The Droves Solar Farm

outline Battery Safety Management Plan

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Executive Summary

This **outline Battery Safety Management Plan (oBSMP) [APP/7.14]** is for the proposed Battery Energy Storage System (BESS) installation with ancillary infrastructure which forms part of the application for Development Consent Order (DCO) for the Droves Solar Farm, a Nationally Significant Infrastructure Project (NSIP) located in an area of countryside to the north of Swaffham and southeast of Kings Lynn. It has been developed on behalf of the Droves Solar Farm Limited (the Applicant). Henceforth this site and installation, in this oBSMP, will be referred to as the Scheme, further details of which can be found in **Environmental Statement (ES) Chapter 5: The Scheme [APP/6.1]**.

The aim of this oBSMP is to define the proposed safety strategy, requirements, and processes necessary to meet derived safety objectives and to set a level of safety performance that the installation is to be measured against. These standards are derived from the following sources:

1 Planning Practice Guidance (PPG) for Renewable and Low Carbon Energies (Ref. 1)

2 Fire and Rescue requirements detailed in the National Fire Chiefs Council (NFCC) Report Grid Scale BESS Planning – Guidance for Fire and Rescue Service (FRS) (Ref. 2); and

3 Factory Mutual (FM) Global Loss and Prevention Datasheet 5-33 (Ref. 3) (as cited in the NFCC Report [Ref. 2]).

It also provides the basis for the safety management processes and procedures required to satisfy the identified safety requirements for a BESS system capability. As required by the DCO, prior to the commencement of construction of the BESS, the Applicant must prepare a detailed Battery Safety Management Plan (BSMP) that aligns with the provisions set out within this oBSMP **[APP/7.14]**. As guidance continues to evolve both in the UK and internationally, the Applicant will take into account the latest best practices in battery system failure prevention and detection, consequence modelling, risk analysis, and emergency response planning as part of the detailed BSMP. A preliminary safety hazard identification and analysis have been conducted, based on comparable energy storage systems utilising Lithium Ferrous Phosphate (LFP) battery technology. This has identified the likely hazards and causes associated with this type of BESS and has facilitated the initial identification of potential control measures. When implemented, these measures are expected to reduce the associated risks to an acceptable level. All identified hazards and corresponding mitigations have been documented in the Scheme-specific Hazard Log (HL) (Ref. 4).

It is concluded that, as far as reasonably practicable, the foreseeable hazards associated with the technology proposed have been identified. These will form the initial safety foundation going forward and will be actively managed as the Scheme and installation matures. At this juncture of the programme the selection of the BESS technology to be positioned at the Scheme has yet to be decided.

The design, development, and manufacture of the BESS require the development and maintenance of high standards in respect of safety and operational sustainability. It will be the responsibility of all personnel involved in the future development of the proposed undertaking to strive to reduce the potential for accidents to the lowest practicable level by being 'risk aware' and promoting a supportive safety and environmental culture at all stages of the development. This oBSMP is the starting point from which the Scheme will progress.

It will be essential that the design process is subject to a Design Risk Analysis by a competent person in compliance with the Construction Design and Management (CDM) Regulations 2015 (Ref. 5) prior to construction.

Abbreviations

AC	Alternating Current
ALARP	As Low As Reasonably Practicable
ARC	Abbott Risk Consulting Ltd
BESS	Battery Electrical Storage System
BMS	Battery Management System
BoM	Bill of Materials
BSMP	Battery Safety Management Plan
CCTV	Closed Circuit Television
CDM	Construction Design and Management
CID	Current Interrupt Device
DCO	Development Consent Order
ERP	Emergency Response Plan
FAQs	Frequently Asked Questions
FDSS	Fire Detection and Suppression System
FM	Factory Mutual
FRS	Fire and Rescue Service
HSAWA	Health and Safety at Work Act
HL	Hazard Log
HSE	Health and Safety Executive
LFP	Lithium Ferrous Phosphate
MW	megawatt
NETS	National Electricity Transmission System
NFCC	National Fire Chiefs Council
NFPA	National Fire Prevention Association
NMC	nickel manganese cobalt
NSIP	Nationally Significant Infrastructure Project
oBSMP	outline Battery Safety Management Plan

PCIP	Preconstruction Information Plan
PPG	Planning Practice Guidance
PTC	Positive Thermal Coefficient
PV	photovoltaic
R2P2	Reducing Risk, Protecting People
SME	Subject Matter Expert
UK	United Kingdom
UL	Underwriters Laboratory
UN	United Nations

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1 oBSMP Purpose

1.1 Introduction

1.1.1 This oBSMP has been prepared on behalf of The Droves Solar Farm Limited ('the Applicant') in relation to the DCO Application for the construction, operation, maintenance, and decommissioning of The Droves Solar Farm (hereafter referred to as the 'Scheme).

1.2 Aim

1.2.1 The aim of this oBSMP is to outline the safety management approach that will be adopted for the Droves Solar Farm (the Scheme) located in an area of countryside to the north of Swaffham and southeast of Kings Lynn. Furthermore, the overall BESS safety aim is that the levels of risk of accident, death or injury to personnel or other parties, and to the environment due to BESS activities are to be mitigated and managed as far as possible through diligent development, design, construction, and operational control measures. In accordance with the Health and Safety Executive (HSE) Reducing Risk, Protecting People (R2P2) – Guidance (Ref. 6), the BESS development should aim to reduce risks to 'As Low As Reasonably Practicable' (ALARP).

1.3 Scope

1.3.1 The scope of this report is for the BESS capability at the Scheme, covering the physical and functional aspects of the equipment. The BESS safety management will cover design, validation, siting, operation, fire strategy and emergency response, and removal from site (decommissioning). It will also include any remote monitoring and control, maintenance, storage / transportation, and calibration.

1.4 Context

1.4.1 This oBSMP has been developed by the role of the Safety Subject Matter Expert (SME) and aims to identify the safety requirements (and any additional derived safety requirements) such that the Scheme can be assessed against a common benchmark, criteria set and safety targets.

1.4.2 This BESS oBSMP has been developed at this early planning stage with the Applicant to identify and assess the potential risks associated with the BESS design, installation, and operating capability, and to provide a robust safety argument, supported by evidence, prior to full commissioning. It is proposed that the safety programme will develop following three phases, reflecting the maturity of the programme:

1 **oBSMP (Planning)** – informs on how safety management is to be conducted. The oBSMP:

   a. Outlines the processes, procedures and means by which the BESS safety management is to be conducted, implemented, and assessed, such that the BESS design and development, initial construction, and operational safety performance can be conducted with an acceptable level of residual risk;

   b. Provides the criteria and targets against which the installation will be assessed;

   c. Provides the initial compliance status against key requirements contained in the PPG (Ref. 1) (and referenced guidance); and

   d. Identifies the generic hazards associated with BESS installations of this type and tabulate these in the supporting HL (Ref. 4).

2 **Detailed Battery Safety Management Plan (BSMP) (Installation and Implementation)** – the detailed BSMP will be produced post planning consent and will be prepared substantially in accordance with the oBSMP and reflect the maturity of the Scheme and availability of detailed information and evidence to support safety claims. This is in accordance with the corresponding requirement of the DCO. The detailed BSMP will:

   a. Assess the level of residual risk posed by the BESS design to individuals (both those directly involved in the operation and 3rd parties), the immediate environment, the asset (i.e. the BESS), interfacing / interdependent assets and property / equipment that could be affected by the operation of the BESS (noise, radiated emissions etc.)

   b. Contain the Emergency Response and Contingency Plans

   c. Reference supporting evidence; and

   d. Detail any recommendations for improvement.

3 **Site Safety Audit (Operation)** – this validates the BESS installation against the safety requirements and identified control measures in the detailed BSMP. It also validates that the safety processes and procedures required to assure that the risk posed by the design remains within the bounds established and associated requirements have been implemented i.e., training, provision of Personal Protective Equipment, calibration, scheduled maintenance etc. Appropriate reports by the manufacturers and installers will be included in the Site Safety Audit to validate competency and technical due diligence.

1.4.3 The incumbent technology at the time of writing is primarily based on Lithium-Ion batteries. Due to the pace at which battery technology is developing, the battery technology to be employed has not been selected at this early stage. Therefore, this report is written leaning on the subject matter expertise that ARC have in this technological domain, more widely, industry good practice and regulation. Selection of equipment will be based on proven and evidential technical and safety performance.

1.4.4 A section of Frequently Asked Questions (FAQs) is provided at Appendix A to the oBSMP.

2 Scheme Overview

2.1 The Scheme

2.1.1 The Scheme comprises the construction, operation, maintenance, and decommissioning of a solar photovoltaic (PV) electricity generating station and Associated Development comprising Battery Energy Storage System (BESS), a Customer Substation, and Grid Connection Infrastructure, including a new National Grid Substation. The Scheme would allow for the generation and export of over 50MW Alternating Current (AC) of renewable energy, connecting into the National Electricity Transmission System (NETS) overhead line that passes through the Site.

2.1.2 As the Scheme would have a generating capacity more than 50MW, it is a NSIP under the Planning Act 2008.

2.1.3 The Scheme would be located within the Order limits, also referred to as 'the Site'. The Order limits contain all elements of the Scheme comprising the Solar PV Site, the Customer Substation, the National Grid Substation, the BESS , Grid Connection Infrastructure, Mitigation and Enhancement Areas, and the Highway Works (shown in **ES Figure 3.1: Scheme Location [APP/6.3]** and described further in **ES Chapter 3: Order limits and Context [APP/6.1]**). Figure 2.1 presents an illustration of potential access points, BESS compound in overview and the two sub-stations only.

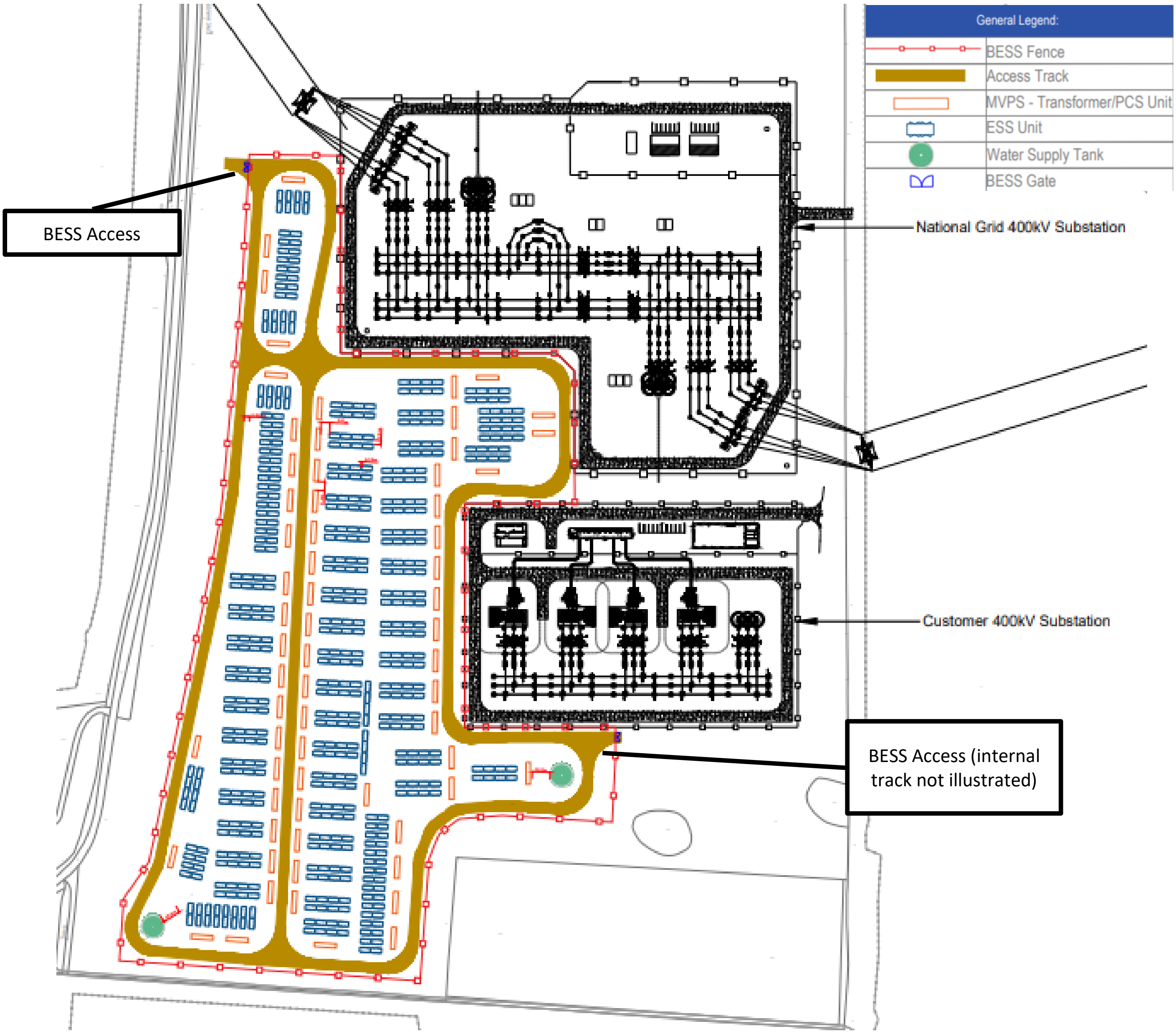


Figure 2.1 Illustrative Scheme Layout

3 Safety Objectives

3.1 High Level Safety Objective

3.1.1 The primary safety objective across the Scheme is to minimise risk to health and safety of the public, employees, property, and the environment by complying with applicable legal requirements and relevant emerging good practice for grid scale connected BESS. These will be distilled into safety requirements that will be included in the requirements for prospective suppliers during the tendering and contracting stage.

3.1.2 Compliance with these safety requirements (by the potential suppliers) will be used as part of the safety argument, to demonstrate that 'The risk posed to individuals, the environment and property from the BESS programme of work has been reduced to a level that is Broadly Acceptable or Tolerable and ALARP' as directed by the HSE. Compliance with the CDM Regulations 2015 (Ref. 5) will require the following documentation:

- Pre-Construction Information Plan (PCIP)
- Review of Contractor Competency and Prequalification
- Review of Contractor Construction Phase Plan
- Registration of the Scheme on HSE UK F10 form, under Regulation 6 of CDM 2015 (Ref. 5)
- On completion of the BESS installation a Health and Safety File is produced by the Principal Contractor for BESS which clearly identifies all Residual Risks
- A comprehensive set of Operational Manuals including all Single Line Diagrams and Schematics; and
- A Fire Strategy and Emergency Response Plan (ERP).

3.1.3 These derived safety requirements will be fundamental to the Scheme and will be used to assure that all direct and indirect safety requirements for BESS are met, and the supplier(s) and installers are safety competent and compliant.

4 Legislation and Compliance Requirements

4.1.1 Legislative compliance, specifically safety, for the BESS will be demonstrated by compliance with the UK Health and Safety at Work Act (HSAWA) 1974 and the appropriate underlying legislation that is enacted through the HSAWA. The following current legislation has been determined as applicable to the Scheme:

1. Health and Safety at Work etc. Act 1974 – UKSI1974/0037
2. Control of Noise at Work Regulations 2005 – UKSI 2005/1643
3. Control of Substances Hazardous to Health Regulations 2002 – UKSI 2002/2677
4. Control of Vibration at Work Regulations 2005 – UKSI2005/1093
5. Electrical Equipment (Safety) Regulations SI 1994/3260
6. Electro-magnetic Compatibility Regulations SI 2006/3418
7. Lifting Operations and Lifting Equipment Regulations 1998 – UKSI1998/2307
8. Management of Health and Safety at Work Regulations 1999 – UKSI1999/3242
9. Manual Handling Operations Regulations 1992 – UKSI1992/2793
10. Personal Protective Equipment Regulations 2002 – UKSI2002/1144
11. Provision and Use of Work Equipment Regulations 1998 – UKSI1998/2306
12. Reporting of Injuries, Diseases and Dangerous Occurrences Regulations SI2013/1471
13. Supply of Machinery (Safety) Regulations 2008 – UKSI2008/1597
14. Workplace (Health, Safety and Welfare) Regulations 1992 – UKSI1992/3004
15. Registration, Evaluation, Authorisation & Restriction of Chemicals Regulations (REACH) – 1907/2006
16. Restriction of Hazardous Substances Directive (RoHS) – 2011/65/EU
17. Dangerous Substances and Explosive Substances Regulations 2002 – SI 2002/2776
18. Construction (Design and Management) Regulations - SI 2015/51
19. Health and Safety (Safety Signs and Signals Regulations 1996)
20. Waste Batteries and Accumulators Regulations 2009
21. Fire Safety (Employees’ Capabilities) (England) Regulations SI 2010/471
22. Fire Safety Order 2023
23. Fire Safety Act 2021
24. Protocol on Persistent Organic Pollutant SI 2007/310.

4.2 Relevant Regulation and Industry Benchmarks

4.2.1 Safety Guidance for the BESS installation will be demonstrated by alignment with prevailing industry guidance, both national and globally. The following industry guidance / best practice has been determined as applicable to this BESS installation:

1. PPG Renewables and Low Carbon Energy (Ref. 1), which refers out to:
   a. NFCC Grid Scale BESS planning – Guidance for Fire and Rescue Services (Ref. 2); and
   b. Factory Mutual (FM) Global Property Loss Datasheet 5-33 – Lithium-Ion BESS (Ref. 3).
2. National Fire Protection Association (NFPA) 885 (Ref. 10) – Stationary Energy Storage Systems, which refers out to:
   a. Underwriters Laboratory (UL)1973 – Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power, and Light Electric Rail Applications (Ref. 7)
   b. UL9540A – BESS Test Methods (Ref. 8)
   c. United Nations (UN)38.3 – Transportation Testing for Lithium Batteries and Cells (Ref. 9)
3. Department for Energy Security and Net Zero – Health and Safety Guidance for Grid Scale Electrical Energy Storage Systems (Ref. 11).

4.3 NFCC Guidance

4.3.1 The NFCC Report Grid Scale BESS Planning – Guidance for FRS (Ref. 2) details the FRS recommendations for BESS installations. The alignment of the Scheme with these guidelines are outlined in Table 6.1 based on the Site layout detailed in Figure 2.1.

5 Safety Controls and Good Practice

5.1 BESS Procurement

5.1.1 The Applicant operates with a stringent prequalification process that leverages the global technological capabilities of the company in the selection of all components. The Applicant is therefore experienced in conducting thorough tendering processes for procuring battery storage equipment and services, working with Tier 1, bankable, suppliers of battery cell manufacturers, inverters, and transformers.

5.1.2 This limits the selection of manufacturers to only those which are approved by the client.

5.1.3 Only suppliers and products that conform to ISO 9001, UN38.3, CE, and local regulation, as well as pass both technical and financial auditing will be considered.

5.1.4 The client procurement processes look to inspect manufacturing facilities and periodically monitor production lines. The inspections evaluate production quality documentation and production line process, against pre-defined documentation to verify that the quality requirement is respected and correctly implemented. The following aspects are specifically checked:

- Material management
- Procurement and supplier management
- Manufacturing processes
- Quality system
- Reliability program
- Training
- Corrective action and non-confirming process and process improvements; and
- Corporate social responsibility, environmental, health and safety.

5.1.5 The Applicant employs a robust quality process at the development and procurement stages that assures safe and continuous operation.

5.1.6 The Applicant requires the designs to incorporate the most advanced fire detection and suppression systems, including adhering to the UL9540 (Ref. 8) test protocols and NFPA 855 (Ref. 10) standards, as well as conforming to local and industry standards.

5.2 Design Safety

5.2.1 As a minimum, it is anticipated that the BESS supplier and operator will provide a layered protection approach from cell to container to remote monitoring. The envisaged safety control measures and design features under consideration, and those that will be flowed to the prospective suppliers, include:

4 Appropriate battery chemistry selection – balancing energy density requirements against available volume and operating parameters

5 Cell module level control – consideration of the use of battery technology incorporating Current Interrupt Devices (CID) and Positive Thermal Coefficient (PTC) protection, enabling the cell to disconnect from the battery in the event of cell failure

6 Implementation in the design of an approved Battery Management System (BMS) and a layered protection system in accordance with UL1973 (Ref. 7) guidelines

7 Safety certification and qualification to UL9540A (Ref. 8) or equivalent

8 The ability for 24/7 Remote Monitoring and Control and automated shut-down

9 Off-gas detection to allow for preventative interaction

10 Battery chemistry bespoke Fire Detection and Suppression Systems (FDSS) fitted to containers

11 Site Security and Monitoring; and

12 At a site and installation level:

   a. The segregation of containers in accordance with the national and international guidance detailed in this report

   b. The landscaping of land adjacent to and between BESS Units, BESS Unit spacing, and maintenance of vegetation to provide a natural firebreak

   c. The provision of suitable and sufficient accesses / passing points for emergency services

   d. Access to the emergency water supply

   e. Communication with local emergency services and the provision of site maps, detailing BESS locations, access points and water sources; and

   f. Drainage Study and other groundwater studies, Soil Investigations, Ground Resistance, Hydrology, Roads, and access assessment. Environmental Impact Assessments, existing buildings and services, for contractors.

5.3 Testing

5.3.1 Once chosen, the battery system will be tested in accordance with UL9450A (Ref. 8) or its successor. UL9540A (Ref. 8) was developed to address safety concerns identified by the building codes and the fire service in the United States and is considered the global standard for evaluating the propensity of BESS to suffer from thermal propagation at cell, module, rack and enclosure level. The results of all four tests at each level will be made available on request.

5.4 Decommissioning

5.4.1 Disposal activities will be considered at the procurement contract stage and will be included within the BESS safety management process and detailed in the detailed BSMP. As the programme matures the hazard log will be expanded to cover each phase of product development and installation.

5.4.2 The chosen BESS supplier will be designated as the producer of the battery components and the party placing the battery components on the UK market, and as such has certain obligations in respect of battery disposal pursuant to the Waste Batteries and Accumulators Regulations 2009 (or such equivalent regulations in force at the time of decommissioning).

5.4.3 It is assumed that all components replaced during the defects notification and warranty period will be returned to the manufacturer and recycled.

5.4.4 The client will follow the hierarchy of waste management throughout the life of the Scheme and during construction (subject to monthly reports) as follows:

- Reduce – batteries have a finite life based on several factors, primarily the total number of cycles undertaken. The operation will attempt to manage the degradation by the selection of services and cycling that maximises the overall life. Consideration will be given to supplementation of the equipment or operation at a lower output.
- Recycle – The supplying manufacturer will have obligations under the Waste Batteries and Accumulators Regulations 2009 (as amended) (or such equivalent regulations in force at the time of decommissioning) and will be contractually obliged to offer a recycling service.
- Recovery – The recycling should allow any useful materials to be recovered and re-enter the supply chain.
- Disposal – Any disposal of batteries shall be undertaken in compliance with all applicable Laws and all regulatory requirements, product stewardship, registration disposal and recycling or take back requirement.

5.5 Hazardous Materials

5.5.1 Any hazardous materials used in the BESS development will need to be fully justified and captured in the BESS Hazardous Materials Register, a sub-set of the Bill of Materials (BoM). The register is used to highlight the hazardous materials contained within BESS and provides justification as to why they cannot be eliminated and to highlight exact quantities of hazardous materials that are present to satisfy legislative requirements. The BESS Hazardous Materials Register will be made available to the local emergency services.

5.5.2 The site will be regularly kept free of vegetation, litter, and any combustible materials.

5.5.3 All internal roads will be maintained to a standard suitable for use during usual operation and emergency response.

5.5.4 All required hazard signage, contact information for emergency response and security will be attached to main gates and boundary fencing, which is compliant with the Health and Safety (Safety Signs and Signals Regulations 1996).

5.6 Emergency Plans

5.6.1 Prior to construction of the BESS, Emergency Plans and a Risk Assessment will be developed that will outline how the operator will respond to incident and accident scenarios at site. This will include the interfaces with external first responder organisations. An onsite fire containment strategy will be incorporated into the overall site drainage design at the detailed design stage and details of this will be contained in the detailed BSMP and ERP.

5.6.2 The ERPs will be developed in an iterative manner in parallel to technical safety requirements. This will demonstrate that the BESS design and Emergency Plans are properly integrated (e.g. that BESS layout provides access for first responders) and that appropriate information can be provided to first responders (e.g. the type and meaning of external indication on containers) to include in their planning activities.

5.6.3 It is important to note that current guidance states that Lithium battery fires will not be tackled with water other than for the purpose of containing the fire and supressing the smoke plume emanating from the BESS.

5.6.4 The ERP will be formed through two distinct elements, both of which will be communicated to the FRS on commissioning of the asset, these being:

1 The Risk Management Plan, a distillation of the oBSMP and BSMP which will include:
   a. The hazards and risks at and to the facility and their proposed management
   b. Any safety issues for the FRS responding to emergencies at the facility
   c. Safe accesses to and within the facility for emergency vehicles and responders, including to key site infrastructure and fire protection systems
   d. The fire detection and suppression systems (i.e. bespoke FDSS fitted to BESS Units, off-gas detection systems, enclosure fire rating etc); and
   e. Any natural or built infrastructure and on-site processes that may impact or delay effective emergency response.

2 The ERP will be developed and include:
   a. How the FRS will be alerted
   b. The site layout including infrastructure details, operations, number of personnel, and operating hours. Key points on site such as entrances and availability of hydrants and shut off isolations as identified by “What 3

Words Codes" for the Local Fire and Rescue Service. This will require consultation and site visits by the regional FRS

c. A site plan depicting key infrastructure, site access points and internal roads

d. Details of emergency resources, including fire detection and suppression systems and equipment; gas detection; emergency eyewash and shower facilities; spill containment systems and equipment; emergency warning systems; communication systems; personal protective equipment; first aid

e. Up-to-date contact details for facility personnel, and any relevant off-site personnel that could provide technical support during an emergency

f. A list of any dangerous goods stored on site

g. Site evacuation procedures; and

h. Emergency procedures for all credible hazards and risks, including building, infrastructure, vehicle and vegetation / flora fires.

6 Site Specific Safety

6.1 Siting

6.1.1 The site has been selected due to its minimal environmental constraints and limited proximity to residences. Figure 2.1 illustrates the indicative site layout and provides the context location for the BESS compound and two electrical sub-stations.

6.2 Security

6.2.1 During construction, the Site will be secured with temporary fencing, Closed Circuit Television (CCTV) and in-person security. During operation, a palisade fence and security cameras will be in place that are remotely monitored 24/7.

6.3 Fire and Rescue Service

6.3.1 The Norfolk FRS is the regional FRS for the Scheme.

6.4 NFCC Planning Guidance

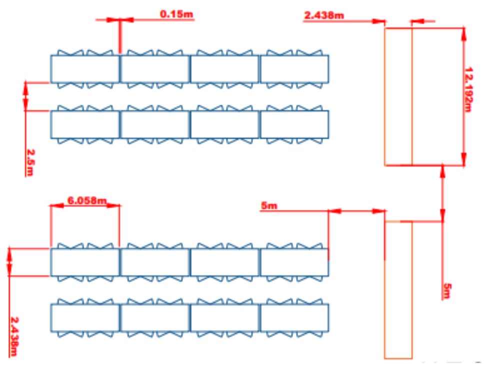
6.4.1 The NFCC has provided planning guidance to regional FRS regarding grid scale BESS and planning. This NFCC Guidance (Ref. 2) has been distilled into the 14 key salient points arising from the guidance and is presented at Table 6.1, this details the Site layout and compliance status reflecting the NFCC guidance.

Table 6.1 Project NFCC Compliance

Ser	NFCC Recommendations	Site Status	Options / Comments
1	Access – Minimum of 2 separate access points to the Site.	Compliant	There are two points of access into the BESS site, allowing access from the east and the west, Figure 2.1 refers, and What3 Word location markers will be provided in the ERP.
2	Roads/hard standing capable of accommodating fire service vehicles in all weather conditions. As such, there should be no extremes of grade.	Compliant	The site service road is a metalled surface a minimum of 4.0m wide. There is no extreme of gradient at the Site. The site access road is suitable for HGV traffic – asphalt in construction.
3	A perimeter road or roads with passing places suitable for fire service vehicles.	Compliant	There is perimeter road in the BESS compound, that is intersected with service roads, allowing for FRS vehicles to manoeuvre and relocate as necessary – Figure 2.1 shows this. Section 13.4 of Approved Document B5 states that FRS vehicles should not have to reverse more than 20m from the end of an access road – given the provision of a circular perimeter service road, the requirement for FRS vehicles to reverse is negated. Section 13.4 references Table 13.1 of the Approved Document B5 which contains typical FRS vehicle access route specifications – the Site meets these specifications.
4	Road networks on sites must enable unobstructed access to all areas of the facility.	Compliant	Access to all BESS Units is afforded from the network of services roads in the BESS compound. The site is designed such that all routes have the capacity to allow for a Fire Tender (based on DB32 Fire Appliance).

Ser	NFCC Recommendations	Site Status	Options / Comments
5	Turning circles, passing places etc. size to be advised by FRS depending on fleet.	Compliant	There is perimeter road in the BESS compound, that is intersected with service roads, allowing for FRS vehicles to manoeuvre and relocate as necessary – Figure 2.1 shows this.
6	Distance from BESS Units to occupied buildings & site boundaries. Initial min distance of 25m.	Compliant	There are no occupied buildings within 25m of the BESS Units.

7	Access between BESS Unit – minimum of 6 metres suggested. If reducing distances, a clear, evidence based, case for the reduction should be shown.	Compliant with Caveats	The suggested 6.0m separation is based on a 2017 Issue of the FM Global Loss and Prevention Datasheet 5-33 (footnote 9 in the NFCC Guidance refers). This Datasheet was revised in Jan 2024, and it now details the following: For containerized LIB-ESS comprised of LFP cells, provide aisle separation of at least 5 ft (1.5 m) on sides that contain access panels, doors, or deflagration vents; and For containerized LIB-ESS comprised of Lithium nickel manganese cobalt (NMC) cells where wall construction is unknown or has an ASTM E119 rating less than 1 hour, provide aisle separation of at least 13 ft (4.0 m) on sides that contain access panels, doors, or deflagration vents. For containerized NMC LIB-ESS where wall construction is documented as having at least a 1-hour rating in accordance with ASTM E119, aisle separation of at least 8 ft (2.4 m) is acceptable. Additionally, the Department for Energy Security and Net Zero (DESNZ) published in March 2024 their Health and Safety Guidance for BESS in which it is stated that the separation distance, for sides with access panel, doors or deflagration panels should be a minimum of 1.5m for LFP. It has been noted that the current NFCC guidance is being revised, and a consultation document has been promulgated. The draft consultation version removes the 6.0m separation distance and refers out to NFPA 855 for guidance on separation. Following this revision to the Datasheet, the BESS Units on-site will be compliant with the minimum distances and conformance to ASTM E119 1-hour fire rating will be confirmed on the down select of the BESS Units to be procured. Current NFCC guidance recommends 6.0m, unless deemed acceptable to be closer based on manufacturers UL testing / fire rating qualification. The BESS Unit separation at the Site is as illustrated below:

Ser	NFCC Recommendations	Site Status	Options / Comments
			
8	Site Conditions – areas within 10m of BESS Units should be cleared of combustible vegetation.	Compliant	The BESS Units will sit on concrete slabs or supporting feet. Internal access tracks will comprise crushed stone and the access road for the abnormal load will be asphalt. Within fence line and between BESS Units the surface is laid over to gravel. All areas within 10m of the BESS are cleared of vegetation.
9	Water Supplies.	Compliant	There are two Emergency Water Tanks within the BESS compound.
10	Signage.	Compliant	Signage is to be positioned at the entrance to the Site. Signage to be confirmed through design process and will be detailed in the ERP.
11	ERP.	Compliant at this juncture	Future iteration of the oBSMP to detailed BSMP will roll up the ERP outlining who within and how the FRS will be alerted, facility description, number of operatives, detailed site plan etc.

Ser	NFCC Recommendations	Site Status	Options / Comments
12	Environmental Impacts.	Compliant at this juncture	In the event of a fire, all firefighting water runoff will be contained in a purpose-built tank. A penstock will ensure the water is retained until it is tested and, if applicable, treated prior to any release to ground.
13	System design, construction, testing and decommissioning.	Compliant at this juncture	Several of the elements under this aspect of the NFCC Guidance are contained in this plan; however, details of the construction, testing and decommissioning will only be available in later stages of the programme and will be contained in the detailed BSMP. The Applicant is compliant with the recommendation at this juncture in the planning procedure.
14	Deflagration Prevention and venting.	Compliant at this juncture	Elements of this requirement are contained in this plan, but the actual technique to be adopted will not be apparent up to the point the decision is made as to what BESS is being used. Deflagration venting is possibly most effective when fitted to the roof of the BESS Units, as such deflecting blast upwards and away from FRS personnel. The Applicant is compliant with the recommendation at this juncture in the planning procedure.

7 Conclusions and Recommendations

7.1 Conclusions

7.1.1 At this juncture of the Scheme the identification of potential hazards, causes and controls is limited to the concept stage. As a result, the controls that have been identified are also conceptual and subject to technological assessment, as such no ALARP statements can yet be formulated, as the evidence to support such claims requires validation once the selection of the infrastructure has been finalised. This approach is in accordance with standard practice and recent examples of this approach include the Springwell Solar Farm (Ref. 12).

7.1.2 All the control measures listed are founded on good practice and based on previous knowledge of BESS. These mitigations may, in some instances, require further development and ratification as the programme progresses. Upon successful implementation, and with suitable evidence available to validate effectiveness, reassessment can be conducted and an ALARP claim substantiated.

7.1.3 It is concluded that, as far as reasonably practicable and for this planning stage of the Scheme, that currently foreseeable hazards associated with the equipment have been identified, and these will be developed and managed within the HL [Ref. 4]. These hazards will be actively managed throughout the life of the installation and added to as necessary as the Scheme develops and will be reported on regularly.

7.1.4 This oBSMP has been developed using existing knowledge of the BESS capability and leans heavily on the subject matter expertise that ARC have in this technological domain. Further development of the BESS design will provide more detailed information that will enhance future safety analysis and management, where further understanding of the hazards and development of mitigations can be undertaken to reduce the potential level of risk posed by BESS.

7.2 Recommendations

7.2.1 It is recommended that the BESS safety management and criteria (for assessment and analysis), as defined in this oBSMP, is adhered to via the detailed BSMP throughout the Scheme lifecycle to assure that safety management is developed as the programme progresses and remains valid through the life of the BESS capability.

7.2.2 During the construction of the Site it will be essential that the design process is subject to a Design Risk Analysis by a competent person in compliance with the CDM Regulations 2015 (Ref. 5).

7.2.3 It is recommended that to maintain an acceptable level of residual risk, all the identified control measures are assessed as the design matures to elicit; applicability, feasibility and the potential amelioration afforded. At this juncture, it is not possible to declare ALARP;

however successful implementation of the proposed framework for safety management presented in this oBSMP will provide the necessary arguments and supporting evidence to make such a claim.

8 References

Ref 1 Practice Planning Guidance Renewables and Low Carbon Energies dated July 2023.

Ref 2 NFCC Grid Scale Battery Energy Storage System Planning – Guidance for FRS dated Nov 2022.

Ref 3 Factory Mutual – Loss and Prevention Datasheet 5-33 – dated Jan 2024.

Ref 4 Droves BESS Hazard Log – ARC-1259-002-R2 dated July 2025.

Ref 5 CDM Regulations 2015 – SI2015/51 dated Dec 2017 (as revised)

Ref 6 R2P2 (HSE Publications)

Ref 7 UL1973 – Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power, and Light Electric Rail Applications.

Ref 8 UL9540A – BESS Test Methods.

Ref 9 UN38.3 Transportation Testing for Lithium Batteries and Cells.

Ref 10 NFPA 855 Standard for the Installation of Stationary Energy Storage Systems dated Aug 2023.

Ref 11 Department for Energy Security and Net Zero – Health and Safety Guidance for Electrical Energy Storage Systems. Health and Safety Guidance for Grid Scale Electrical Energy Storage Systems (publishing.service.gov.uk).

Ref 12 https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010149/EN010149-000589-7.14.2%20Outline%20Battery%20Safety%20Management%20Plan.pdf

Appendix A FAQs

Ser	Question	Answer
1	How does a BESS work?	A BESS employs technology to temporarily store electrical energy, very much in the same manner as a mobile phone or laptop battery, but on a much bigger scale. The energy can be stored and released when demand on the National Grid is high and assists in balancing out variations in demand or alternately when connected to a Renewable Energy source can be used to store the energy as it is being generated.
2	How safe is a BESS?	The Department for Energy Security and Net Zero promulgates on a quarterly basis the Renewable Energy Planning Database (REPD). From the Jul 2025 report this data has been filtered for BESS installations and the following deduced[1]: 1 Listed in the REPD[2], there are: • 127 operational BESS sites. • 8 BESS sites have been decommissioned. • 102 BESS sites are under construction. • 903 BESS sites have planning consent and are awaiting construction. 2 There have currently been only three reported BESS fires in the UK that have required FRS attendance; these occurred at Carnegie Road, Liverpool in Sept 2020, Cirencester March 2025 and East Tilbury in Feb 2025[3].

[1] The REPD tracks the progress of energy projects, including BESSs, through the planning system. Until 2021, the REPD only recorded projects with a capacity over 1 MW). Since 2021, it also includes projects with a capacity over 150 kilowatts (kW). Therefore, BESSs that were going through the planning system before 2021 may not have been captured in the REPD. Source: Commons Library Research Briefing, 19 April 2024 – BESS.

[2] This is a conservative figure as the REPD did not account for project under 1MW until 2021.

[3] The root cause of the fires at Cirencester and East Tilbury has yet to be established.

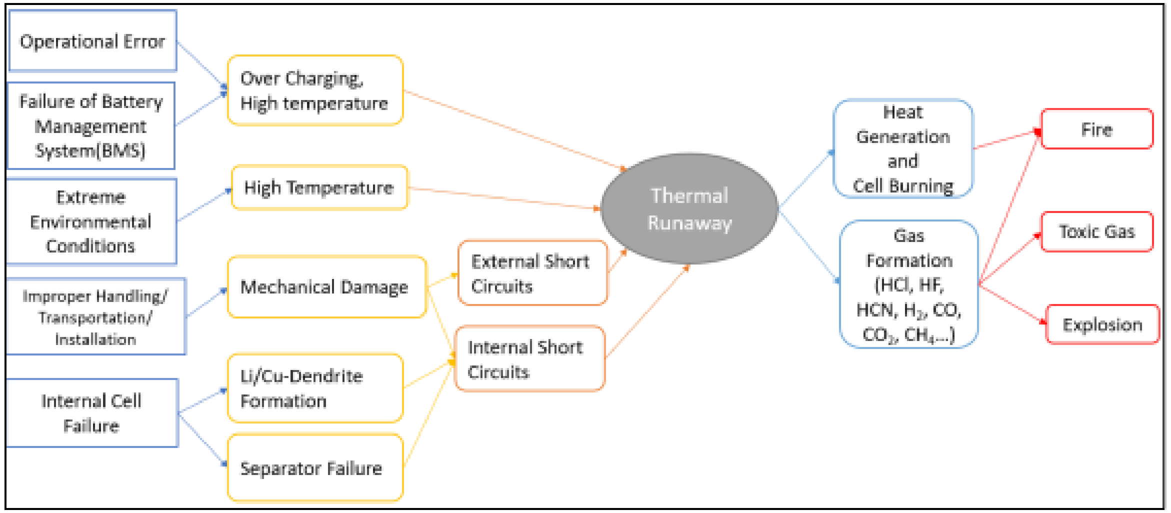
		3 The current operational UK BESS installations have accumulated an estimated 710 years of operation[4], which equates to 240,000 days or 6.2 million hours of operation. 4 Given the 6.2 million hours of operation, this extrapolates out to approx. 4.8E-07 (0.00000048) failures per hour (fph) for BESS in the UK. 5 To date, there have been no recorded fatalities, third-party injuries, or environmental damage resulting from BESS incidents in the UK. Reflecting on the HSE R2P2 guidance, an individual risk of death of 1.0E-05 per year (or 1 in 100,000 annually) is considered broadly acceptable for workers. Based on this framework, the risk associated with BESS operation is assessed to be within the broadly acceptable range and compliant with the HSE ALARP principles.
3	Lithium-Ion is sensitive to temperature variations – how is this controlled?	The batteries are housed in an enclosure which is fitted with an Environmental Control Unit (ECU) and/or Active Ventilation System (AVS). The ECU maintains the temperature and humidity within the container, allowing the Lithium-Ion batteries to operate within the optimum temperature range. The temperature of individual cells in each battery is monitored by the BMS and is reported back to the container level BMS which adjusts the internal temperature in response. Should the ECU develop a fault, the container will isolate charge and discharge to the batteries until the fault has been rectified. All faults in the BESS are remotely fed to a centralised Operational Control Room (OCR). In some BESS, the AVS will activate if any cell off gas is detected, sweeping the enclosure of the gas. Activation of the AVS will raise an alarm in the OCR.
4	What is Thermal Runaway?	Thermal Runaway (TR) is the term used to describe when an internal short-circuit in one of the battery cells, that can lead to cell over-pressure and the venting of combustible gases, results in adjacent cells heating up and likewise venting combustible gases. On ignition of the gas the cell will increase in over-pressure, and the resulting fire will be self-sustaining until all the material in the cell is expended, a quasi-chain reaction event. The propensity for

[4] This does not include the operating time of the BESS sites now decommissioned.

TR differs from cell chemistry to cell chemistry and the design of the battery can reduce the risk of TR. Cell short-circuits are generally a result of:

1. Cell penetration by a foreign object (not usually an issue for a BESS as the batteries are housed in sturdy containers in secured compounds);
2. Impurities in the electrolyte (deposited during the manufacturing process), which over time can lead to the formation of dendrites (electrolytic crystals) which puncture the membrane isolating the anode and cathode – this can, but not always, result in a short-circuit and TR; or
3. Over-temperature in the cell because of:
    - Over-charging (which is controlled by 2 separate BMS – battery and rack); and/or
    - High ambient temperature – controlled by the ECU.

The illustration below provides an outline of the possible causes of TR.



5	How can TR be controlled?	TR is not inevitable, and the nature of the cell design is such that early warning signs of a stressed cell can be detected by the BMS. Initial signs of cell degradation are an increase in the time it takes the cells to reach full charge (maximum voltage) and a decrease in the time it takes to discharge – slow charge, rapid discharge – as experience in mobile phones as the battery reaches end of life. In a BESS, these indicators are picked up by the BMS and if persistent the BMS will isolate (prevent charge and discharge) to the battery and inform the OCR. In turn, an engineer will be dispatched to remove the battery and replace it with a serviceable item. Since the early inception of BESS, safeguards in the design have developed and are now detailed in UL1973. If these indicators are not present, and the cell enters early stages of short-circuit, the over-pressure in the cell will result in the venting of off-gas which is detected by the off-gas detectors built into the enclosure. This will result in the container disabling the charge and discharge (the act of charging and discharging the batteries generates heat, which is to be avoided) and setting the ECU/AVS to maximum volume setting. This has a twofold effect: it clears the container of combustible gas and cools the internals, taking the energy out of the cells (the cells used in BESS, like other batteries do not perform well in low temperature conditions). It should be noted that most BESS only operate at between 80-90% of capacity to provide an engineering margin that mitigates the probability of over-charging the cells.
6	How is a BESS fire controlled and suppressed?	If a TR is not controlled and ignition occurs, the FDSS will activate. There are generally two types of FDSS that are used in BESS; gaseous systems and aerosol systems. Each system has advantages and disadvantages: 1 Aerosol systems are better in terms of extinguishing the fire and benefit against gaseous systems, which generally supress the fire by reducing the level of oxygen in the container; 2 Gaseous systems are instantaneous in operation; the gas being kept under pressure in bottles. Aerosol, by the nature of the deployment as a fine mist, take a little longer to reach all areas of the container;

		3 Aerosol systems generally require a more complex and intricate delivery system to reach all areas of the container; 4 Gaseous systems require a sealed environment in which to operate. As such, if the container is opened and oxygen reintroduced it can lead to the fire reigniting; therefore, they require the ECU to close prior to activation (to prevent the ECU from pushing out the extinguishing medium); and 5 Various FDSS aerosols (also known as aqueous) and gaseous systems are available, and they use a variety of aerosol solutions. Under consideration for this site is the use of an aerosol aqueous solution containing potassium carbonate (K2CO3) – this inhibits the fire by isolating at a molecular level with the chemical chain reactions forming the flame front. This aerosol is non-harmful to the environment and presents no health and safety concerns to first responders.
7	Can water be used to extinguish a Lithium-Ion fire?	The use of water to extinguish a BESS fire has some drawbacks and disadvantages over bespoke FDSS aerosol mediums, these being: 1 Due to the design of the BESS batteries and racks (in which they are contained), the inability of water to cool the cell interiors may result in re-ignition of a fire once the water application is halted; 2 The high conductivity of water may cause short circuiting of cells presenting collateral damage risk and increase the spread of the fire internal in the BESS; 3 A high volume of water is required to cool the cells below the critical temperature to prevent TR propagation, which results in a high volume of fire water run-off and a potential environmental impact; and 4 The application of water on a BESS fire increases the generation of gases such as carbon monoxide (CO), hydrogen (H2) and hydrogen fluoride (HF). Applying water causes incomplete combustion of organic substances inside the battery resulting in production of CO rather than CO2; when water is applied, H2 is released that,

		without combustion, can react with phosphorus pentafluoride, if present in free form, to produce gaseous HF.
8	What are the environmental consequences of a BESS fire?	In the event of a BESS fire, several chemicals in gaseous form can be released and the composition and concentration of the plume (also referred to as the vapour cloud) will vary according to vell chemistry, state of charge and materials used in the construction fo the BESS. In the event of a BESS fire, amongst the general gases released are CO, HF, oxygen and hydrogen. The BESS fire at Carnegie Road, Liverpool – September 2020 was monitored, and the resultant composition of the plume was determined as being negligible in toxic gas concentration. Subsequent plume and concentration modelling has demonstrated that the concentration of HF in the plume is limited to Acute Exposure Level Guidance Level 1, the lowest level of HF. This concentration level is non-fatal. Should the resulting fire be treated with water in the presence of HF, the result can be the formation of a HF acid which can be detrimental to the environment, especially the aquatic habitat. To prevent this, it is possible to contain the fire run-off water, but often best to let the fire run its course and burn out. It is worth noting that the fire run-off water at Carnegie is considered to have been neutralised by the lime-based gravel covering used at the base of the BESS and on testing was found to be a low alkaline level, as opposed to acidic. Further to this, the recent fire at Moss Landing California (Feb 2025), was monitored at one second intervals for toxic substances in the smoke plume. It was established that the composition of the plume emanating from the fire was within US Air Pollution limits. California Air Quality limits for HF are stricter than those in the UK.
9	How is the BESS site secured?	The BESS Site is secured through fences / walls and monitored remotely via security cameras. Warning signs along the fence indicate the presence of electrical storage facilities within the Site.
10	How is the serviceability of the BESS assured?	The Health and Usage data for each BESS is remoted to a centralised control room and the serviceability of each battery determined on an hour-to-hour basis. Given that the batteries have a finite number of cycles over a given period, it is envisaged that the batteries will be renewed multiple times in the 60-year life of the Site.

Appendix 1 Battery Plume Assessment

HOARE LEA

The Droves Solar Farm. Swaffham.

The Droves Solar Farm Limited.

AIR QUALITY

BATTERY FIRE PLUME ASSESSMENT

REVISION 01 – 11 NOVEMBER 2025

Audit sheet

Rev.	Date	Description of change / purpose of issue	Prepared	Reviewed	Authorised
00	23/04/2025	First Draft	LC	JJ	AD
01	11/11/2025	First Issue	JJ	AD	AD

This document has been prepared for The Droves Solar Farm Limited only and solely for the purposes expressly defined herein. We owe no duty of care to any third parties in respect of its content. Therefore, unless expressly agreed by us in signed writing, we hereby exclude all liability to third parties, including liability for negligence, save only for liabilities that cannot be so excluded by operation of applicable law. The consequences of climate change and the effects of future changes in climatic conditions cannot be accurately predicted. This report has been based solely on the specific design assumptions and criteria stated herein.

Project number: 34/22484
Document reference: 3422484-HLE-RP-AQ-The Droves Solar Farm BESS Plume Assessment-Rev01.docx

Contents

Executive summary.

Hoare Lea have been appointed by The Droves Solar Farm Limited (the 'Applicant') to assess the potential air quality impacts on the local area in the event of battery failure and potential risk of fire, resulting in the plume dispersion of hazardous gas emissions at the proposed Battery Energy Storage System (BESS) at the Droves Solar Farm.

The aim of the study is to provide preliminary information by identifying the potential impact and dispersion of the gas plume and to quantify potential air quality impacts on the local area in the event of a battery failure at the BESS. For the assessment approach, robust and reasonable worst-case assumptions have been made.

The risk of fire during a battery failure event could potentially result in the plume dispersion of hazardous gas emissions, including the highly toxic hydrogen fluoride (HF). As such, the plume dispersion of a potential toxic gas plume emitted during the rare event of a battery fire scenario must be studied in order to consider the potential impact on sensitive receptors in the vicinity of the Site.

Due to the high toxicity of HF and because its emission rates, although limited, are available in the literature, the emissions of HF alone have been assessed to represent the worst-case impact of a battery fire scenario.

The results of the battery fire assessment indicate that the relevant Acute Exposure Guideline Level (AEGL) Levels 2 and 3 for HF were not exceeded for any of the five exposure periods considered. There is a higher risk of adverse health impacts for AEGL Level 2 and Level 3 exceedances, including irreversible or other serious long-lasting health impacts at nearby receptors. As AEGL Levels 2 and 3 are not exceeded, a battery fire is unlikely to lead to serious or long-term health impacts on receptors at any distance from the Site.

The modelled BESS location is based on a worst-case assumption due to its proximity to sensitive receptors. The AEGL Level 1 maximum area of exceedance of 157 m for the 10-minute exposure period, based on the BESS design parameters outlined and considered in this assessment, should be considered to minimise risk.

Furthermore, these results are based on other worst-case assumptions including that the fire will occur on worst-case meteorological conditions for that wind direction. The in-combination possibility of a fire event taking place during the worst-case meteorological conditions is considered to be extremely low.

It is important to note that health impacts associated with AEGL Level 1 values are transient and reversible upon cessation of exposure. In the unlikely event of a battery fire occurring at the site, as a precautionary measure, the areas within the AEGL Level 1 maximum area of exceedance should be avoided by the general public where possible.

In summary, the key findings of this assessment indicate that it is unlikely that there will be serious or permanent health impacts predicted at any distance under worst-case battery fire conditions. The AEGL Level 1 maximum area of exceedance of 157 m for the 10-minute exposure period reach minor roads near the Site under a reasonable worst-case fire (in the unlikely event) and worst-case meteorological conditions. In this scenario the predicted impacts are transient and reversible.

1. Introduction.

Hoare Lea have been commissioned by The Droves Solar Farm Limited (the 'Applicant') to assess the potential air quality impacts on the local area in the event of battery failure and potential risk of fire, resulting in the plume dispersion of hazardous gas emissions at the proposed Battery Energy Storage System (BESS) at the Droves Solar Farm (the 'Proposed Facility'), within the administrative boundary of Breckland District Council (BDC). The Proposed Facility is part of a wider development comprising solar panels and other infrastructure at Droves Solar Farm (the 'Site').

The aim of the study is to provide preliminary information by identifying the impact and dispersion of the gas plume and to quantify air quality concentrations within the local area in the event of a battery failure at the BESS. For the assessment approach, robust and reasonable worst-case assumptions have been made.

In reality, the direction of the plume will depend on the wind direction, while the dispersion will also depend on wind speed and atmospheric turbulence at the time of battery failure. To ensure a robust approach, the impacts presented within this report are independent of specific wind direction.

1.1 Location context.

The location of the Proposed Facility is presented in Figure 1 for context. The Site area that will include BESS located to the north of town of Swaffham.

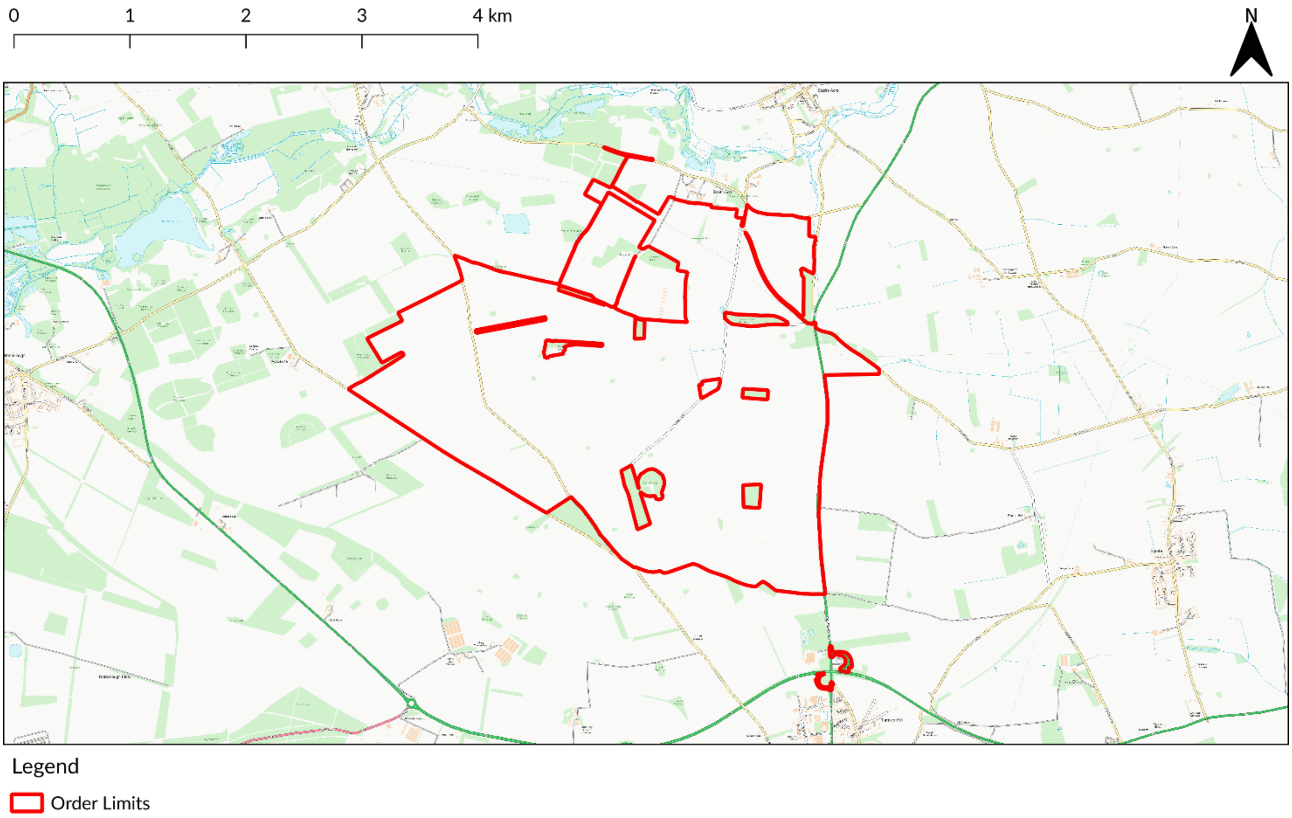


Figure 1: Location of the Approximate Order Limits. Contains Google Satellite data © Crown copyright and database rights 2025.

1.2 Proposed facility.

At the time of undertaking the dispersion modelling exercise, the Applicant has confirmed that the BESS could be located either at field 27 or 33, as shown in Figure 2. For the purpose of the dispersion modelling assessment, it has been considered that the BESS will be located at field 33, as a worst-case battery container location, for potential risk to human receptors, as this location is in closer proximity to existing farms to the east of Petticoat Drove and northwest of South Acre Road.

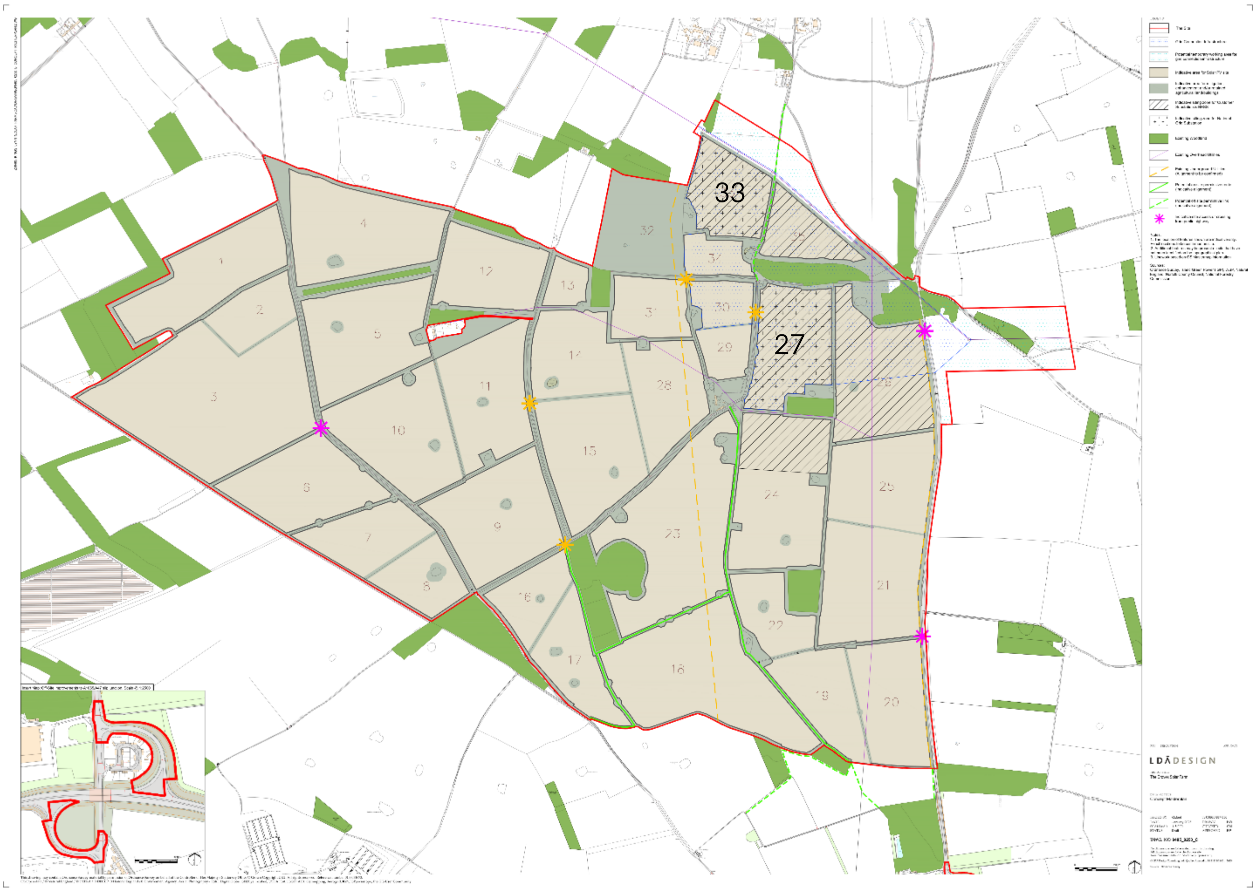


Figure 2: Layout of the Proposed Facility. Drawing provided by LDA Design (ref: 9485_0250_C_Concept_Masterplan.pdf).

At this stage the battery manufacturer has not been specified. However, the Applicant has confirmed that the BESS will utilise Lithium Iron Phosphate (LFP) batteries which forms the basis of this assessment. Based on information provided by the Applicant, the batteries will be housed in containers with each container measuring 16 m in length, 3 m in width and 3.2 m in height. This is the container size used to inform the dispersion modelling.

It is important to note that battery failure is an unlikely event, and the BESS will include safety systems to mitigate, control and avoid hazardous outcomes. To ensure a robust approach, this assessment considers the burn out of an entire container. It has been confirmed by the Applicant that the minimum separation between containers will comply with the National Fire Chiefs' Council Guidance. Therefore, container spacing should be sufficient to ensure that there is no propagation.

1.3 Scope of the assessment.

It is understood that a battery failure at the Proposed Facility has the potential to result in thermal runaway. Thermal runaway occurs when the battery cells enter an uncontrolled self-heating state, resulting in high temperature and the emission of potentially hazardous gases. In the worst-case event that ignition occurs during thermal runaway, this assessment involves the quantitative analysis of the dispersion of the gases emitted from the Proposed Facility during a fire scenario.

A dispersion modelling assessment has been undertaken to consider the dispersion of hydrogen fluoride (HF) gases emitted from one container at the Proposed Facility in a fire scenario. The thermal runaway event itself has not been modelled as typically only traces of HF gases are observed during this event. In addition, the impact of gas emissions during the thermal runaway event are anticipated to be within close distance to the batteries and unlikely to impact sensitive receptors in the area. The dispersion modelling of HF gases during a fire scenario is considered the worst-case scenario in the event of battery failure and this has been modelled using emission rates sourced from existing literature.

BESS fire parameters have been sourced from technical documentation in existing literature. These technical documents have been used to determine some of the parameters for a fire scenario that have been included within the assessment. It is noted that only the emissions of HF have been considered and these were also sourced from existing literature. This is because HF is considered highly toxic, and although the emission rates are limited, they are available in the literature.

It is acknowledged that there will be levels of nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter (PM), hydrogen chloride (HCl) and hydrogen cyanide (HCN) emitted as a result of a fire event. However, NO_x levels are expected to not have a significant effect and HCl and HCN emissions expected to be lower than HF emissions. Additionally, there is limited availability of PM emissions from representative battery fires available in the literature. As such, these pollutants will not be considered further within the assessment, with HF being assessed as the worst-case pollutant, due to the criteria stated above. This is considered to be a robust approach.

The dispersion of the HF emissions associated with a fire scenario has been modelled to predict the spread of the gas plume, to predict HF concentrations and to determine the maximum areas of exceedance and exclusion zones (if required) around the battery containers in comparison to the relevant assessment criteria. The maximum area of exceedance can be applied to any battery container within the confirmed field and finalised BESS design.

2. Methodology.

A modelling assessment has been undertaken to consider the dispersion of HF gases emitted from the Proposed Facility during a fire scenario.

2.1 Model inputs, emissions and scenario.

2.1.1 Model parameters

Research of LFP battery fire events indicated that during a fire event, traces of HF gases can be found. HF emissions have been sourced from the following reports:

- Larsson et al. (2016) report '*Gas emissions from Lithium-ion battery cells undergoing abuse from external fire*'[1]; and,
- Larsson et al. (2017) report '*Toxic fluoride gas emissions from lithium-ion battery fires*'[2].

These reports provide HF emission rates (mg/Wh) for LFP batteries with varying geometries at specified state of charge (SOC) during test conditions. An average of the HF emissions reported for cylindrical LFP batteries at 50-100% SOC, has been utilised for the dispersion modelling exercise. There is limited availability of emissions data for prismatic LFP cells in the literature, as such, these could not be included in the average HF emission rate calculation. Additionally, emissions data for pouch cells have not been included as their properties were not considered to be representative of the proposed battery model in the event of a battery failure. Therefore, this approach is considered to provide the most comprehensive data on HF emissions for the battery storage used on Site, based on available data at the time of writing and in the absence of specific emissions for the battery storage used at the Site.

The fire scenario has considered one entire container flaming during a battery failure event. To calculate the HF emission rates representative for the fire, information on the battery capacity and dimensions, as provided by the Applicant, was used. This information, along with the emission rates from the publications outlined above, was used to calculate the hourly HF emission rate. To ensure a robust assessment, the emission rate is assumed constant throughout the fire scenario.

Due to the limited available data, in the existing literature, on the velocity of the gas release to the atmosphere during the fire event, a low velocity of 0.1 m/s has been utilised in order to account for thermal buoyancy effects in the model. This is considered a robust approach as the velocity of HF emissions to air is likely to be quicker, particularly during the peak release.

For the purpose of this assessment, an illustrative container was assessed located in the northwest corner of field 33, with the area of exceedances calculated to be applied to all BESS containers within the Proposed Facility. The modelled BESS location is based on a worst-case assumption due to its proximity to existing sensitive receptors in the surrounding area (i.e., existing farms to the east of Petticoat Droe and northwest of South Acre Road).

The container has been modelled as an area source to represent the emissions distributing equally across the top of the container at the peak flame height. In line with information detailed within the existing literature, an average flame height (i.e. emissions release) of 2.1 m above the container top has been utilised in the model. This is considered a robust assumption for the modelled fire scenario.

Fire temperature has been sourced utilising information detailed within the existing literature, with an external fire temperature of 822.5°C used in the assessment which has been assumed constant throughout the entire fire scenario.

Further information on the fire scenario emissions is detailed in Appendix 1.

[1] Larsson et al (2016) Gas emissions from Lithium-ion battery cells undergoing abuse from external fire – [online], (Last accessed: 14/04/2025), Available at www.research.chalmers.se/en/publication/243272

[2] Larsson et al (2017) Toxic fluoride gas emissions from lithium-ion battery fires – [online], (Last accessed: 14/04/2025), Available at: www.nature.com/articles/s41598-017-09784-z/

2.1.2 Scenario

The model has been run considering one full container being on fire, on the basis that the Outline Battery Safety Management Plan (OBSMP) will commit to the minimum separation distance outlined within the National Fire Chiefs' Council Guidance. In order to ensure a robust approach has been undertaken, the model was run for a full calendar year at the 100th percentile for HF at all exposure periods considered. The 100th percentile represents the worst-case period average of the year when concentrations are predicted to be at their greatest. This approach results in predicting concentrations for the worst-case meteorological conditions and subsequently, predicted HF concentrations can be considered robust.

The likelihood of a fire event occurring during the worst-case meteorological conditions is very low. Meteorological data from Marham meteorological station has been used for the purpose of dispersion modelling. This meteorological station was selected as the most representative of the meteorological conditions anticipated at the Site, due to its location in relation to the Site, at approximately 9.5 km, and being set back from the coast at approximately 25 km compared to the Site, at approximately 27 km.

Data for 2022, 2023 and 2024 has been utilised and the results presented within the report outline the predicted concentrations associated with the worst-case meteorological year for the relevant exposure period.

A fire duration of 8 hours has been utilised to inform emission calculations and considered a reasonable fire duration. As the model has been ran for a full calendar year of data, this covers any type of length a full container could be on fire.

Further information on the fire scenario modelling parameters is detailed in Appendix 1.

2.2 Assessment criteria and model.

Acute Exposure Guideline Levels (AEGLs) are used as guidance to support the handling of rare, usually accidental, releases of chemicals into the air. AEGLs are used worldwide by emergency planners and responders to support guidance and responses during an emergency event. Due to the unlikely event of a thermal runaway and subsequently of a fire at the Proposed Facility, the use of AEGLs as the assessment criteria is considered to be the most representative.

AEGLs are calculated for five short exposure periods:

- 10-minutes;
- 30-minutes;
- 1-hour;
- 4-hours; and
- 8-hours.

They are expressed as specific concentrations at which health effects may occur. AEGLs for a specific pollutant can be categorised into Level 1, 2 or 3, with Level 1 being the least and Level 3 being the most severe. The levels are summarised below:

- Level 1: Notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure;
- Level 2: Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape; and,
- Level 3: Life-threatening health effects or death.

Levels 1, 2 and 3 AEGL values for HF have been used to represent the assessment criteria for comparison against the modelled HF concentrations. The AEGLs for HF are provided in Table 1.

Table 1: Acute Exposure Guideline Levels for Hydrogen Fluoride.

Exposure Period	AEGL level 1 (ppm)	AEGL level 2 (ppm)	AEGL level 3 (ppm)
10-minute	1	95	170
30-minute	1	34	62

Exposure Period	AEGL level 1 (ppm)	AEGL level 2 (ppm)	AEGL level 3 (ppm)
1-hour	1	24	44
4-hour	1	12	22
8-hour	1	12	22

For the purpose of the assessment maximum areas of exceedance will be discussed for AEGL Level 1 given the transient nature of the effects, whereas zones of exclusion are discussed for AEGL Levels 2 and 3 due to the higher risk of adverse health impacts.

Impacts have been modelled using the ADMS 6 (v.6.0.0.1) dispersion modelling software. ADMS 6 is an extensively validated Gaussian plume air dispersion model, and is used by regulators, government departments, consultancies, and industry. The model is able to simulate the entrainment of the plume in the wake of buildings.

2.3 Receptors.

HF emissions from fire event could have an impact on the health and wellbeing of sensitive receptors.

Concentrations of HF emissions from the modelled scenarios have been predicted within a 1 km by 1 km grid at a 10 m resolution in order to predict the spread of the fire plume, predict pollutant concentrations and to determine the required maximum areas of exceedance and exclusion zones (if required) around the battery container for the modelled scenario in comparison to the relevant AEGL values. The size of the grid will ensure that all nearby existing receptors have been captured.

2.4 Assumptions and limitations of the study.

Modelling the impact of air emissions during a potential battery failure is complex, because each event is different. It depends on many factors including the number and type of battery modules failing, their SOC, whether/how they are damaged, and the weather at the time of the event. Therefore, a number of assumptions have been made to represent a robust and worst-case assessment in a reasonable manner.

Any dispersion modelling study involves a range of uncertainties, including the model inputs, assumptions, the model and post-processing of model results. The dispersion model used in the assessment is dependent upon emission rates, flow rates, exhaust temperatures and other parameters for each source, all of which are variable in reality. There are then additional uncertainties, as models are required to simplify real-world conditions into a series of algorithms. The model used for this assessment has been validated for this type of modelling studies.

Assumptions and considerations made to ensure a robust approach are listed below:

- HF emissions are assessed to represent the worst-case impact of a battery failure scenario, due to its high toxicity and because its emission rates, although limited, are available in the literature;
- Emission rates for HF are based on average of the HF emissions in mg/Wh reported from the literature[1,2] for cylindrical LFP batteries at 50-100% SOC – an average of 33.88 mg/Wh has been used for this assessment. The mass emitted is spread uniformly across the total duration of the flaming event, which has been assumed to last for eight hours. It is noted that the eight-hour fire duration has been used solely to inform emission calculations. Further detail on the HF emission rate calculation is provided in Appendix 1.
- It is assumed the entire container will be flaming, taking into consideration slow propagation of the fire from cell to cell. Due to the unknown length of flaming for the entire container, a full year of meteorological data has been used, covering any possible length.
- Due to limited available data on the velocity of the gas release to the atmosphere during the fire event, a low velocity of 0.1 m/s has been utilised in order to account for thermal buoyancy effects in the model. This is considered a robust approach as the velocity of HF emissions to air is likely to be quicker, particularly during the peak release;
- A flame temperature of 822.5°C representative of the temperature for a fire of this kind was used;

- For the modelling process, a full calendar year of meteorological data has been used to predict the peak concentration for each gas assessed per hour. The worst-case meteorological year out of three years of 2022-2024 for each exposure period has been used;
- The model has assumed that the 4-hour and 8-hour exposure periods are considering continuous and consistent emission release during these periods. This takes account of the possibility of continuous fire propagation between modules within a single container; and,
- As the resolution of the ADMS pollutant grids was 10 m in X and Y directions, an additional 10 m has been added on to the area of exceedances to account for the uncertainty due to the grid resolution of the model used to predict areas of exceedance.

3. Results.

The potential for air quality impacts from the fire scenario in the Proposed Facility are assessed in this section.

As previously mentioned in Section 2, the model has been run for a full calendar year at the 100th percentile for the exposure periods considered. The 100th percentile represents the worst-case averaging period of the year when concentrations are predicted to be at their greatest. In the unlikely event that a fire scenario occurs, it is considered very low risk that this would coincide with the worst-case meteorological conditions. Subsequently, the results provided below are considered conservative.

The maximum concentration of pollutants in each scenario was calculated for the 10-minute, 30-minute, 1-hour, 4-hour and 8-hour exposure periods. Where the limit concentrations, provided in Table 1, have been exceeded, the maximum distance from the source where these exceedances occur have been provided in Table 2. These can be used to determine the maximum areas of exceedance and exclusion zones (if required) surrounding the battery container during the relevant exposure period. The maximum areas of exceedance around the Proposed Facility (AEGL 1 exceedances) are shown in Figure 3.

The results of the assessment indicate that AEGL Levels 2 and 3 for HF were not exceeded for any of the five exposure periods considered. There is a higher risk of adverse health impacts for AEGL Level 2 and Level 3 exceedances, including irreversible or other serious long-lasting health impacts at nearby receptors.

The modelled BESS location is based on a worst-case assumption due to its proximity to existing sensitive receptors. The AEGL Level 1 maximum area of exceedance of 157 m, for the 10-minute exposure period, should be accounted for when selecting the fixed BESS location in order to minimise the risk to human health at sensitive receptors, noting that this AEGL Level 1 maximum area of exceedance is subject to the BESS design parameters outlined and considered in this assessment.

AEGL Level 1 refers to notable discomfort, irritation, or certain asymptomatic non-sensory effects. It is important to note that health impacts associated with AEGL Level 1 values are transient and reversible upon cessation of exposure. Moreover, these results are based on other worst-case assumptions including that the fire will occur on worst-case meteorological conditions for that wind direction. The in-combination possibility of a fire event taking place during the worst-case meteorological conditions is considered to be extremely low.

These areas of exceedance are expected to occur downwind of any battery container; however, the maximum area of exceedance (AEGL Level 1) has been stated to account for all possible wind conditions.

There is no requirement for exclusion zones surrounding the Proposed Facility, as no exceedances of the AEGL Levels 2 and 3 were predicted for any exposure period.

In the unlikely event of a battery fire occurring at the Site, as a precautionary measure, the areas within the AEGL Level 1 maximum area of exceedance should be avoided by the general public where possible.

Table 2: Fire Scenario Results

AEGL level	AEGL		Maximum Distance of Exceedance (m)
	Exposure Period	Value (ppm)	
1	10-min	1	157
	30-min	1	130
	1-hour	1	105
	4-hour	1	79
	8-hour	1	78
Notes: Maximum distance of exceedance (m) values were rounded to the nearest whole number.			

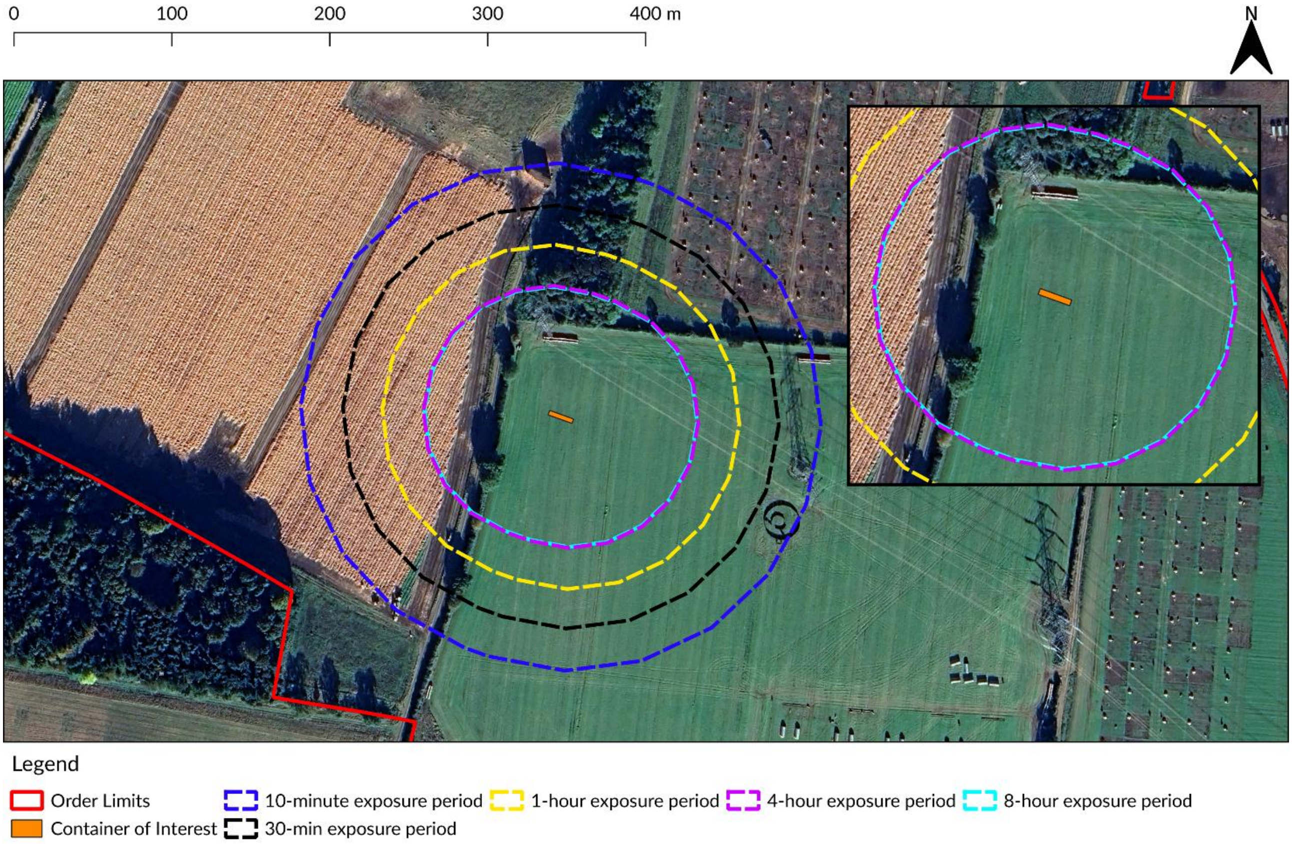


Figure 3: The maximum distance of exceedance zones for AEGL 1 exceedance (dashed line) for the exposure periods considered. Contains Google Satellite data © Crown copyright and database rights 2025.

4. Conclusion.

Hoare Lea have been commissioned by the Applicant to assess the potential air quality impacts on the local area in the event of a battery failure, resulting in the plume dispersion of hazardous gas emissions at the proposed BESS at the Droves Solar Farm.

This assessment has considered air pollutant emissions dispersion in a fire scenario to assess the potential impact on existing receptors in the vicinity of the Site. It is important to note that battery failure is an unlikely event, however, should this occur, there will be adequate safety systems in place to control the situation and avoid further failure. However, for the assessment approach, robust and worst-case assumptions have been made in a reasonable manner.

The results of the assessment indicate that AEGL Levels 2 and 3 for HF were not exceeded for any of the five exposure periods considered. These are levels where irreversible or other serious long-lasting health impacts could be experienced.

It is worth noting that the modelled BESS location is based on a worst-case assumption due to its proximity to existing sensitive receptors. The AEGL Level 1 maximum area of exceedance of 157 m for the 10-minute exposure period, which is based on the BESS design parameters considered in this assessment, should be accounted for when selecting the fixed location of the BESS in order to minimise the risk to human health at sensitive receptors.

Further, these results are based on other worst-case assumptions including that the fire will occur on worst-case meteorological conditions for that wind direction. The in-combination possibility of a fire event taking place during the worst-case meteorological conditions is considered to be extremely low.

It is important to note that health impacts associated with AEGL Level 1 values are transient and reversible upon cessation of exposure. As such, a worst-case battery fire is unlikely to lead to serious or long-term health impacts on receptors at any distance from the Site.

In the unlikely event of a battery fire occurring at the Site, as a precautionary measure, the areas within the AEGL Level 1 maximum area of exceedance should be avoided by the general public where possible.

In summary, the key findings of this assessment indicate that it is unlikely that there will be serious or permanent health impacts predicted at any distance under worst-case battery fire conditions. The AEGL Level 1 maximum area of exceedance of 157 m for the 10-minute exposure period is likely to reach minor roads likely to be accessible to the general public, in the vicinity of the Site, under a reasonable worst-case fire (in the unlikely event) and worst-case meteorological conditions. In this scenario the predicted impacts are transient and reversible.

5. Glossary of terms.

AEGL	Acute Exposure Guideline Levels
BDC	Breckland District Council
BESS	Battery Energy Storage System
BSMP	Battery Safety Management Plan
CO	Carbon Monoxide
HCl	Hydrogen Chloride
HCN	Hydrogen Cyanide
HF	Hydrogen Fluoride
LFP	Lithium Iron Phosphate
NO_x	Nitrogen Oxides
PM	Particulate Matter
SOC	State of Charge

Appendix 1 – Model input parameters.

An assessment has been undertaken using ADMS 6 to consider the gases emitted from the Proposed Facility in a fire scenario.

Model input and emissions parameters.

Fire scenario

Section 2.1 within the report details the methodology and calculations behind the emissions used within the dispersion model for the fire scenario. As a robust and reasonable worst-case assumption, the fire scenario was considered for one entire container flaming during a battery failure event.

The data inputted into the model is shown in Table 3.

Table 3: Model Input Parameters used in ADMS 6

Parameter	Value
Container dimensions (length, width, height) (m)	16, 3.0, 3.2
Container area (top) (m^2)	48
Battery container energy capacity (MWh)	5.0
Fire temperature (°C)	822.5
Velocity of gas release from fire (m/s)	0.1
HF emission (per cell at 50-100% SOC) (mg/Wh)	33.88*
HF emission rate (g/s)	5.88
HF emission rate ($g/m^2/s$)	0.1225
Modelled flame height (m)	5.3
Note: * indicates HF emission per cell associated with the literature[1,2]	

HF Emission rate

The calculation of the HF emission rate per container area (48 m^2) for the area source of HF emissions used in the ADMS 6 model is demonstrated below, with the respective model inputs summarised in Table 3.

The 33.88 mg/Wh battery HF emission rate taken as an average from the various literature reports[1,2] (per cell at 50-100% state of charge) was used to calculate the mass of HF gas emitted by the battery container. To ensure a robust assessment the emission rate was assumed constant throughout the fire event.

The model has been run for every hour of a year with an hourly emission rate of 0.1225 $g/s/m^2$ to cover any potential flaming length. As a worst-case assumption, utilising relevant information provided by the project team, the fire duration has been assumed to be 8 hours for the emissions calculation, with the entire container assumed to burn out within this duration.

Exposure periods.

Two out of the five AEGL exposure periods are below 1-hour: 10-minute and 30-minute, respectively. The model used for the purpose of the dispersion modelling exercise has allowed for the calculation of peak 1-hour concentrations (100% percentile) to align with the modelling process and input parameters such as the meteorological data, which is based on hourly data.

Subsequently, two separate factors have been applied to peak 1-hour concentrations (100% percentile) to determine the concentrations for a 10-minute and 30-minute average, which are provided below:

- 1.65 to convert into a 10-minute average; and
- 1.3 to convert into a 30-minute average.

The calculation for the factor to convert to a 10-minute average has been derived from the equation specified within Section 17 of Ontario Regulation 419/05 'Air Pollution – Local Air Quality'[3]. The factor to convert into a 30-minute average has been obtained from the Environment Agency (EA) document 'Air emissions risk assessment for your environmental permit'[4].

Background.

The HF background concentration used for the purpose of the assessment is detailed within Table 4.

Table 4: Predicted Background Concentrations.

Pollutant	Daily Background Concentration (µg/m^3)	Source
HF	0.5*	EPAQS (February 2006), Guidelines for Halogen and Hydrogen Halides in Ambient Air for Protecting Human Health Against Acute Irritancy Effects
*A range of 0.5 – 2 µg/m^3 is outlined in the EPAQS Guidelines, with heavily polluted areas at the upper end of this range, however, according to the UK Pollutant Release and Transfer Register (PPTR)[5], no industrial sites within 3 km vicinity of the Site have reported hydrogen fluoride pollutant release to air in any of the years 2019-2024. As such, a background HF concentration of 0.5 µg/m^3 has been used.		

Topography.

Topography data can also be added as an input to ADMS-6 model where required. Topography data can have an effect on the flow of the emissions and should be considered when a slope gradient of 1:10 is observed in the terrain surrounding the site. As the topography surrounding the site is less than a gradient of 1:10, topography data was not included in this assessment.

Meteorological Data.

The dispersion model includes a meteorological pre-processor developed by the UK Met Office to calculate values of meteorological parameters in the boundary-layer. The pre-processor requires a set of meteorological parameters on an hour-by-hour basis: wind speed, wind direction, temperature, and cloud cover.

It is important to use meteorological data which is representative of the conditions within the Proposed Facility to simulate local weather conditions in the model. Marham station is located approximately 9.5 km southwest of the Proposed Facility. There is an approximate 33 m difference in elevation between Marham meteorological station and the Proposed Facility, with similar surroundings and set back at similar distance from the coastline (approximately 25 km and 27 km, respectively). As such, Marham meteorological station has been used as it is considered representative of conditions surrounding the Proposed Facility. Meteorological analysis was conducted to assess the worst-case year of meteorological conditions, upon which 2023 was determined to be the worst-case year for the 10-minute, 30-minute, 1-hour and 8-hour exposure periods and 2024 was determined to be the worst-case year for the worst-case year for 4-hour exposure period. This is based on the highest peak HF concentrations observed in each meteorological year.

Wind roses from 2022, 2023 and 2024 are shown in Figure 4.

[3] Ministry of the Environment, Conservation and Parks (2023) Ontario Regulation 419/05 Air Pollution – Local Air Quality – [online] (Last accessed: 14/04/2025), Available at: www.ontario.ca/laws/regulation/050419

[4] EA (2016) Air emissions risk assessment for your environmental permit – [online] (Last accessed: 14/04/2025), Available at: www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit

[5] Defra (2014) UK Pollutant Release and Transfer Register – [online], (Last accessed: 14/04/2025), Available at: www.gov.uk/guidance/uk-pollutant-release-and-transfer-register-prtr-data-sets

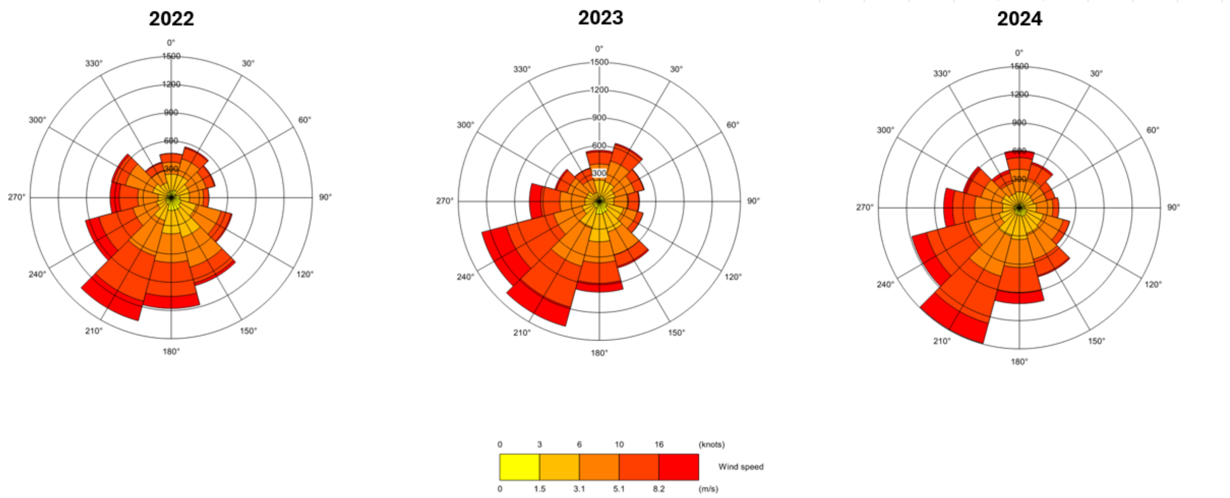


Figure 4: Wind roses from Marham Meteorological Station in 2022, 2023 and 2024.

The wind roses show a south westerly prevailing wind in all three years. Table 5 shows the values for surface roughness and the Monin-Obukhov length inputs used in the model. There same values for surface roughness and Monin-Obukhov Length were utilised around the Proposed Facility and the Marham meteorological station, due to both being predominantly surrounded by agricultural land and small villages, which has been reflected in the model.

Table 5: Meteorological Data Settings used in ADMS 6

Meteorology		Value
Monin-Obukhov Length (m)	Dispersion Site	10
	Meteorological Measurement Site	10
Surface Roughness (m)	Dispersion Site	0.3
	Meteorological Measurement Site	0.3

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