. Thermal runaway is most effectively minimised and contained using water rather than an inert gas system.	Refer to item 7.
24	The provision of a dry pipe system, for the use by the Fire Service, to support an inert gas system would not be sufficient to prevent thermal runaway, due to the time delay for sufficient resources to arrive on site and set up operations. A dry pipe connected to the sprinkler system would enable the Service to augment the supply. Any sprinkler augmentation dry pipe needs to be accessible without placing personnel at risk.	This proposal is no longer applicable. Refer to item 7 for the current proposal.
25	The design of the containers to provide a sump for contaminated water removal is not sufficient to mitigate against the environmental impact of a significant fire in a	Currently the design options for containment is either: • Sump on each BESS container, OR

Item	Requirement	Response
	container. The body of the container may become breached due to fire, explosion of excessive heat build-up. No details of how the Applicant would remove contaminated water from the site during firefighting operations has been provided.	• External floor surface surrounding each BESS container, which will be impermeable. The current proposal in this Outline Battery Fire Safety Management Plan combines both of the above options as one solution to provide resiliency and an extra layer of protection should the BESS container be breached from explosion or excessive heat build-up. The BESS area will be lined with an impermeable membrane. The drainage strategy will include for bunded holding lagoons within the BESS area which will contain the fire water runoff. This will be tested following the fire and if contaminated will be tankered offsite to a suitable waste facility for treatment. The approach has been discussed and agreed with the Environment Agency.
26	The provision of water to support operations for 45 minutes would be insufficient to contain and extinguish a fire if the installation experienced thermal runaway. In addition of water for firefighting, water would also be required to create a thermal barrier to prevent radiated heat transfer to adjacent structures and containers.	The most onerous design requirement for the water supply for either of the automatic sprinkler or automatic water mist system options will apply. For the option of the automatic water mist system, it is proposed a water supply duration of at least 60 minutes will apply unless a specific fire test protocol indicates that a lower or higher water supply duration is proven to extinguish a fire. For the option of the automatic sprinkler system, a water supply duration of at least 45 minutes will apply based on FM Global fire testing for the protection of Energy Battery Storage Systems. The firefighting water flow of 1500 l/min for a duration of 120 minutes shall be sufficient to prevent radiant heat transfer between BESS containers.
27	The Service has previously recommended the following Ensure that sufficient water is available for manual firefighting. An external fire hydrant should be in close proximity of the BESS containers. The water supply should be able to provide a minimum of 1,900 l/min for at least 2 hours. Further hydrants should be strategically located across the Scheme. These should be tested and regularly serviced by the operator.	Refer to item 15.
28	This capacity is in addition to the provision of water to support the drencher system when operating.	The total water supply provision will be sufficient for the operation of all firefighting systems (manual and automatic).

Item	Requirement	Response
29	The design should ensure that following the activation of the detection system the container is isolated and batteries discharged to ensure the safety of responding personnel.	If battery abuse is detected, all battery racks and modules within the affected container will be isolated automatically depending on failsafe. Battery discharge is not possible once isolated.
30	The Service will need confirmation that the affected container has been isolated from the system and no residue charge remains within the batteries or structure. This should be in writing from a suitably qualified person before firefighting measures can commence.	The container will be isolated depending on fail safes. The level of charge will only be obtainable through the battery monitoring system and will require the Fire & Rescue Service to communicate with the operations team when arriving on site. At this stage of the project, it’s currently unknown whether a residual charge can be safely dissipated to a remote location. This will be confirmed during the detailed design stage and in the final Battery Fire Safety Management Plan.
31	The production of a fire service site specific risk assessment should be developed during construction and operation of the facility. This should include regular familiarisation visits for local operational personnel and periodic training.	A fire services site specific risk assessment will be added to the final Battery Fire Safety Management Plan at later stages of design; the details of the risk assessment will be implemented during construction and operation of the Scheme.

4 Building Regs, Safety Standards and Guidelines

4.1 General

4.1.1 This Outline Battery Fire Safety Management Plan will be kept up-to-date by the Operations and Maintenance company that is awarded the contract for maintaining the Scheme and which will be contractually required to produce a revised version of the Battery Fire Safety Management Plan, if relevant legislation / guidance is introduced that triggers a change to the Battery Fire Safety Management Plan, or if there is a change to the Scheme (development or process) itself.

4.2 Building Regulations

4.2.1 The relevant building regulations includes BS 9999 'Fire safety in the design, management and use of buildings, Code of practice'. This has been considered in the preparation of this Outline Battery Fire Safety Management Plan.

4.3 Safety Standards

4.3.1 The minimum safety standards proposed by this Outline Battery Fire Safety Management Plan for this Scheme have been divided into group categories shown in Table 4. This list is non-exhaustive and based on experience from other projects of a similar nature for life safety purposes. These safety standards will be confirmed in the final Battery Fire Safety Management Plan, which will be submitted for approval to the relevant planning authorities, and will be updated during the project lifecycle.

Table 4: Applicable Safety Standards

Group Category	Standard	Year	Description
Electrical Installation	BS 7671	2018	Requirements for electrical installations. Institute of Engineering and Technology (IET) wiring regulations.
Fire Detection and Alarm	BS EN 54	-	All parts.
	BS 5839-1	2017	Fire detection and fire alarm systems for buildings. Code of practice for design, installation, commissioning and maintenance of systems in non-domestic premises.
	BS 6266	2011	Fire protection for electronic equipment installations.
	BS EN 60079-29-3	2014	Part 29-3. Gas detectors. Guidance on functional safety of fixed gas detection systems.
Firefighting	BS 9990	2015	Non automatic firefighting systems in buildings. Code of practice.
Automatic Fire Protection	BS 5306-0	2020	Fire protection installations and equipment on premises. Guide for selection, use and application of fixed firefighting systems and other types of fire equipment.
	BS EN 12845	2015	Fixed firefighting systems. Automatic sprinkler systems. Design, installation and maintenance.
	BS EN 14972-1	2020	Fixed firefighting system. Water mist Systems. Design, installation, inspection and maintenance.
Product Safety General	BS EN 62619	2017	Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for

Group Category	Standard	Year	Description
			secondary lithium cells and batteries, for use in industrial applications.
Product Safety Inverters	BS EN 62109-1	2010	Safety of power converters for use in photovoltaic power systems. General requirements.
	BS EN 62109-2	2011	Safety of power converters for use in photovoltaic power systems. Particular requirements for inverters.
	BS EN 62477-1	2012	Safety requirements for power electronic converter systems and equipment. General.
	BS EN IEC 62368-1	2020	Audio / video, information and communication technology equipment. Safety requirements.
Product Safety EMC	BS EN IEC 61000-6-1	2019	Electromagnetic compatibility (EMC). Generic standards. Immunity for residential, commercial and light-industrial environments.
	BS EN 61000-6-3	2007	Electromagnetic compatibility (EMC). Generic standards. Emission standard for residential, commercial and light-industrial environments.
Energy Storage Systems	BS EN IEC 62933-1		Electric Energy Storage (EES) systems. Part 1. Vocabulary.
	BS EN IEC 62933-2-1	2018	Electrical Energy Storage (EES) systems. Part 2-1 Unit parameters and testing methods – General specification.
	BS EN IEC 62933-5-2	2020	Electrical Energy Storage (EES) systems. Part 5-2 Safety requirements for grid integrated EES systems. Electrochemical-based systems.
Transport	BS EN IEC 62281	2019	Safety of primary and secondary lithium cells and batteries during transport.

4.4 Guidelines and Recommendations

4.4.1 The proposed guidelines and recommendations for the Fire Safety of the BESS's on this Scheme have been divided into group categories as shown in Table 5. This list is non-exhaustive and based on experience from other projects of a similar nature for property protection purposes. Furthermore, the requirements listed in the documents below are supplementary and not prescriptive code requirements for the Scheme.

Table 5: Safety Guidance and Recommendation

Group Category	Document No.	Year	Description
Firefighting	-	2007	Water UK National Guidance Document on the Provision of Water for Firefighting.
Product Safety General	RC61 (RiscAuthority)	2014	Recommendations for the storage, handling and use of batteries. Published by the FPA.
	RC62 (RiscAuthority)	2016	Recommendations for fire safety with photovoltaic panel installations. Published by the FPA.
Energy Storage Systems	10209302-HOU-R-01	2020	DNV GL McMicken Battery Energy Storage System Event Technical Analysis and Recommendations.
	OAPUS301WIKO	2017	DNV GL Considerations for ESS Fire Safety
	DNVGL-RP-0043	2017	DNV GL Recommended Practice: Safety, Operation and Performance of Grid-connected Energy Storage Systems
	FM DS 5-33	2020	FM Global Datasheet. Electrical Energy Storage Systems.

Group Category	Document No.	Year	Description
	NFPA 855	2020	Standard for the Installation of Stationary Energy Storage Systems.

5 Risk Assessment

5.1 General

5.1.1 This section details the proposed methods used to mitigate the potential risk of a fire event leading to the spread of heat and uncontrolled fire with associated emissions through the Scheme lifecycle.

5.1.2 The Scheme will minimise fire risk using safety features that are becoming well-established within the industry, and these features will be applied throughout the Scheme lifecycle. Many of the features focus on the cell level fire hazards. Regardless of the size, the safety of Li-ion batteries is intrinsically related with the safety at the cell level where several phenomena can occur at cell level, such as chemical imbalance or internal short-circuit, resulting in failures.

5.1.3 In order to mitigate these risks, the following steps have been taken from the STABALID project (Ref. 13) and adapted to suit the Scheme to address life safety and property protection requirements:

a. Risk Identification - Identification of the risks that may appear in each stage of the battery life cycle.

b. Risk Evaluation - Qualitative evaluation of the risks that may appear in each stage of the battery life cycle.

c. Mitigation Measures - Safety measures to mitigate the risks identified.

d. Risk Re-evaluation - Qualitative evaluation of the risks that may appear in each stage of the battery life cycle because of the mitigation measures being implemented.

5.1.4 Further detail regarding these steps are presented in Sections 5.2 to 6.

5.1.5 The first stage of the risk analysis is the identification of all the fire hazards that may arise during the life cycle of the battery (Ref. 13). After analysing all the hazards (orange shapes), they were separated into seven main categories (blue shapes), as shown in Figure 1.

5.1.6 In the next (risk evaluation) step of the risk control process, this Outline Battery Fire Safety Management Plan considers the fire events further.

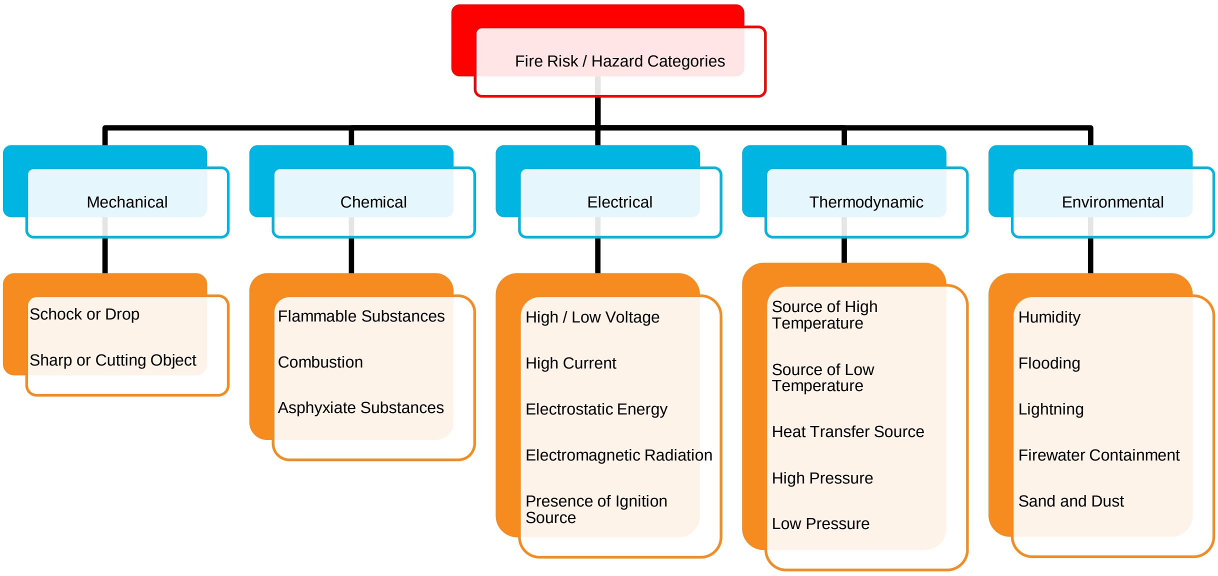


Figure 1: Risks and Hazards Considered (Ref. 13)

5.2 Risk Evaluation

5.2.1 The second stage of the risk control process is to break down the hazards identified into the different phases of the battery life cycle. The stages considered are presented in Figure 2. For the purpose of this work, the risks of the transportation / removal, periodic inspection / maintenance, and installation / decommissioning are considered similar in nature as the activities in these stages.

5.2.2 The hazards previously identified in Figure 1 are mapped to the different stages of the battery life cycle of Figure 2. The same hazard may therefore appear in different stages of the battery life cycle. The results of this mapping process are presented for fire events in tables (one for each life-cycle process stage) in the following sections (Sections 5.3 to 5.6).

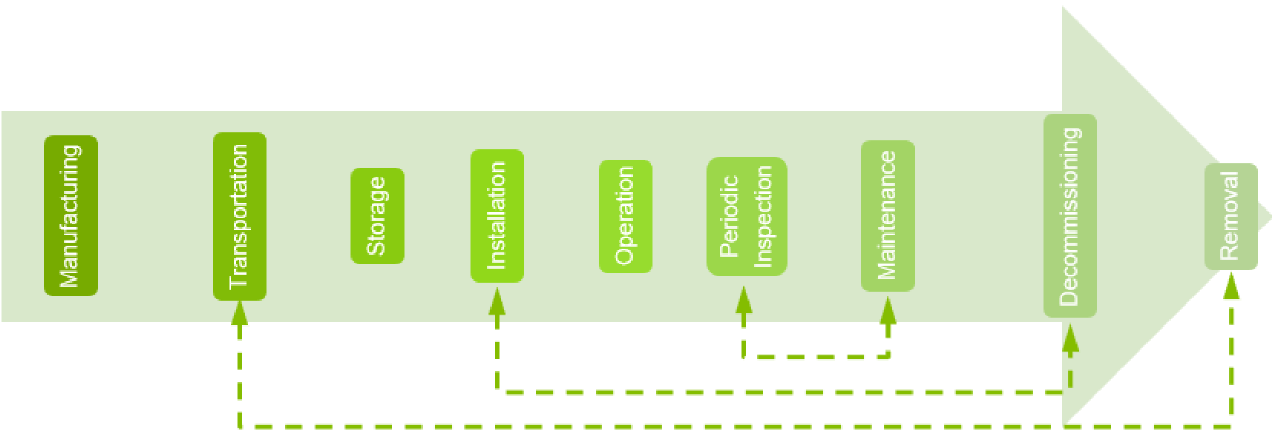


Figure 2: Stages of Battery Life Considered (Ref. 13)

5.2.3 The following step in the risk control process is to evaluate the risks. This is done by describing and characterising the risk, as described by the following bullet points, and illustrated in Figure 3 and Figure 4) and presented for fire events in detail for each lifecycle stage in the subsequent sub-sections of this Outline Battery Fire Safety Management Plan (Section 5.3).

a. **Hazard** – something that is dangerous and likely to cause any kind of damage.

b. **Element** – specific part or item that may cause or be exposed to damage.

c. **Cause** – Origin of the failure that may cause damage to people / equipment in the nearby surrounding area or to the battery element itself.

d. **Dangerous Occurrence** – An action or circumstance that may lead to an undesirable event.

e. **Undesirable Event** – The result of a dangerous occurrence and a dangerous situation.

f. **Probability** – The probability level of the undesirable event occurring. Refer to Figure 3.

g. **Severity** – The severity level of the undesirable event. Refer to Figure 3.

h. **Risk Rating** – The residual risk remaining when applying the risk probability and risk severity of an undesirable event. Refer to Figure 4.

i. **Risk Mitigation Methods** – Action(s) designed to eliminate, reduce of control the impact of the identified risks. The identifier used is RMM and referenced in Table 11.

Probability	Severity				
	5 - Catastrophic	4 – Critical	3 – Major	2 – Moderate	1 - Minor
5 – Frequent	25	20	15	10	5
4 – Probable	20	16	12	8	4
3 – Occasional	15	12	9	6	3
2 – Remote	10	8	6	4	2
1 - Improbable	5	4	3	2	1

Figure 3: Risk Probability and Severity Matrix (Ref. 14)

Risk Rating (Probability x Severity)
1 to 4 (Low)
5 to 9 (Medium)
10 to 25 (High)

Figure 4: Risk Rating Scoring (Ref. 14)

5.2.4 Table 6 to Table 10 present the identified fire event risks for each project stage, along with the proposed risk mitigation method identification number (further described in Section 6).

5.3 Manufacturing Stage

5.3.1 Li-ion batteries are slowly becoming a more significant and important technology regarding energy storage solutions. In this context, adequate safety performances in addition to an extended life cycle are key factors that shall be considered by the manufacturers. An appropriate design and manufacturing process of the cells/modules and their incorporation into flexible storage systems, that can be rapidly deployed in the grid, are essential to meet customer's exact power and energy requirements. Failures during assembling, due to technical or human nature, can damage or influence the future performance of the battery.

5.3.2 At the assembly line, visible and detectable defects, such as dropped, or physically damaged modules shall be immediately replaced. There are several possible defects during cell manufacturing that may escape this visual inspection such as contaminants introduction, electrode defects, components misalignment or welding defects. To deal and mitigate these defects several manufacturing quality control techniques must be applied including undertaking reliability tests (such as charge/discharge cycles, resistance measurements or X-ray) to ensure that the equipment is distributed without damage or defects as this could lead to internal short circuits or battery fires at a later stage.

5.3.3 The manufacturer shall ensure that fire tests for their assembled racks of modules reflect the same installed condition (i.e. within a predefined space) to assess conditions such as a flash over, heat radiation, etc. (Ref. 13).

Table 6: Manufacturing Stage Hazard and Risk Mitigations (Ref. 13)

Hazard and Risk Identification							Pre-mitigation Assessment				Post-mitigation Assessment		
Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Probability	Severity	Risk Rating	Risk Mitigation Methods	Probability	Severity	Risk Rating
1	Cell internal short- circuit during control process (charge)	Cell	Cell contamination	Thermal runaway	Incorrect quality evaluation	Toxic gas release / Fire	2	3	6	RMM02	1	3	3

5.4 Transportation and Removal Stages

5.4.1 Transportation and removal should be neutral stages for the Li-ion batteries, in the sense that transportation/removal means moving the battery from the factory to the location where it is going to be installed and from here to somewhere else. These stages will be carried out by trained personnel with the adequate equipment to maintain the original characteristics of the batteries. Safety regulations and supervision during these phases are essential procedures to maintain the safety conditions. The most common procedures for moving the battery enclosure are road and sea transportation. The latter is more commonly used for long distance journeys.

Table 7: Transportation and Removal Stages Hazard and Risk Mitigations (Ref. 13)

Hazard and Risk Identification							Pre-mitigation Assessment				Post-mitigation Assessment		
Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Probability	Severity	Risk Rating	Risk Mitigation Methods	Probability	Severity	Risk Rating
1	Flammable substances	Cell	Electrolyte leakage and inflammation	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM04 RMM05	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
2	High temperature or Heat transfer source	Cell	Thermal Runaway (the cell can reach thermal runaway in case of abnormal conditions such as: cell over charge, charge after an over discharge, external short circuit on cell/module, internal short circuit on cell/module, etc.)	Battery fire	People in proximity	Burns / loss of life	3	4	12	RMM01 RMM02	1	4	4
					Equipment in proximity	Fire propagation	3	4	12		1	4	4

Hazard and Risk Identification							Pre-mitigation Assessment			Risk Mitigation Methods	Post-mitigation Assessment		
Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Probability	Severity	Risk Rating		Probability	Severity	Risk Rating
		Battery System, Module or Cell	High temperature induced by the environment (fire, external heat source) or heat radiation coming from the external environment	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01 RMM07	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	3
3	Shock or drop	Module or Cell	Shock against a heavy object or drop	Battery fire	Equipment in proximity	Fire propagation	3	4	12	RMM01	1	4	4
4	Sharp or cutting objects	Module or Cell	Impact against a heavy object	Battery fire	Equipment in proximity	Fire propagation	3	4	12	RMM01	1	4	4

5.5 Storage Stage

5.5.1 The storage of the battery prior to installation, as considered in the risk analysis, is the act of keeping the battery in a specific place for use in the future. Thus, the storage phase occurs at different times of the battery life cycle. The battery can be stored on the manufacturer site waiting to be transported by road or ship, on the harbour waiting to be boarded on a ship or on the client site, waiting to be installed and put in operation. The storage sites shall be safe places with restricted access to reduce the probability of shock or other external aggression occurrence. It is also important to assure that during the storage phase the temperature of the environment external to the battery system and modules is lower than the maximum recommended by the manufacturer.

Table 8: Storage Stage Hazard and Risk Mitigation (Ref. 13)

Hazard and Risk Identification							Pre-mitigation Assessment			Risk Mitigation Methods	Post-mitigation Assessment		
Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Probability	Severity	Risk Rating		Probability	Severity	Risk Rating
1	Flammable substances	Cell	Electrolyte leakage and inflammation	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM04 RMM05	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
2	High current	Rack	High current delivered by the battery system	High current	People in contact with the battery	Electrical shock	4	2	8	RMM06	2	2	4
3	High temperature or Heat transfer source	Cell	Thermal Runaway (the cell can reach thermal runaway in case of abnormal conditions such as: cell over charge, charge after an over discharge, external short circuit on cell/module, internal short circuit on cell/module, etc.)	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01 RMM02	1	3	3
					Equipment in proximity	Fire propagation	3	4	12		2	4	8
		Battery system, module or cell	High temperature induced by the environment (fire, external heat source) or heat radiation coming from the external environment	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01 RMM07	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		2	2	4
4	High pressure	Cell		Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01	1	3	3

Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Pre-mitigation Assessment: Probability	Pre-mitigation Assessment: Severity	Pre-mitigation Assessment: Risk Rating	Risk Mitigation Methods	Post-mitigation Assessment: Probability	Post-mitigation Assessment: Severity	Post-mitigation Assessment: Risk Rating
			Thermal Runaway (the cell can reach thermal runaway in case of abnormal conditions such as: cell over charge, charge after an over discharge, external short circuit on cell/module, internal short circuit on cell/module, etc.)		Equipment in proximity	Fire propagation	2	4	8		1	3	3
5	Shock or drop	Battery system, module or cell	Shock against a heavy object	Battery fire	People in proximity	Burns / loss of life	4	3	12	RMM01 RMM06	2	3	6
					Equipment in proximity	Fire propagation	4	4	16		2	4	8
6	Sharp or cutting objects	Battery system, module or cell	Impact against a heavy object	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01	1	3	3
					Equipment in proximity	Fire propagation	3	4	12		2	4	8
7	High voltage	Module or cell	During storage of modules, as spare parts, some charge could be done. Failure in charger or not appropriate charger.	Module fire	People in proximity	Burns / loss of life	3	3	9	RMM01 RMM06 RMM09	1	3	3
					Equipment in proximity	Fire propagation	3	4	12		2	4	8
8	High current	Module or cell	During storage of modules, as spare parts, some charge could be done. Failure in charger or not appropriate charger.	Module fire	People in proximity	Burns / loss of life	3	3	9	RMM01 RMM09	1	3	3

5.6 Installation and Decommissioning Stages

5.6.1 It is very important to collect information and specifications from the manufacturer so that the batteries selected can meet the required performance without unexpected reactions or limitations. At this point, the batteries characteristics must meet, without reservations, the customer requirements since the installation stage precedes the operational phase where it is expected that the selected storage solution will attend its purpose. Correct connections, proper protections, sustained by technical supervision should be the main concerns at the installation stage, as well as at decommissioning stage since this is basically the opposite of the installation. The risks during decommissioning are the same in nature as the installation phase.

Table 9: Installation and Decommissioning Stages Hazard and Risk Mitigations (Ref. 13)

Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Pre-mitigation Assessment: Probability	Pre-mitigation Assessment: Severity	Pre-mitigation Assessment: Risk Rating	Risk Mitigation Methods	Post-mitigation Assessment: Probability	Post-mitigation Assessment: Severity	Post-mitigation Assessment: Risk Rating
1	Flammable substances	Cell	Electrolyte leakage and inflammation	Battery fire	People in proximity	Burns loss of life	2	3	6	RMM04 RMM05	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
2		Cell		Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01	1	3	3

Hazard and Risk Identification							Pre-mitigation Assessment				Post-mitigation Assessment		
Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Probability	Severity	Risk Rating	Risk Mitigation Methods	Probability	Severity	Risk Rating
	High temperature or Heat transfer source		Thermal Runaway (the cell can reach thermal runaway in case of abnormal conditions such as: cell over charge, charge after an over discharge, external short circuit on cell/module, internal short circuit on cell/module, etc.)		Equipment in proximity	Fire propagation	3	4	12	RMM02 RMM06	2	3	6
		Battery system, module or cells	High temperature induced by the environment (fire, external heat source) or heat radiation coming from the external environment	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01 RMM07	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
3	High pressure	Cell	Thermal Runaway (the cell can reach thermal runaway in case of abnormal conditions such as: cell over charge, charge after an over discharge, external short circuit on cell/module, internal short circuit on cell/module, etc.)	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01 RMM06	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
4	Shock or drop	Battery system, module or cell	Shock against a heavy object	Battery fire	People in proximity	Burns / loss of life	4	3	12	RMM01 RMM06	2	2	4
					Equipment in proximity	Fire propagation	4	4	16		2	3	6
5	Sharp or cutting objects	Battery system, module or cell	Impact against a heavy object	Battery fire	People in proximity	Burns / loss of life	4	3	12	RMM01	2	2	4
					Equipment in proximity	Fire propagation	4	4	16	RMM06	2	3	6

5.7 Operation Stage

5.7.1 Large stationary Li-ion batteries are required to deal with unexpected power fluctuation in the electricity grid. Therefore, a safe and continuous service is expected from this kind of asset. The operation phase starts from the moment when the battery system is fully integrated in the electricity grid and all procedures related with its installation are concluded.

Table 10: Operation Stage Hazard and Risk Mitigations (Ref. 13)

Hazard and Risk Identification							Pre-mitigation Assessment				Post-mitigation Assessment		
Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Probability	Severity	Risk Rating	Risk Mitigation Methods	Probability	Severity	Risk Rating
1	Flammable substances	Cell	Electrolyte leakage and inflammation	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM04 RMM05	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
2		Module or cell		Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01	1	3	3

Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Pre-mitigation Assessment: Probability	Pre-mitigation Assessment: Severity	Pre-mitigation Assessment: Risk Rating	Risk Mitigation Methods	Post-mitigation Assessment: Probability	Post-mitigation Assessment: Severity	Post-mitigation Assessment: Risk Rating
	High temperature or Heat transfer source		Thermal Runaway (the cell can reach thermal runaway in case of abnormal conditions such as: cell over charge, charge after an over discharge, external short circuit on cell/module, internal short circuit on cell/module, etc.)		Equipment in proximity	Fire propagation	3	4	12	RMM02 RMM06	2	3	6
		Battery system, module or cells	High temperature induced by the environment (fire, external heat source) or heat radiation coming from the external environment	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01	2	3	6
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
3	High pressure	Cell	as: cell over charge, charge after an over discharge, external short circuit on cell/module, internal short circuit on cell/module, etc.)	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
		BESS enclosure	Thermal runaway propagation inside the BESS enclosure or operation of gaseous fire extinguishing system	Pressure rise in the container due to fire propagation or gaseous fire extinguishant release	-	BESS enclosure over pressure	1	4	4	RMM22	1	4	4
4	Overheat	Cell	Bad Connections, fault in cell	Battery fire	People in proximity	Burns / loss of life	4	3	12	RMM01 RMM10	2	3	6
					Equipment in proximity	Fire propagation	4	4	16		2	3	6
		Battery system	Bad battery cooling, high number of cycling or failure of the heating / cooling system	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01 RMM13 RMM21	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
5	Over charge	Cell	Failure in Battery Management	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01 RMM11	2	3	6
					Equipment in proximity	Fire propagation	4	4	16		2	3	6
6	Forced discharge or recharge of an over discharged cell	Module or cell	Failure in Battery Management	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01 RMM12	2	3	6
					Equipment in proximity	Fire propagation	3	4	12		1	4	4
7	Internal short circuit	Cell	Production failure that results in internal short circuit with possible thermal runaway	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01 RMM02	1	3	3
					Equipment in proximity	Fire propagation	3	4	12		1	4	4
		Module	Module internal short circuit (equivalent to a cell external short)	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01	1	3	3
					Equipment in proximity	Fire propagation	3	4	12	RMM03 RMM08	2	4	8
		Rack	Rack internal short circuit is equivalent to a module external short	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01 RMM08 RMM14	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
		Battery system		Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01	1	3	3

Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Pre-mitigation Probability	Pre-mitigation Severity	Pre-mitigation Risk Rating	Risk Mitigation Methods	Post-mitigation Probability	Post-mitigation Severity	Post-mitigation Risk Rating
			A battery system internal short is equivalent to a module external or internal short or a rack external or internal short		Equipment in proximity	Fire propagation	2	4	8	RMM08 RMM14	1	4	4
8	External short circuit	Cell	Bus bar or another electronic component in short circuit	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01 RMM03 RMM08	1	3	3
					Equipment in proximity	Fire propagation	3	4	12		2	4	8
		Module	External short circuit between one or several modules caused by bad assembly or short circuit on bus bar	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01 RMM08 RMM14	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
			Bad assembly or a short circuit on the Battery Management Module	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01 RMM08. RMM14	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
9	Fire propagation in the BESS enclosure	Battery system	Thermal Runaway (the cell can reach thermal runaway in case of abnormal conditions such as: cell over charge, charge after an over discharge, external short circuit on cell/module, internal short circuit on cell/module, etc.)	Battery fire or explosion	People in proximity	Burns / loss of life	3	4	12	RMM17 RMM18 RMM19	2	4	8
					Equipment in proximity	Fire propagation	3	4	12		2	4	8
			Automatic suppression system failure	Battery fire	People in proximity	Burns / loss of life	1	3	3	RMM01	1	3	3
					Equipment in proximity	Fire propagation	1	4	4		1	4	4
10	Shock or drop	Battery system	Shock against a heavy object of a module/cell during operation phase (human error)	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01	1	3	3
					Equipment in proximity	Fire propagation	3	4	12		2	4	8
11	Sharp or cutting objects	Battery system	Shock against a sharp object	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01 RMM06	1	3	3
					Equipment in proximity	Fire propagation	3	4	12		2	4	8
12	High voltage	Battery system	High voltage from external or failure in charger	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM11 RMM01 RMM06	2	3	6
					Equipment in proximity	Fire propagation	3	4	12		1	4	4
13	High current	Battery system	High current from external or failure in charger or an external short circuit or overload	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM14 RMM01 RMM06	2	3	6
					Equipment in proximity	Fire propagation	3	4	12		1	4	4
14	Electromagnetic radiation	Electronic board	Electromagnetic from surrounding environment or external sources	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM11 RMM01 RMM06	1	3	3
					Equipment in proximity	Fire propagation	3	4	12		1	4	4
15	Sand and dust	BESS enclosure		Battery fire	People in proximity	Burns / loss of life	3	2	6	RMM20	2	2	4

Hazard and Risk Identification							Pre-mitigation Assessment			Risk Mitigation Methods	Post-mitigation Assessment		
Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Probability	Severity	Risk Rating		Probability	Severity	Risk Rating
			Dust particles, due to rural location, entering the BESS container and causing short circuit		Equipment in proximity	Fire propagation	3	2	6		2	2	4
16	Lightning	Battery system	High current can damage the electronic components	Battery fire	Equipment in proximity	Fire propagation	3	4	12	RMM01	2	4	8
17	Firewater containment	BESS enclosure	Manual firefighting operations by fire and rescue services	Environment contamination	-	Environment contamination	5	4	20	RMM15	3	3	9
18	Insufficient access	Fire rescue service access	Delayed attendance of fire rescue services	Uncontrolled fire	People in proximity	Burns / loss of life	3	4	12	RMM24	2	4	8
					Equipment in proximity	Fire propagation	3	4	12		2	4	8
19	Water ingress in BESS container from flooding following heavy rain fall	Battery system, module or cell	Short circuit of battery system	Battery fire	People in proximity	Burns / loss of life	3	2	6	RMM20	2	2	4
					Equipment in proximity	Fire propagation	3	2	6		2	2	4
20	Explosion originating from inside BESS enclosure	BESS enclosure	Accumulating hazardous gas	Explosion and fire	People in proximity	Burns / loss of life	3	4	12	RMM23	2	4	8
					Equipment in proximity	Fire propagation	3	4	12		2	4	8

5.8 Maintenance and Inspection Stages

5.8.1 Periodic inspection and maintenance require careful considerations to ensure that the return to the operational stage occurs as planned. The personnel involved in these stages will be trained and technically prepared to successfully perform inspection and maintenance tasks. Also, machinery and utilities used during inspection and maintenance must not damage the battery modules and the manoeuvres performed must not affect the module integrity as well as the neighbouring equipment. Periodic inspection will be performed to ensure that the battery modules are operating as expected. The evaluation will be performed by trained personnel, without compromising the normal operation of the modules. It is performed with specified time intervals, depending on the operator planning. This process typically consists in several visual and physical inspections executed according to a pre-set schedule. The maintenance stage consists in replacing or adjusting pre-selected components that failed or are potential targets for failure. The removal of the pre-selected elements must not compromise or damage other components. Safety procedures and technical supervision are crucial at this stage.

Table 11: Maintenance and Inspections Stages Hazard and Risk Mitigations (Ref. 13)

Hazard and Risk Identification							Pre-mitigation Assessment			Risk Mitigation Methods	Post-mitigation Assessment		
Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Probability	Severity	Risk Rating		Probability	Severity	Risk Rating
1	Flammable substances	Cell	Electrolyte leakage and inflammation	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM04 RMM05	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
2	High temperature or Heat transfer source	Cell	Thermal Runaway (the cell can reach thermal runaway in case of abnormal conditions such as: cell over charge, charge after an over discharge, external short circuit on cell/module, internal short circuit on cell/module, etc.)	Battery fire	People in proximity	Burns / loss of life	3	3	9	RMM01 RMM02 RMM06	1	3	3
					Equipment in proximity	Fire propagation	3	4	12		2	4	8

Hazard and Risk Identification							Pre-mitigation Assessment				Post-mitigation Assessment		
Item	Hazard	Element	Cause	Dangerous Occurrence	Dangerous Situation	Undesirable Event	Probability	Severity	Risk Rating	Risk Mitigation Methods	Probability	Severity	Risk Rating
		Battery System, Module or Cells	High temperature induced by the environment (fire, external heat source) or heat radiation coming from external environment	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01 RMM07	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
3	High pressure	Cell	Thermal Runaway (the cell can reach thermal runaway in case of abnormal conditions such as: cell over charge, charge after an over discharge, external short circuit on cell/module, internal short circuit on cell/module, etc.)	Battery fire	People in proximity	Burns / loss of life	2	3	6	RMM01 RMM06	1	3	3
					Equipment in proximity	Fire propagation	2	4	8		1	4	4
4	Shock or Drop	Battery System, Module or Cell	Shock against a heavy object	Battery fire	People in proximity	Burns / loss of life	4	3	12	RMM01 RMM06	2	3	6
					Equipment in proximity	Fire propagation	4	4	16		2	4	8
5	Sharp or cutting objects	Battery System, Module or Cell	Impact against a heavy object	Battery fire	People in proximity	Burns / loss of life	4	3	12	RMM01 RMM06	2	3	6
					Equipment in proximity	Fire propagation	4	4	16		2	4	8

6 Mitigation and Control Measures

6.1 General

6.1.1 This section details the possible methods used to mitigate the potential residual risks of fire event leading to the spread of heat and uncontrolled fire with associated emissions through the project cycle. The Scheme will minimise fire risk using life safety features that are listed minimum code requirements as well as recommended industry practice (property protection) throughout the project lifecycle. The priority of the risk mitigation approach must be:

a. Inherently fire safety design measures.

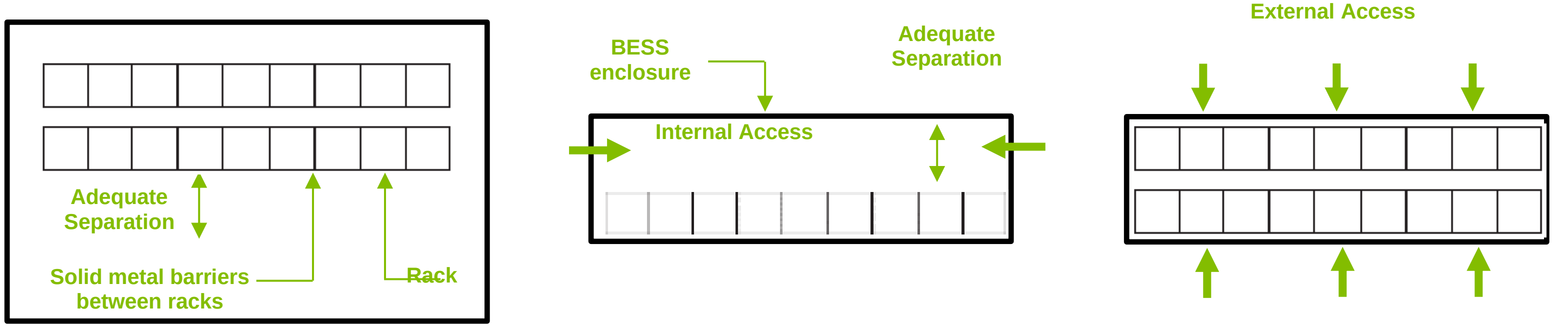
b. Guards and protective devices such as BESS disconnection and shutdown controls.

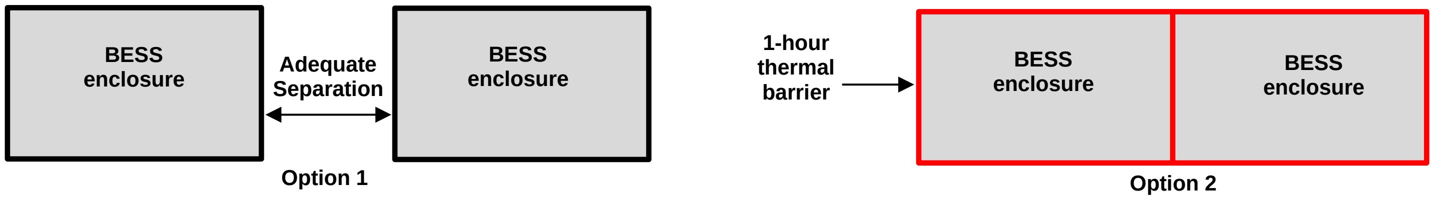
c. Information and training for end users.

6.1.2 The mitigation measures for the hazards and risks proposed by this Outline Battery Fire Safety Management Plan, along with the person responsible for providing the mitigation, is shown in Table 12.

Table 12: Proposed List of Risk Mitigation Methods (Ref. 13)

Risk Mitigation Method	Description	Action
RMM01	Implement thermal barriers between cells or provide adequate separation to limit propagation within battery module during thermal runaway. Implement thermal barriers between battery modules or provide adequate separation to limit fire contamination outside the battery modules. The module construction and assembly shall be solid to minimise internal damage arising from drop or shock. Provide thermal barriers to separate switchgear and battery module areas within BESS enclosure in accordance with FM Global Datasheet 5-33. Racks within the BESS enclosure shall be installed either in single row or double row arrangements with racks back to back. Each rack will be separated by non-combustible thermal barriers to prevent heat transfer. Racks will also have adequate separation from the perimeter walls and between the aisle faces of adjacent racks.	Manufacturer

<table>
<tr><th>Risk Mitigation Method</th><th>Description</th><th>Action</th></tr>
<tr><td></td><td>

Each BESS enclosure will be over the 46.5 m² threshold stated in FM Global Datasheet 5-33 and will therefore be treated as individual buildings having non-combustible walls, floor and ceiling. Separation distances between BESS enclosures will be determined in accordance with FM Global Datasheet 5-33 for Electrical Energy Storage Systems.
If the separation distances can't be maintained, thermal barriers shall be provided in accordance with FM Global Datasheet 1-21 for Fire Resistance of Building Assemblies. This will allow containers to be located directly next to each other. Cable and pipe penetrations into each BESS enclosure will be sealed and provided with rating equal to that required for the BESS enclosure.

</td><td></td></tr>
<tr><td>RMM02</td><td>Protective devices and electric circuits shall be rated in accordance with the safety requirements of BS EN IEC 62933-5 to protect electric circuits against short-circuits.</td><td>Manufacturer</td></tr>
<tr><td>RMM03</td><td>Use an electronic board design which avoids fire contamination on cell in case of short circuit on the board.</td><td>Manufacturer</td></tr>
<tr><td>RMM04</td><td>Find out, according to the empty space existing in the battery container, the air leak and nature of gas generated, the acceptability of the substances released in case or thermal runway, venting or leaking cell. Calculate the maximum number of cells below which the concentration of flammable substances is not hazardous.</td><td>Manufacturer</td></tr>
</table>

Risk Mitigation Method	Description	Action
RMM05	The cell size must be enough to create enough air renewal and stay below the hazardous concentration of flammable substances threshold.	Manufacturer
RMM06	The maintenance and installation operators must be qualified, strictly follow the maintenance and installation protocols and wear individual protective equipment.	Developer Installer Operator
RMM07	The maximum allowable operating temperature set by the manufacturer must be higher than the highest anticipated temperature of the environment internal external to the battery system and modules.	Installer
RMM08	During assembling phases (cells and modules) verify if each connection is correct.	Manufacturer
RMM09	Strictly follow the maintenance and user manuals.	Operator
RMM10	Implement an electronic protection against cell overheat. High cell temperature trip will isolate the module or rack when detecting cell temperatures that exceed limits. Thermal runaway trip will isolate the battery system when a cell is detected to have entered a thermal runaway condition. Rack switch fail-to-trip will disconnect the rack if any failure is detected. Inverter / charger fail-to-trip will isolate the BESS enclosure at the breaker if the inverter / charger fails to respond to a trip command.	Manufacturer
RMM11	Implement an electronic protection against overcharge on cell (to stop charge/discharge if a cell reaches the maximum voltage value).	Manufacturer
RMM12	Implement an electronic protection against cell charge after an over discharge.	Manufacturer
RMM13	Implement on the battery an electronic protection against overheating on battery which may lead to a battery fire or thermal runaway. The electronic protection will consist of high cell temperature trip which will isolate the module or rack when detecting cell temperatures that exceed limits. A thermal runaway trip will isolate the battery system when a cell is detected to have entered a thermal runaway condition. Rack switch fail-to-trip will disconnect the rack if any failure is detected. Inverter / charger fail-to-trip will isolate the BESS enclosure at the breaker if the inverter / charger fails to respond to a trip command. This will provide additional layers of protection.	Manufacturer
RMM14	Implement on the battery an electronic and electrical protection against short circuit and overload to avoid fires.	Manufacturer
RMM15	Each BESS enclosure will be provided with a sump and drain valve to allow extraction of contaminated fire water and / or electrolyte spill without having to open the door of the enclosure and will prevent contamination of surrounding environment with the extracted liquid being taken off site for treatment (Ref. 15). The sump construction will be designed to allow for chemical resistance of electrolyte which may be released from a battery fire and have capacity to hold the total volume of electrolyte plus a 10% safety factor. The sump will encompass the entire floor area of the BESS enclosure with a mentis grating type floor to allow spilled electrolyte to drain without pooling near other racks. An extra layer of protection will be provided for containment of firewater external of the BESS enclosure in case of rupture or overflow of contaminants. The external floor surface surrounding each BESS container will be lined with an impermeable	Developer Installer

Risk Mitigation Method	Description	Action
	membrane. The drainage strategy will include for bunded holding lagoons within the BESS area which will contain the firewater runoff. The firewater will be tested post incident and if contaminated, will be tinkered off site to a suitable waste facility for treatment. The approach has been discussed and agreed with the Environment Agency.	
RMM17	Install a fire detection and alarm system using coincidence detection in accordance with BS 7273-1 and incorporating aspirating smoke detection and carbon monoxide (CO) detection within the BESS enclosure for early detection of gases produced during off-gassing and prior to thermal runaway. The detection of gases will also allow fire and rescue services to remotely monitor for an explosive atmosphere. Coincidence detection shall be arranged as follows: 1. The EMS for the BESS enclosure will engage the first stage alarm and will close access doors, louvres, shut down ventilation system and BESS electrical installation. 2. The fire detection and alarm system will engage the second stage alarm which will be confirmation of off-gassing. A fire signal will be sent to a monitored location.	Developer Installer
RMM18	The CFRS preferred system for the protection of the BESS containers is a water drenching system. The following two options will be put forward as design options and discussed with the FRSs at detailed design stage: Automatic sprinkler system designed to BS EN 12845 and FM Global Datasheet 5-33 OR Watermist system design to BSEN 149721	Developer Installer

<table>
<tr><th>Risk Mitigation Method</th><th colspan="2">Description</th><th>Action</th></tr>
<tr><td rowspan="3">RMM19</td><td colspan="2">Due to the remote location of the BESS compounds and limited availability and supply of water, the follow options will be considered. For both options, an underground private fire hydrant system will be provided around the site.

<u>Option 1</u>
Two half capacity fire water storage tanks dedicated for firefighting operations only. The additional fire water storage tank will ensure availability and resiliency in the event of a single water storage tank not being available in the case of maintenance and / or impairment.

The water supply for the firefighting operations will be 180m³ based on two jets of 750 l/min operating for a duration of 120 minutes as required by CFRS. It's expected the firefighting operations will limit fire spread beyond a single BESS container. Each of the BESS containers will have their own dedicated water storage tank for the water drenching system operation. Until the choice of water drenching system is confirmed, the most onerous requirement will be used. Therefore, the water supply will be 62.5m³, based on a design density of 12.2mm/min/m³ for a duration of 45 minutes as required by FM Global Datasheet 5-33.

The fire water storage tanks will be remotely monitored and filled with water tankers when the level of water drops. Frost protection measures to the fire water storage tanks shall be provided. The options for the fire water storage tank will be as follows but the siting and number of tanks will be determined at the detailed design stage of the project. The options for the water storage tanks will be as follows.</td><td rowspan="3">Developer
Installer</td></tr>
<tr><td>Two half capacity sectional steel panel tanks
6m (L) x 6m (W) x 3m (H) (97.2m³ effective)

Example of Sectional Steel Panel Tank (Ref. 16)</td><td>Two half capacity cylindrical steel tanks
4.58mØ x 6m (H) + 0.3m (H) concrete base (91.9m³ effective)

Example of Cylindrical Steel Tank (Ref. 17)</td></tr>
<tr><td colspan="2"><u>Option 2</u>
Two half capacity fire water storage tanks for the simultaneous operation of the water drenching system and firefighting operations.</td></tr>
</table>

Risk Mitigation Method	Description	Action
	The water supply for firefighting operations will be 180m³ as calculated in Option 1. The water supply for the water drenching system will be 62.5m³ as calculated in Option 1. Therefore, the total effective fire water storage for simultaneous operation of the water drenching system and firefighting operations will be 242.5m³. The options for the water storage tanks will be as follows. Two half capacity sectional steel panel tanks: 8m (L) x 6m (W) x 3m (H) (129.6m³ effective) Two half capacity cylindrical steel tanks: 5.35mØ x 6m (H) + 0.3m (H) concrete base (124.8m³ effective)	
RMM20	The BESS enclosure shall be installed by third party certified and qualified installer. The BESS enclosure shall be insulated (IP rated) and specified for the relative ambient conditions, to prevent external agents such as dust or water entering the enclosure.	Manufacturer Developer Installer
RMM21	A heating and cooling system will be provided on each BESS enclosure to prevent the battery system experiencing overheating or freezing environments. Additional electric heater may be provided for humidity control. Monitoring will be provided by the EMS. In the event of a heating / cooling failure being detected, the enclosure will be automatically switched into standby mode, preventing the battery modules from charging or discharging, and sending a notification to the maintenance team for action. This reduces the risk of temperature rise within the modules and allows time for a repair to take place on site before the system is restarted. The heating and cooling system will be subject to routing maintenance inspections to ensure the risk of failure is minimised.	Installer Operator
RMM22	The BESS enclosure will be designed to withstand pressure of gaseous fire extinguishing system operation and / or propagation of fire. A pressure relief damper will also be provided.	Manufacturer Developer Installer
RMM23	Permanent operating mechanical ventilation with a rate of at least 0.3 m³/min/m² will be provided with air flow monitoring system and alarm to prevent concentration of hazardous gas. Air flow through the fire rated louvre will be closed automatically by signal from Automatic Fire Detection System (Ref. 2).	Developer Installer
RMM24	Access will be provided for pump appliances to manoeuvre within the Scheme with full access to all BESS enclosures. The structures and enclosures within the Scheme are expected to be lower than 6 m height and high reach appliances will therefore not be required. The access routes will be structurally designed to allow a minimum carrying capacity of 15 tonnes (Ref. 18) for hardstanding of pumping appliances. An alternative site access point shall be provided and maintained to enable pump appliances to approach from an up-wind direction. *Example of Turning Facilities Provided (Ref. 19)*	Developer

7 Conclusion

7.1.1 This Outline Battery Fire Safety Management Plan has demonstrated in a systematic way the mitigation of the fire safety risks posed by the BESS's in the Scheme.

7.1.2 The next step is for further stakeholder consultations to be held to review and agree the plan, or determine actions for further iterations, as required.

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