Heckington Fen Solar Park

EN010123

Outline Energy Storage Safety Management Plan

Applicant: Ecotricity (Heck Fen Solar) Limited

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OUTLINE ENERGY STORAGE SAFETY MANAGEMENT PLAN

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Report

Outline Energy Storage Safety Management Plan

Prepared for – Ecotricity (Heck Fen Solar) Limited

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EXECUTIVE SUMMARY

This document presents a Outline Energy Storage Safety Management Plan (OESSMP) for the Energy Storage System (ESS) element of the Heckington Fen Energy Park. The OESSMP presents an approach and methodology for the safety assurance activities required to support a safety justification for the ESS section of the Heckington Fen facility.

Ecotricity (Heck Fen Solar Limited), hereafter referred to as 'the Applicant', have received a number of responses during pre-application scoping and consultation in relation to battery fire safety, including from The Planning Inspectorate, Lincolnshire Fire and Rescue (LFR) and North Kesteven District Council. This report applies to generic, grid scale EES, including Battery Energy Storage Systems (BESS). The activities described in the this report address the safety related comments from the external stakeholders as well as providing a summary safety report that can be used to present all safety arguments for the ESS to other consultees. Additionally, the OESSMP will be secured within a requirement in the Development Consent Order (DCO), and the core safety assurance tasks, detailed in this OESSMP, will be produced prior to commencement of the ESS.

The tasks described in the plan are split in to two groups:

Section 2.1 - Core Safety Assurance Tasks - these tasks provide the core safety assurance for the ESS, the completion of the summary safety justification for the ESS is dependent on completion of all tasks in this section.

- Standards Review
- Hazard Identification and Management
    - Concept HAZID Workshop
    - Hazard Register
    - Safety Requirements
    - Design HAZID workshop
- Fire Risk Assessment
- Site Emergency Response Plan (ESS)
- Summary Safety Report

At the conclusion of the above core assurance tasks, the Summary Safety Report will describe all safety assessments, their outputs and findings to complete the safety justification for the ESS at Heckington Fen Energy Park, demonstrating that all risks have been reduced As Low As Reasonably Practicable (ALARP).

Section 2.2 - Additional Tasks - further, independent and optional tasks which may add further value to the core safety tasks.

- Presentation of Hazards to 3rd parties via the Bowtie Method
- Human Factors analysis

ISSUE RECORD

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0.2	3-Oct-22	Matthew Sephton	Nick Taylor		Draft release to client
1.0	28-Oct-22	Matthew Sephton	Nick Taylor	Gordon Dixon	Issue 1.0 release
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3.0	10-Feb-23	Matthew Sephton	Edward Thomas	Edward Thomas	Update to Issue 2.0 to include Plume assessment only.
4.0	1-Dec-23	Matthew Sephton	Edward Thomas	Edward Thomas	Minor update to 2.1.4 to add fees payable for familiarisation and annual review

DISTRIBUTION

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ABBREVIATIONS

Abbreviation	Description
ALARP	As Low As Reasonably Practicable
BESS	Battery Energy Storage System
DCO	Development Consent Order
ESS	Energy Storage System
FRA	Fire Risk Assessment
HAZID	Hazard Identification
HF	Human Factors
LFR	Lincolnshire Fire and Rescue
OESSMP	Outline Energy Storage Safety Management Plan

1 INTRODUCTION

1.1 Overview

The Applicant is in the planning stages for an Energy Storage System (ESS) delivering up to 400MW/800MWhr of energy storage linked to a solar farm at the Heckington Fen Energy Park in Lincolnshire. As a part of the planning process, a number of external stakeholders have asked questions relating to the management of hazards associated with an ESS using Battery Energy Storage System (BESS) technology.

1.2 Purpose

This OESSMP presents an approach and methodology for the safety assurance activities required to support a safety justification for the ESS section of the Heckington Fen Energy Park. This methodology includes the activities required to identify and manage all foreseeable hazards associated with the ESS, within the relevant regulatory frameworks.

Following the approach outlined in this OESSMP will allow the Applicant to manage the hazards/risks identified through the hazard identification activities such that they can be engineered-out where possible, or where not, appropriate arrangements are established to reduce the residual risk As Low As Reasonably Practicable (ALARP), thereby presenting a robust safety justification for the ESS.

1.3 Risktec

Risktec is an established, independent and specialist risk management consulting and training company, and is part of the TÜV Rheinland Group. We assist clients in major hazard industries as well as commercial and public sectors to manage health, safety, security, environmental and business risk.

Risktec have completed a number of system safety assessments on grid scale energy storage systems, including Hydrogen and BESS. Risktec have worked with a BESS supplier as well as with BESS operators to integrate BESS in to clean energy infrastructure. Furthermore Risktec routinely provide system safety support to our clients, through our consultancy and learning (education and training) divisions.

1.4 Scope

The OESSMP covers the footprint of the ESS and its interfaces to the wider Heckington Fen site; it applies to generic, grid scale EES, including battery energy storage systems. The interim energy park design drawing (ref. 1) shows a BESS concept for energy storage; in this concept, the BESS is located in the central red shaded section close to the 400kV substation. At the initial design stage the solar collection and battery storage is expected to be split in to 4 or 5 independent electrical sections, each feeding a high voltage connection to the grid transformer. Each section is expected to be able to be isolated from and operate independently of the others, allowing for maintenance or repair to take place without isolating the entire site.

The ESS storage is expected to be up to 400MW/800MWhr, however the supplier, and therefore the specifc energy storage technology, have not yet been selected. From examples of BESS products from four different suppliers under consideration (ref. 3, 4, 5 & 6) it is likely that a BESS concept would be a modular Li-ion based system housed in outdoor cabinets and including integrated battery management, cooling, fire suppression and AC to DC inverters. The safety management approach set out in this report is applicable to all solutions under consideration.

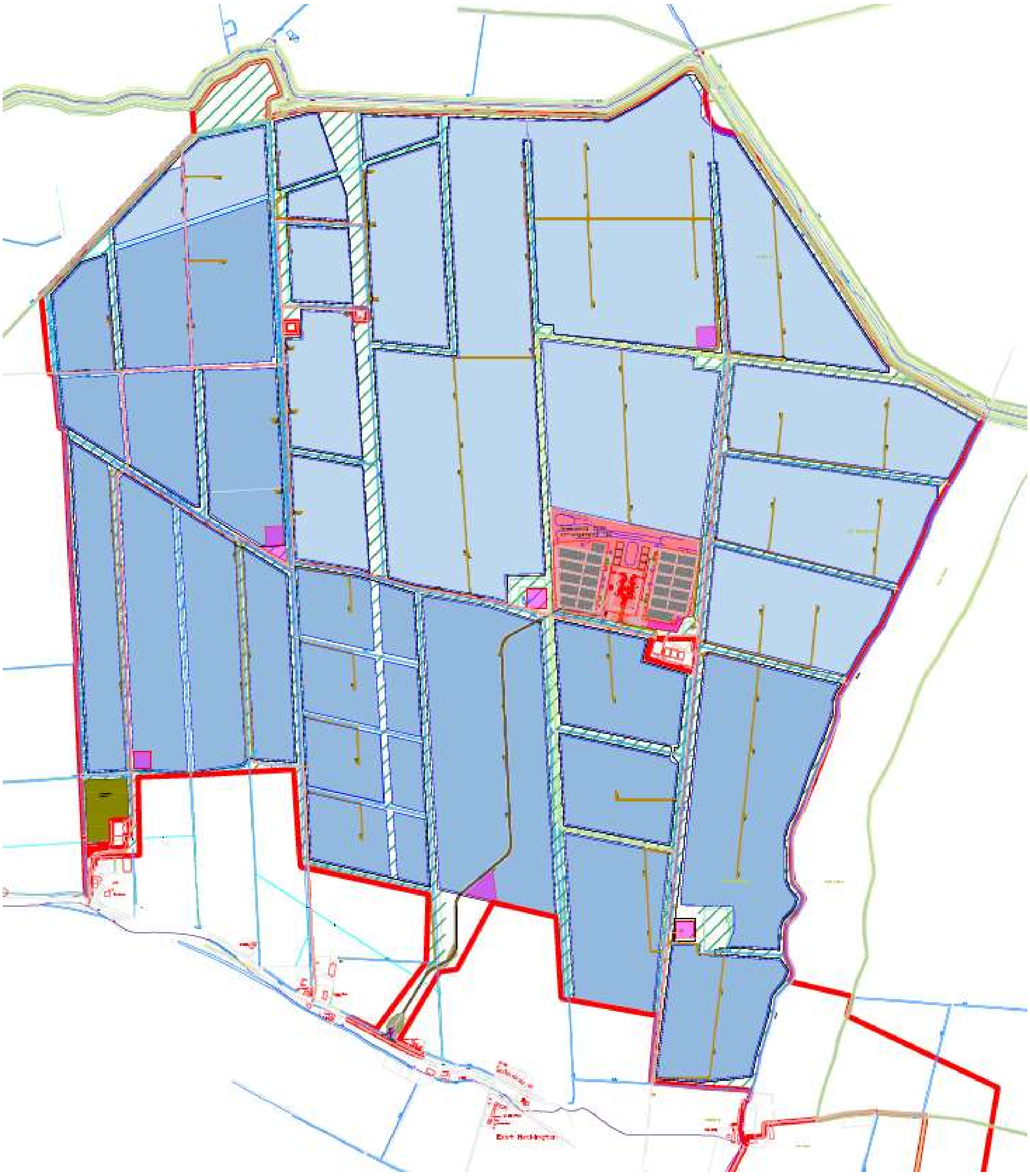

Figure 1: Heckington Fen Energy Park initial layout (ref. 1)

1.5 External Stakeholder Requirements

The Applicant has received a number of responses during pre-application scoping and consultation in relation to battery fire safety, including from The Planning Inspectorate, Lincolnshire Fire and Rescue (LFR) and North Kesteven District Council.

1.5.1 The Planning Inspectorate

The Planning Inspectorate will oversee the application process for the Heckington Fen Energy Park.

Following review of the Environmental Impact Scoping Report (ref. 10) and a consultation period The Planning Inspectorate produced a Scoping Opinion (ref. 11); this draws together responses from a number of 3rd parties to the consultation, and places the following requirement on the Heckington Fen Energy Park:

- *The Inspectorate considers that the risk of battery fire/explosion should be addressed in the Environmental Statement (ES), including where any measures designed to minimise impacts on the environment in the event of such an occurrence are secured.*

1.5.2 Lincolnshire Fire and Rescue

LFR are the local fire and rescue service in the vicinity of the proposed Heckington Fen site.

LFR have identified the following requirements in an undated letter received on 12th September 2022 in response to the initial Heckington Fen Energy Park designs (ref. 2):

1. Risk Reduction Strategy – in collaboration with LFR
    a. Covering construction, operational and decommissioning phases of the project
2. Emergency Response Plan
3. BESS Facility design and specification requirements relating to fire safety
4. Transport Strategy
5. Environmental Impact

Requirements 1 to 3 in the list above are addressed in this OESSMP; requirements 4 & 5 are to be addressed in the Environmental Statement.

A majority of the design and specification requirements identified by LFR are likely to be included as part of a system that would be purchased. Industry recognised mititigations will be considered, such as automatic fire detection, fire suppression systems, off gas detection, and multiple layers of protection including the use of fire-resistant materials and built-in thermal barriers. For a product to be marketed in the UK it is expected it would comply with the relevant legislation, and the Applicant would make this a requirement of the tendering process. The Applicant's design has incorporated LRF comments, including separation between units (5m), located away from residential areas, and providing sufficient access for firefighting appliances. Furthermore, air conditioning systems have also been assumed within the design to control the temperature. The system will be continuously monitored during operations, which would include detection of: off-gases; carbon monoxide; and an early warning fire detection system.

An Emergency Response Plan (ERP) will be completed once a technology has been confirmed and in advance of the ESS being constructed, see section 2.1.4. The ERP will be regularly reviewed, and material changes communicated to the LFR. The ERP will contain information on water supplies, should these be confirmed as required, and drainage plans. If applicable, the ERP will contain details of the hazards associated with lithium-ion batteries, isolation of electrical sources to enable fire-fighting activities, measures to extinguish or cool batteries involved in fire, management of toxic or flammable gases, minimisation of the environmental impact of an incident, containment of fire water run-off, handling and responsibility for disposal of damaged batteries, establishment of regular onsite training exercises. A copy of this information could be included in an Information Box available onsite.

1.5.2.1 Water Requirements

Initial water requirement assumptions are based on a BESS, water requirements may change in response to relevant national guidance or policies in relation to the handling of fires within the ESS technology chosen for the site.

Whilst fire hydrants are available in the local area, they are too far from the energy storage to be reached with typical firefighting equipment. Water tanks are therefore included in the design to provide water in excess of the 1,900 l/min for at least 120 minutes (228,000 litres), should at the time of construction a suitable alternative not be available. The reason for this caveat is that technology is developing quickly, and water may not be the most suitable method to fight a fire comprising electronic equipment.

In order to ensure a deliverable worse case design, the Applicant has built in sufficient water provision, via eight large storage tanks (a maximum parameter of 10m diameter and 4m height) to provide sufficient water to meet the indicative requirements provided by feedback from stakeholders. Using the maximum parameters the design could store up to 2,500,000 litres of water onsite.

It is expected a fire hydrant could be extended into the site via the new site access onto the A17 whereby the current water main runs. Should the detailed design and safety report require it, in consultation with the LFR, a relevant application for one or more fire hydrants will be made at the appropriate time. As confirmed by the Environment Agency, emergency abstractions could also take place in the nearby drains should water be available, however this is not assumed and the water tanks are again provided in the layout, should detailed design prior to construction require them.

1.5.3 North Kesteven District Council

North Kesteven District Council made the following comment in response to the scoping proposal:

In terms of the proposal to scope out 'Major Accidents or Disasters', the applicant confirms that the risk of an accident would relate primarily to the risk of fire or explosion associated with the battery storage element. Whilst the extent and positioning of the battery storage is to be determined, it is unclear as to the magnitude or effect of such an event. Whilst it is recognised that the battery energy storage system would have mitigation through cooling systems, this does not eliminate the risk. Therefore, whilst we agree that 'Major Accidents or Disasters' does not warrant formally 'scoping in', nevertheless further information should be presented with the DCO application which sets out how these risks will be mitigated and managed through scheme design and maintenance

1.6 Development Consent Order Requirement

As part of the planning process for the Heckington Fen Energy Park and its associated ESS, the Applicant is applying for a DCO. The OESSMP will be secured within a requirement in the DCO; this will formally set out how ESS hazards will be identified and managed.

2 ENERGY STORAGE SAFETY MANAGEMENT PLAN METHODOLOGY

The methodology for the OESSMP is presented in this section. The tasks included in the plan have been chosen to deliver safety assurance of the Heckington Fen ESS as well as to show a route to compliance to requirements set by key stakeholders. It is envisaged that the safety assurance process will work in collaboration with the design process as hazards identified in the early stages can be highlighted to the design team, giving the opportunity to mitigate by design rather than by adding additional systems later in the project.

The tasks included in the OESSMP are divided in to two sections:

> Section 2.1 Core Safety Assurance tasks – These tasks provide the core safety assurance for the ESS, and are intended to meet the 'requirements set by external stakeholders as described in section 1.5. The completion of the summary safety justification for the ESS is dependent on completion of all tasks in this section.
>
> Section 2.2 Additional Tasks – Further, independent and optional tasks which may add further value to the core safety tasks.

2.1 Core Safety Assurance tasks

2.1.1 Standards Review

A regulatory review will be undertaken to determine the relevant standards and regulations that apply to the installation, operation and decommissioning of the technology type chosen for the ESS. This output of the standards review will be a list, in table form, detailing the standard and any notes on its scope and applicability.

The list of standards will be used as guidance prior to and during the Hazard Identification phase, and to inform the requirements of ESS to aid in supplier and technology options selection.

2.1.2 Hazard Identification and Management

The Hazard Identification stage aims to ensure that all reasonably foreseeable hazards associated with the design, operation and maintenance of the ESS have been identified and compiled into a Hazard Register. Once complete, the Hazard Register will act as the single source of safety requirements for the ESS. Evidence that the safety requirements have been met will be collated and referenced in the Hazard Register as the project progresses through the design stages. When all safety requirements are evidenced the Hazard Register will form the basis of the safety justification for the ESS by demonstrating that all foreseeable hazards have been identified and risks managed to an acceptable level.

2.1.2.1 Concept HAZID workshop

The aim of the concept hazard identification (HAZID) workshop is to identify reasonably foreseeable hazards and their respective prevention and mitigation measures for the ESS concept, given the best knowledge of the system available at the time of the HAZID.

This workstream will primarily identify hazards with a safety related consequence, it is likely that hazards with environmental, or commercial consequences will also be identified.

The concept HAZID will use initial site layouts and requirements as well as drawing on the Applicant and Risktec's experience from other similar projects, and will use a structured approach and a set of key words (Appendix A) to identify high level hazards associated with the ESS concept and its interfaces to the wider Heckington fen site. The keywords suggested for use in the HAZID workshop have been derived from checklists recommended from similar industries, specifically BS EN ISO 12100 (ref. 12), BS EN ISO 17776 (ref. 13), DNVGL-ST-0145 (ref. 14) and Risktec's experience of facilitating similar hazard identification workshops. The hazards identified will feed in to the first issue of the Heckington Fen ESS Hazard Register.

2.1.2.2 Hazard Register

A formal Hazard Register will act as the central repository for all hazards identified and evidence of how preventative and mitigation measures, safety requirements and actions have been addressed.

The Hazard Register will include a Risk Acceptance Matrix which will be used to score the hazards, identifying those which are acceptable, and those which require further evidence of mitigations. The Risk Acceptance Matrix will use scoring criteria shown in Appendix B to ensure consistency with pre existing Heckington Fen risk registers (ref. 9).

Where hazards fall outside the scope of the safety assurance activities, or where they are managed by other workstreams or 3rd parties, a process will be put in place to transfer ownership of the hazard and responsibility for mitigations.

The Hazard Register will be a live document which is managed through the life of the project; showing the status of all safety hazards at any point in the project lifecycle as they are being added, or evidenced and closed as the design process progresses. At the end of the design process, the Hazard Register should show that all hazards are managed to a tolerable level with evidence; this will form the basis of the safety justification for the ESS installation.

2.1.2.3 Safety Requirements

Through the hazard identification, standards review, and from 3rd party requirements (e.g. LFR), a set of safety requirements (hazard mitigation measures) will be identified. The safety requirements identified will be evidenced in the Hazard Register to show how the hazards are mitigated, this will feed in to the overall safety justification for the ESS. The safety requirements that are identified following the concept HAZID can also be used as part of the options selection process for ESS supplier and any optional safety technologies they may offer.

2.1.2.4 Design HAZID Workshop

As the design matures, site layout and interfaces are designed, and the ESS supplier is chosen, a further HAZID workshop is recommended to build upon the concept stage hazards identified.

The Design HAZID will take a deeper look in to the detail of the design and technologies selected to give a more detailed, site specific set of hazards than initially identified in the concept HAZID. The scope of the final HAZID workshop will consider all lifecycle phases, namely:

- Installation and transportation;
- Commissioning;
- Operation;
- Maintenance; and
- Decommissioning.

2.1.3 Fire Risk Assessment

The ESS Fire Risk Assessment (FRA) will directly address any fire/explosion hazards that are anticipated to be identified in the HAZID workshops.

The FRA is a methodical review in terms of fire hazards, the likelihood that a fire could start within the ESS system or at its interfaces, and people that could be harmed by the incident. The FRA will comply with the requirements of Regulation 9 of the Regulatory Reform (Fire Safety) Order 2005 (ref. 7), which requires any company that employs five or more people to:

- Identify fire hazards;
- Identify people at risk;
- Evaluate, remove, reduce and protect from risk;
- Record, plan, inform, instruct and train;
- Review.

The Regulations (ref. 7) require that for any significant findings of the assessment, actions to be taken arising from the assessment, or any persons who is especially at risk, must be recorded.

The assessment will be conducted following the methodology and guidance within BS PAS 79-1:2020 (ref. 8), Fire risk assessment – Guidance and recommended methodology. If during the FRA process any dangerous substances are identified (this is dependent on ESS technology or battery chemistry) the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) (ref. 15) will apply; and a DSEAR Risk Assessment will also be completed for the ESS.

An Indicative Plume Assessment (Air Quality Technical note shown in Appendix C) has been completed. Once a technology provider is chosen, and the composition of the energy storage is known, a further Plume Assessment will be completed and included in the FRA.

The Fire Risk Assessment will be released following completion of the design HAZID and population of the Hazard Register, however a concept Fire Risk Assessment can be released following completion of the Concept HAZID if required by stakeholders.

2.1.4 Site Emergency Response Plan – ESS

A Site Emergency Response Plan will be created for the ESS site; this can be a standalone document or included in the wider Heckington Fen Energy Park Emergency Response Plan as required.

The Emergency Response plan is a key requirement of the Lincolnshire Fire and Rescue (LFR) (ref. 2) and for a BESS should include the following:

- Details of the hazards associated with the technology chosen, e.g. lithium-ion batteries,
- Isolation of electrical sources to enable fire-fighting activities,
- Measures to extinguish or cool batteries involved in fire,
- Management of toxic or flammable gases,
- Minimise the environmental impact of an incident, including the prevention of ground contamination, water course pollution, and the release of toxic gases,
- Containment of fire water run-off, (contaminated water, if applicable)
- Handling and responsibility for disposal of damaged batteries,
- Establishment of regular onsite training exercises.

The emergency response plan will be developed through the design stage of the ESS and in consultation with LFR and any other relevant stakeholders. The undertaker must, prior to the date of final commissioning of the ESS use reasonable endeavours to facilitate a site familiarisation exercise for LFR for the purposes of providing the necessary assurance to them that all the required systems and measures are in place in accordance with the Energy Storage Safety Management Plan. A fee of £16,665 will be paid to LFR (or another body as deemed appropriate by them, e.g. Lincolnshire County Council) to facilitate this site familiarisation exercise. Once the ESS is operational the Emergency Response Plan will be maintained by the site operator and regularly reviewed with any material changes notified to LFR. Following the first year of operation, the undertaker must use reasonable endeavours to facilitate an annual review of the site by LFR up until the year in which the undertaker commences decommissioning. An index linked fee of £1,530 will be payable following the annual review by LFR.

The ESS Emergency Response Plan will be released following completion of the design HAZID and population of the Hazard Register, however a concept ESS Emergency Response Plan can be released following completion of the Concept HAZID if required by stakeholders.

2.1.5 Summary Safety Report

At the conclusion of the above safety management and assurance activities, a Summary Safety Report will be created, detailing the methodology and results of all the safety activities carried out in support of the ESS at Heckington Fen Energy Park. The Summary Safety Report will also include assurance that there are robust quality assurance and competence management systems in place for the ESS. The Summary Safety Report will present a safety justification for the ESS, supported by evidence, demonstrating that all risks have been reduced ALARP.

2.2 Additional Tasks

The following sections describe optional and independent tasks which may add further value to the core safety tasks.

2.2.1 Presentation of Hazards to 3rd parties via Bowtie method

It is proposed that the bowtie method is used to present the major hazards associated with the ESS to 3rd parties such as LFR or relevant planning authorities.

The bowtie technique is a way of clearly illustrating how risk is being managed within a facility, operation, task, etc. It helps to ensure that risks are managed rather than just analysed, partly by going beyond the usual risk assessment “snapshot” and highlighting links between the risk control and management systems.

Figure 2 illustrates the basic structure of a bowtie diagram.

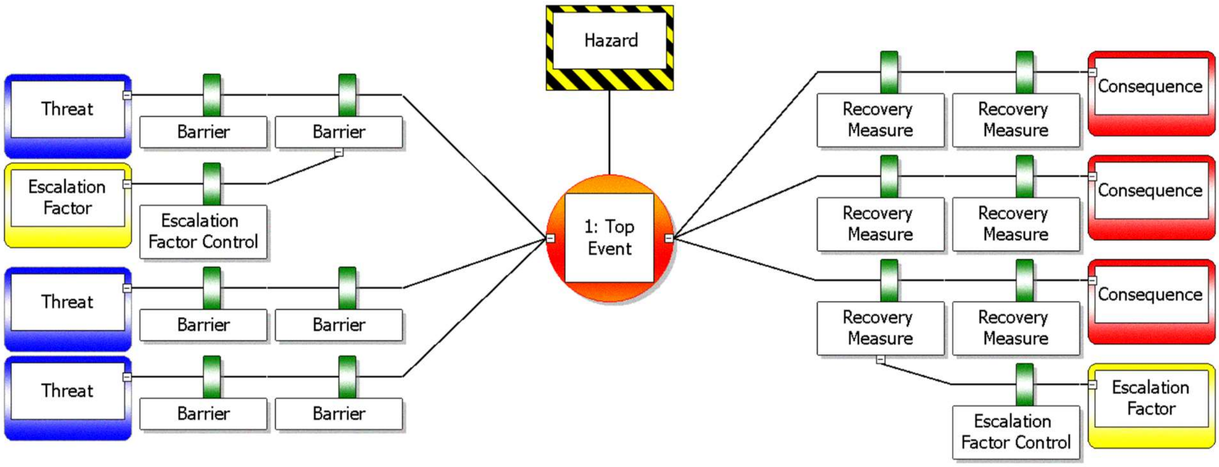

Figure 2: Basic Structure of a Bowtie Diagram

The key elements of a bowtie are:

- The Hazard that has the potential to give rise to the unwanted event you are concerned about. This is illustrated in the yellow/black striped box.
- The unwanted event you are concerned about if the hazard is realised. This is called the Top Event and is the red circle, which forms the "knot" of the bowtie.
- The credible causes of the unwanted event. These are the Threats and are illustrated in blue on the left hand side of the diagram.
- The unmitigated Consequences of the unwanted event. These are illustrated in red on the right hand side of the diagram.
- An Escalation (or Degradation) Factor which could compromise the integrity of a barrier. These are illustrated in yellow.
- The Barriers in place to prevent the unwanted event occurring or minimise its consequences. Those on the left hand side of the diagram prevent the hazard being realised and are categorised as Prevention. Those on the right hand side minimise the ultimate consequences of the hazard if realised and hence represent Mitigation. Barriers can also be included to eliminate or minimise the impact of an Escalation Factor on the integrity of a specific barrier, either prevention or mitigation.

The bowtie methodology provides a clear, auditable trail from hazards from identification to implementation for the specific systems, processes, and procedures.

It is proposed that bowtie diagrams are created for the major ESS hazards, e.g. fire and electrocution; these bowtie diagrams would then be validated in a bowtie workshop, to ensure that good safety measures/barriers are introduced and to ensure risks are reduced ALARP.

2.2.2 Human Factors

It is recommended that Human Factors (HF) specialists support the design phase by helping to consider HF analysis early in the design process, to optimise human interactions within the ESS, which in turn reduces the need for modifications to the design and/or operational and maintenance procedures at a later stage.

A HF Integration Plan will be produced to describe how all aspects of HF will be integrated into the design, operations and maintenance of the ESS within the wider Heckington Fen Energy Park.

Details of the required tasks to be undertaken will be captured in the HF Integration Plan once the Applicant's requirements are fully scoped. Typical human factors assessments that may be pertinent to this facility include (but are not limited to) the following:

- Early human factors analysis
- Safety critical task analysis / human error analysis
- Human error analysis

- Alarms assessment
- Human-machine interface assessments
- Management of HF issues in issues register
- Training needs analysis
- Physical ergonomics assessments
- Control room assessment
- Environmental ergonomics assessment (where separate from control room assessment)
- Manual handling assessments

2.2.3 Interim Summary Safety Report

Prior to completion of all safety activities, an Interim Summary Safety Report can be issued to report on work done at the point of issue. Risktec suggest after the concept HAZID and Hazard Register population as an appropriate point for reporting; at this stage the interim report would cover the concept ESS Hazards and associated Safety Requirements as well as work to do in the next stages of the project.

3 CONCLUSION

This OESSMP presents a set of activities that when carried out, will identify and manage all foreseeable hazards associated with the ESS and will present an Emergency Response Plan and Summary Safety Report.

The Applicant has received a number of responses during pre-application scoping and consultation in relation to battery fire safety, including The Planning Inspectorate, LFR and North Kesteven District Council. This report applies to generic, grid scale EES, including battery energy storage systems. The activities described in the this report address the safety related comments from the external stakeholders as well as providing a summary safety report that can be used to present all safety arguments for the ESS to other consultees. Additionally, the implementation of the OESSMP will be secured as a requirement within the DCO application.

The optional inclusion of the bowtie analysis for presenting the major ESS hazards along with their threats, consequences and mitigations provides a graphical way to present hazards and explain the protections to other stakeholders where applicable.

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Ref	Title
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15.	UK Government. The Dangerous Substances and Explosive Atmospheres Regulations 2002. UK Statutory Instruments No. 2776, 2002.

Appendix A HAZID GUIDEWORDS

Ref	Hazard Category & Description
1	**Electrical Incident**
1.1	High voltage faults
1.2	Short circuit in electrical installations (LV)
1.3	Touch and step voltages
1.4	Impressed voltage
1.5	Short circuit in electrical installations
1.6	Release of SF6
1.7	Electrocution, electric shock
1.8	Unattended electrical consumer
1.9	Failure of lightning protection
1.10	Electromagnetic compatibility / health problem
1.11	Induced voltages
1.12	Loss of (emergency) power
1.13	Fuel release from emergency generator, day tank or storage tank
1.14	Hydrogen release from batteries
1.15	Battery leakage
1.16	Crossing services (overhead / buried)
2	**Fire and Explosion Incidents**
2.1	Battery fire or explosion
2.2	Main / utility transformer fire or explosion
2.3	Capacitor fire or explosion
2.4	HV switchgear fire or explosion
2.5	Cabling fire or explosion
2.6	Cable termination fire or explosion
2.7	Other equipment fire
2.8	LV equipment fire
2.9	Emergency generator fire
2.10	Fuel release from emergency generator, day tank, or storage tank
2.11	Toxic smoke
2.12	Office / store room fire
2.13	Fire or explosion in chemical store
2.14	Other flammable materials
2.15	Bottled gas under pressure / Equipment and welding during construction
2.16	Hot works (maintenance)
2.17	Buried services (gas)
3	**Access**
3.1	Unauthorised access to facility
3.2	Sabotage
3.3	Theft, pilferage
3.4	Assault
3.5	Cyber crime
4	**Structural Incident**
4.1	Structural damage due to environment (e.g. subsidence)
4.2	Vehicle collision with building
4.3	Dropped Object, swinging load
5	**Dynamic Situation Hazards**
5.1	Road Transport
5.2	Equipment with moving or rotating parts
5.3	Use of hazardous hand tools (grinding, sawing)
5.4	Use of knives, machetes and other sharp objects
6	**Emergency Response Incident**
6.1	Loss of escape route from building
6.2	Loss of communications
6.3	Loss of remote control
6.4	Failure of emergency lights, signage
6.5	Alarm system impairment
6.6	Lone working
6.7	Lack of emergency response / rescue
7	**Other Incidents**
7.1	Release from cooling system
7.2	Failure of HVAC system
7.3	Occupational hazards
8	**Hydrocarbons**
8.1	Transformer oil
8.2	Hydraulic oil
8.3	Diesel fuel
8.4	Petroleum spirit/gasoline
8.5	Hydrogen
8.6	Hydrocarbon gas
8.7	Greases / other lubricants
9	**Other Flammable Materials**
9.1	Cellulosic materials
9.2	Pyrophoric materials
10	**Pressure Hazards**
10.1	Bottled gas under pressure
10.2	Bottled gas under pressure
10.3	NonHC gas under pressure in pipework
10.4	Air under high pressure
10.5	Oil and hydrocarbon gas under pressure
11	**Hazards Associated with Differences in Height**
11.1	Personnel at height
11.2	Trips / slips / falls on same level
11.3	Overhead equipment
11.4	Lifting operations
12	**Weather**
12.1	High wind
12.2	Lightning
12.3	Heavy rain / snow / flooding
12.4	Ice
12.5	High temperature
12.6	Low temperature
12.7	Tectonic
13	**Hot Surfaces**
13.1	Equipment with surface temperature 60-150°C
13.2	Equipment with surface temperature >150°C
14	**Hot Fluids**
14.1	Temperatures 100-150°C
14.2	Temperatures >150°C
15	**Cold Surfaces**
15.1	Equipment with surface temperature 25 to -80°C
16	**Cold Fluids**
16.1	Temperatures <10°C
17	**Electromagnetic Radiation**
17.1	E/M radiation: high voltage ac cables
18	**Asphyxiates**
18.1	Insufficient oxygen atmospheres
18.2	Excessive CO2 / inert gas
18.3	Hydrogen
18.4	Excessive N2
18.5	Halon
18.6	Smoke
18.7	SF6 Release
19	**Toxic Gas**
19.1	H2S, sour gas
19.2	Exhaust fumes
19.3	Welding fumes
19.4	Tobacco smoke
19.5	CFCs
20	**Toxic Liquid**
20.1	Glycols
20.2	Degreasers (terpenes)
20.3	Isocyanates
20.4	Corrosion inhibitors
20.5	Scale inhibitors
20.6	Alcohol-containing beverages
20.7	Non-prescribed drugs
20.8	Used engine oils / coolants
20.9	Carbon tetrachloride
20.10	Grey and/or black water
20.11	Man made mineral fibre
20.12	Dusts
20.13	Other chemicals
21	**Ergonomic Hazards**
21.1	Manual materials handling
21.2	Restricted space / difficult access
21.3	Lighting
21.4	Heat stress
21.5	Cold stress
22	**Noise and Vibration Hazards**
22.1	Damaging peak noise
22.2	Continuous loud noise
22.3	Hand arm vibration
22.4	Whole Body Vibration
23	**Interfaces**
23.1	Building to environment
23.2	Building to WTG site - physical
23.3	Building to WTG site - grid
23.4	Building to WTG site - comms
23.5	Building to internal systems - lighting
23.6	Building to internal systems - HVAC
23.7	Building to internal systems -emergency management (e.g. fire detction/ prevention)
23.8	Battery storage system to building - physical
23.9	Battery storage system to building - electrical
23.10	Battery storage system to building - comms
23.11	Battery storage system to building internal systems
23.12	Spare parts to building
23.13	Spare parts to battery storage system
23.14	EMC
24	**Other**
24.1	Contaminated land

Appendix B RISK ACCEPTANCE MATRIX

Table 1: Risk ranking matrix, taken from the Substation Hazard Register (ref. 9)

Severity					Probability				
People	Assets	Environment	Reputation	Severity Rating	**Highly Improbable** Extremely unlikely to ever occur **1**	**Improbable** Unlikely but may occur exceptionally **2**	**Occasional** Likely to occur sometimes **3**	**Probable** Likely to occur often **4**	**Frequent** Regular or continuous occurrence **5**
Multiple fatalities	Extensive damage	Significant harm	International impact	**5**					
Single fatality	Major damage	Moderate, long term harm	National impact	**4**				High	
Major Injury	Localised damage	Moderate, short term harm	Considerable impact	**3**			Medium		
Lost time injury	Minor damage	Low impact, little harm	Limited impact	**2**		Low			
First aid injury	No damage	No impact	No impact	**1**					

Appendix C PLUME ASSESSMENT TECHNICAL NOTE

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Regulation Reference	Regulation 5(2)(q)	
Planning Inspectorate Scheme Reference	EN010123	
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Title	Appendix C: Plume assessment Technical Note of Outline Energy Storage System Management Plan	
Prepared By	Heckington Fen Energy Park Project Team (Hoare Lea)	
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Version	**Date**	**Version Status**
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HOARE LEA

Heckington Fen Energy Storage. Lincolnshire. Ecotricity (Heck Fen Solar) Limited.

AIR QUALITY

APPENDIX C - TECHNICAL NOTE

REVISION 02 – 09 FEBRUARY 2023

Audit sheet.

Rev.	Date	Description of change / purpose of issue	Prepared	Reviewed	Authorised
00	31/01/2023	First Draft	CH/AC	KL/LB	CE
01	03/02/2023	First Issue	CH/AC/AJ	KL/LB	KW
02	09/02/2023	Final Issue	CH/AC/AJ	KL/LB	KW

Project number: 10/13713
Document reference: REP-1013713-LB-5A-20230209-AQA-Heckington Fen Energy Storage-Rev02.docx

Contents.

1. Introduction.

Hoare Lea, with the support of Air Pollution Services (APS), has been commissioned by Ecotricity (Heck Fen Solar) Limited, to assess the potential air quality impacts on the local community in the event of a fire at the proposed Energy Storage System (ESS) at Heckington Fen Energy Park, Lincolnshire (herein the 'Proposed Facility') within the administrative boundary of North Kesteven District Council (NKDC). The Proposed Facility is part of a wider development which comprises solar panels and other infrastructure at Heckington Fen Energy Park, and an offsite cable route to, and extension at Bicker Fen Substation - which lies within Boston Borough Council (BBC).

The aim of the study is to provide preliminary information to inform an emergency response plan by identifying the direction and dispersion of the plume in the event of a fire at the ESS. 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 the fire.

To carry out the assessment a dispersion modelling study has been undertaken, details of which are presented in the technical note (Ref: APS_S1040A_E1-1) appended to this Note.

1.1 Location Context.

The location of the Proposed Facility is presented in Figure 1 for context. The proposed Heckington Fen Energy Park will lie within a rural area with few dwellings close by.

Figure 1: Proposed Facility Location

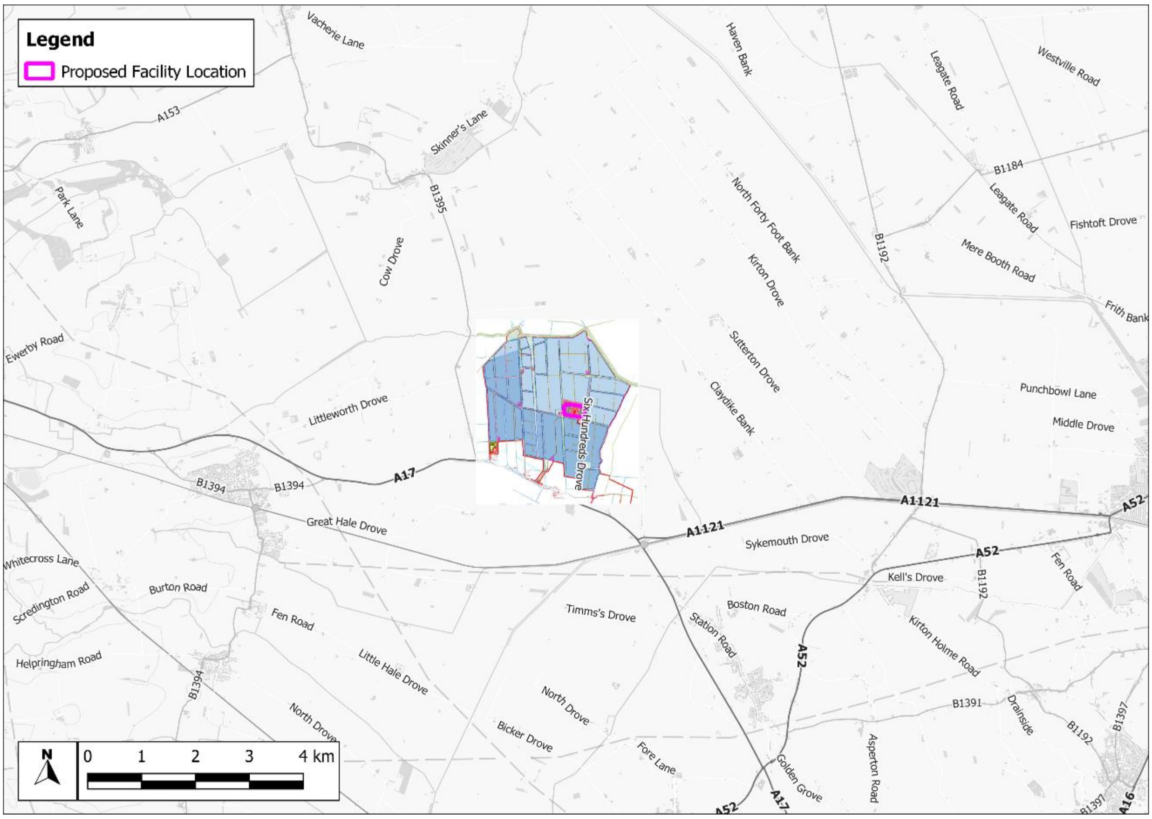


Figure notes: Contains OS data © Crown copyright and database right (2023).

1.2 Proposed Facility.

The initial concept for the ESS is shown in Figure 2. The ESS is located in the central red area close to the 400 kV substation. The ESS is expected to be up to 400MW/800MWhr. The specific energy storage technology has not been selected but is likely to be a modular lithium ion (Li-ion) based system housed in outdoor cabinets, with an integral battery management system, with cooling, fire suppression and AC to DC inverters. The system will be continuously monitored during operation. This will ensure early detection of any abnormal conditions within the energy storage system.

The areas shown in blue on Figure 2 will house ground mounted solar panels. There will be a direct access track from the public highway to the ESS.

Uncontrolled fires can last many hours. In the unusual case of an energy storage fire, the management system should extinguish it relatively rapidly, and therefore it is not anticipated that a fire will be prolonged.

The main types of energy storage are considered in Section 2.

Figure 2: Initial layout of the Energy Storage System

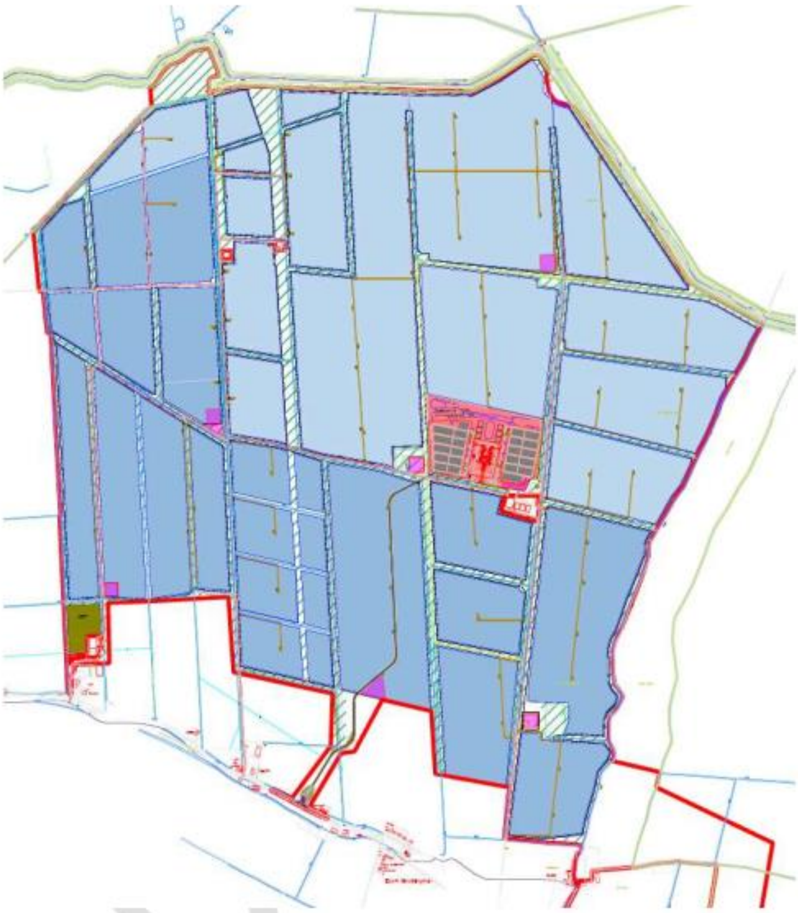


Figure notes: Imagery from Risktec, 2022, Outline Energy Storage Safety. Management Plan, document EC-01_r_01

2. Li-ion Battery Fires.

Li-ion batteries contain lithium-ions in a flammable electrolyte.

Battery fires can start due to a number of reasons including physical damage, over-charging, over discharging, short circuiting and exposure to high temperatures. Battery failure causes an increase in internal temperature which sets-off a series of exothermic reactions which further increases the internal temperature causing the release of the flammable and toxic electrolyte gas. This thermal runaway starts in a single cell of the battery before thermal propagation creates a domino effect thorough adjacent cells.

In the event of overheating, the electrolyte will evaporate and eventually be vented out from the battery cells. The gases may or may not be ignited immediately. In the case the emitted gas is not immediately ignited, the risk for a gas explosion may be imminent.

This issue is well acknowledged, and the batteries should have in-built safety devices to detect abnormal conditions which shut down the batteries before thermal runaway occurs (Fire Industry Association, n.d.).

Relatively little is known of the emissions from li-ion battery fires. Factors such as state of charge of the batteries, ambient pressure, battery configuration and heat flux can have an impact on the fire and the emissions.

A large number of air pollutants have been associated with battery fires including alkyl-carbonates, methane, ethylene and ethane, hydrogen, carbon monoxide, carbon dioxide, and other particulate matter containing nickel, cobalt, lithium, aluminium, copper.

One of the main concerns centres on the emission of hydrogen fluoride (HF) and other fluorinated compounds, which are highly toxic (Department for Business, Energy & Industrial Strategy + Office for Product Safety and Standards, 2020). The electrolyte used in lithium-ion batteries generally contains lithium hexafluorophosphate (LiPF6) or other Li-salts containing fluorine which are highly flammable. At elevated temperature the electrolyte and other parts of the battery such as the polyvinylidene fluoride (PVdF) binder in the electrodes may form gases such as HF. The HF is formed by the decomposition of these compounds, promoted by the presence of water/humidity (Larsson, Andersson, Blomqvist, & Mellander, 2017).

2.1 Emissions and Temperature.

The emissions and temperature of a fire, used in this study, were derived from Larsson et al. (2017) burn tests. These suggest that the HF emissions peak at around 5mg/s for a few minutes before declining to around 2 mg/s. The higher value was used in the modelling (see APS_S1040A_E1-1). In the tests the peak emissions occurred at a temperature of 300˚C , with lower emissions as the temperature increased to 8000˚C . A value of 300˚C was used in the dispersion modelling. The higher temperatures would increase the buoyancy of the plume causing it to reach ground level further from the source, allowing greater dispersion and likely reduced concentrations at the ground. Further work is required to test the impact of temperature and other inputs to the model.

2.2 Fire Scenario.

In the modelling it has been assumed that each battery fire lasts for three hours.

Several scenarios have been modelled with a different number of batteries (up to five) catching fire sequentially. The scenario where five batteries are on fire assumes a total of 15 hours of emissions. This is the longest period of emissions, as such the impacts are greatest and this scenario is the focus of this study.

Knowing which meteorological conditions will coincide with the potential occurrence of the fire is not possible and therefore it is standard practice to model full calendar year meteorological conditions from several years. The greatest 15-minute mean concentration can then be compared to the assessment criteria. However, when the potential for emissions is not continuous throughout a year and is likely to only occur for a small number of hours per annum, assessing the maximum concentration assuming continuous emissions throughout an entire year would be too conservative and not appropriate.

Instead, an assessment approach which considers the potential for a more than 1% risk of a 15-minute mean exceedance of the assessment criteria based on a fire occurring for limited period of the year e.g. 15 hours in a year is more appropriate. Such an approach can be based on a discrete probability distribution (hypergeometric distribution) which can be used to determine the probability that the emissions of a source for a limited number of hours in a year will cause an exceedance of a given threshold condition.

The approach is as follows:

- A maximum acceptable risk (probability of occurring) of 1% is defined.
- It is assumed each 15-minute period either exceeds the assessment criteria or does not.
- A hypergeometric distribution function is used to calculate the number of 15-minute periods in a full calendar year which could theoretically exceed an assessment threshold, such that if more than one 15-minute period was selected at random, there would be a less than 1% chance that it would be one of the 15-minute periods which exceeded the assessment threshold.
- This number of theoretical 15-minute exceedances is used to calculate an equivalent percentile of annual 15-minute periods.

As an example:

- Assuming there are 15 hours of fire (the longest scenario tested) there will be 60 15-minute periods.
- If fewer than 87 15-minute periods within a full year (35,040 15-minute periods) exceed the assessment criteria of 25 µg/m^3 then there is a <1% chance that more than one selected 15-minute would breach the assessment criteria of 25 µg/m^3.
- This equates to a 99.75th percentile of 15-minute means which would be the assessment percentile for a fire which was 15 hours in duration.

Thus, where the scenario specific assessment percentile does not predict an exceedance of the assessment level, this is less than 1% risk of a breach of the assessment level i.e. extremely low.

Note, this approach is supported by the Environment Agency (EA) for regulating permitted facilities and for those purposes a probability of less than 5% is considered low risk.

3. Assessment Criteria.

The assessment criteria considered for this study are shown in Table 1.

Table 1: Assessment Criteria

Source	Averaging period	Concentration	Criteria used in this study
EA Environmental assessment Level (EAL) (Environment Agency, 2021)	One hour	16 $\mu g/m^3$	Not used
Worker Exposure Limit (WEL) Health and Safety Executive (Health and Safety Executive, 2020)	15-minutes	2.5 mg/m^3	0.025 mg/m^3 (25 $\mu g/m^3$)

Workers are generally considered to be healthier than members of the public at large, since those most sensitive to the effects of air pollution generally include children and the elderly. As such, an uncertainty factor has been applied to take account of the variability in sensitivity of individuals to the health effects of air pollutants. Generally, a factor of 10 is used to account for these differences, but to be more conservative a factor of 100 has been used in this study. The resulting 25 $\mu g/m^3$ averaged over 15-minutes is likely to be more stringent than the EA's EAL averaged over one hour.

The indicative dispersion model results have been assessed against the 15-minute WEL.

4. Limitations of Study.

It is not possible to accurately model the impact of air emissions during a potential battery fire as every fire is different. It depends on many factors including the number, type and configuration of the batteries, their state of charge, whether/how they are damaged, the weather at the time of the fire and how the gases are emitted from the battery casing.

The quantity of emissions is strongly dependent on the combustion conditions (Hadden & Switzer, 2020) which in turn will be affected by the meteorological conditions at the time of the fire.

This assessment has modelled HF emissions due to its high toxicity compared to other releases from battery fires, and because emission rates, albeit limited, are available. Larsson et al. (2017) measured emission rates using two different measurement techniques during fires of seven different types of commercial scale Li-ion batteries. There is an order of magnitude variation in the emissions per kWh between the different types of battery. In the absence of information on the batteries to be used for the ESS, the data from Larson et al. (2017) for five type A cells at 0% charge has been used as the only available emission rate (in g/s) for HF.

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. Although the model has been validated, it is not possible to verify the point-source model outputs.

Examples of unknowns:

- Will the entire container be on fire or will the fire emit from a breach (hole) in the container?
- Will the fire from one container spread to another container, or multiple containers?
- How tall will the fire become and hence what is the average release height of emissions?
- Will the containers be situated on top of raised foundations to minimise the risk of surface water upon the containers, and if so, how would this change the emission release height?
- What are the exact locations of the containers within the Proposed Facility and hence the exact locations of where emissions are released?
- If the containers a located close together, the overall temperature would be higher; would this potentially lead to lower emissions?
- How many containers are there within the Proposed Facility and hence how long may the fire burn in total?
- What is the exact composition of the containers and hence what is the emission rate?
- Combustion processes typically release other pollutants, such as nitrogen oxides, nitrogen dioxide, particulate matter, etc., what are the impacts of these?
- The combustion process depends on the availability of oxygen in air, which will vary depending on the wind speed and direction. How would this effect the emissions and concentrations?
- How long would the fire service take to control the fires? Would all containers burn?
- What pollutants would be released from the use of fire suppressants?
- What would happen during extremely calm conditions?
- Is there a risk of a temperature inversion trapping the pollutants near the ground in the local area?

The emission release characteristics need to be modelled as an appropriate source type within the dispersion model. Typically for high temperature releases such as fires, the source term is defined using a point source emission or a jet source. However, due to the limitation of available mass release properties, a volume source has been used to define the emissions. One of the implications will be that the emission source will be more diffuse than using a point or jet source which would have a more concentrated emission. The dispersion pattern near to the source would ultimately be quite different. However, not knowing where the individual ESS containers would be means that any greater level of near field dispersion is not possible at this stage.

Until the design of the ESS is finalised and more information can be provided, there is high uncertainty regarding the impacts.

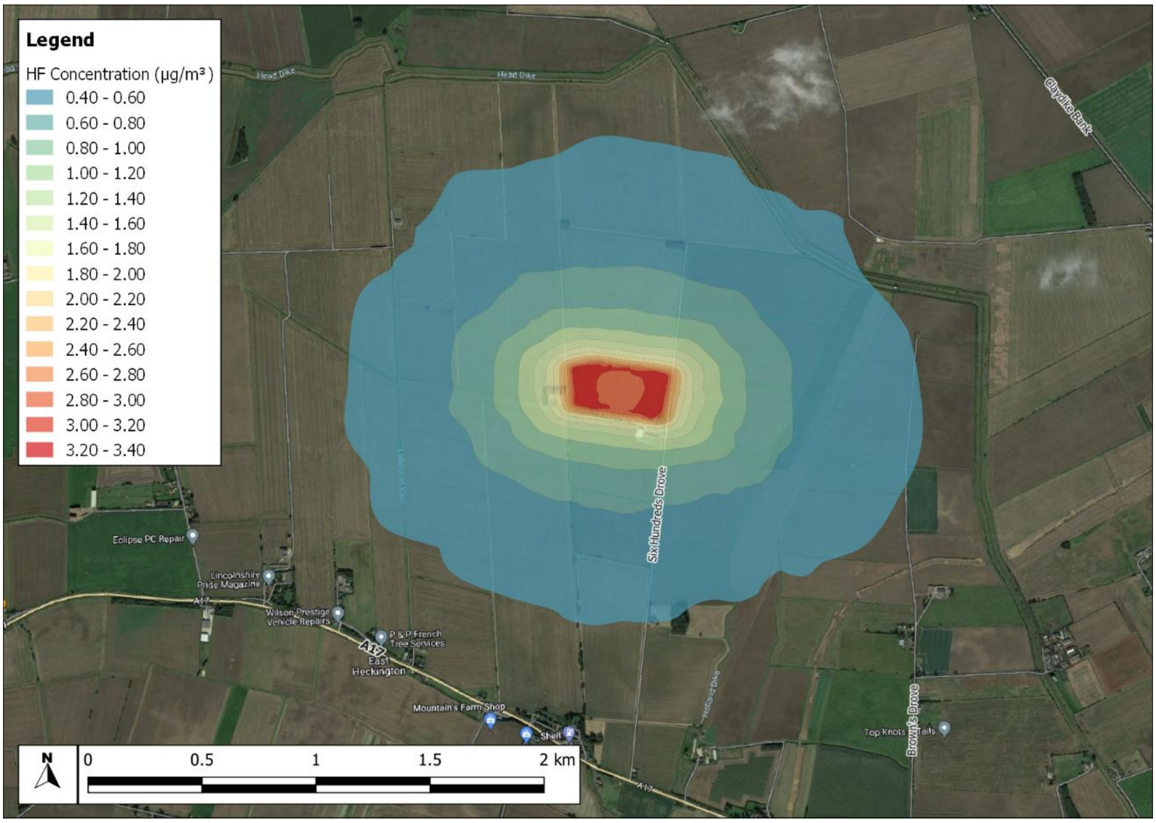
5. Assessment of Dispersion Modelling Results.

The maximum modelled concentration anywhere within the modelling domain is approximately 4 µg/m^3, therefore all of the assessment percentile concentrations were well below the assessment level of 25 µg/m^3 and there is a less than 1% risk of an exceedance occurring in the modelling domain. If this modelled scenario is representative of the final design of the ESS, there is a low risk of there being an adverse effect on human health due to HF emissions from the fire for the general public.

Figure 3 illustrates the likely spatial pattern of how 15-minute average HF concentrations would likely be distributed across the local area. The concentrations shown are the assessment percentile concentrations and thus it is not strictly relevant to consider the magnitudes because they represent the concentration during a specific 15-minute mean within an annual dataset. Irrespective of the predicted concentration levels, the spatial pattern demonstrates that emissions are dispersed in all directions. This is considered typical of short-term dispersion patterns, especially when considering 1-hour mean or shorter periods from ground level volume sources (the source type used in the initial modelling exercise).

Since there are existing residential properties, although only a small number, on all sides of the solar farm at the furthest extent on the field boundaries, situating the Proposed Facility centrally within the solar farm helps to minimise the impacts at locations of sensitive exposure.

Figure 3: Spatial Dispersion Pattern – 99.75th Percentile of 15-minute Mean Concentrations



This figure shows the 99.75th 15-minute average concentration.

Figure notes: Contains OS data © Crown copyright and database right (2023).

6. Recommendation for Further Assessment.

Once details of the design of the ESS are known, it is recommended that the potential impacts are re-modelled using a number of different fire scenarios including a range of source types (e.g. point sources and jet sources) to give a more realistic estimate of the potential impacts on HF concentrations in the local community.

7. Glossary.

APS	Air Pollution Services
EA	Environment Agency
EAL	Environmental Assessment Level
ESS	Energy Storage System
HF	Hydrogen Fluoride
Li-ion	Lithium Ion
LiPF6	Lithium Hexafluorophosphate
PVdF	Polyvinylidene Fluoride
WEL	Worker Exposure Limit

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Health and Safety Executive. (2020). EH40/2005 Workplace Expoure Limits.

Larsson, F., Andersson, P., Blomqvist, P., & Mellander, B.-E. (2017). Toxic Fluoride Gas Emissions from Lithium-ion Battery Fires. Nature, 7, 10018. doi:DOI:10.1038/s41598-017-09784-z

Appendix 1 – Air Quality Modelling Approach.

Introduction.

Hoare Lea, with the support of Air Pollution Services (APS), has been commissioned by Ecotricity (Heck Fen Solar) Limited, to assess the potential air quality impacts on the local community in the event of a fire at the proposed Energy Storage System (ESS) at Heckington Fen Energy Park, Lincolnshire (herein the 'Proposed Facility') within the administrative boundary of North Kesteven District Council (NKDC). The Proposed Facility is part of a wider development which comprises solar panels and other infrastructure at Heckington Fen Energy Park, and an offsite cable route to, and extension at Bicker Fen Substation - which lies within Boston Borough Council (BBC).

To carry out the assessment a dispersion modelling study has been undertaken, details of which are presented in this document. This appendix provides a modelling overview; description of the model used; the list of the modelled receptors; meteorology and surface characteristics used; combustion plant emissions modelling; and a glossary of useful terms used in this assessment.

Location Context

The location of the Proposed Facility is presented in Figure 1 for context.

Figure 4: Proposed Facility Location

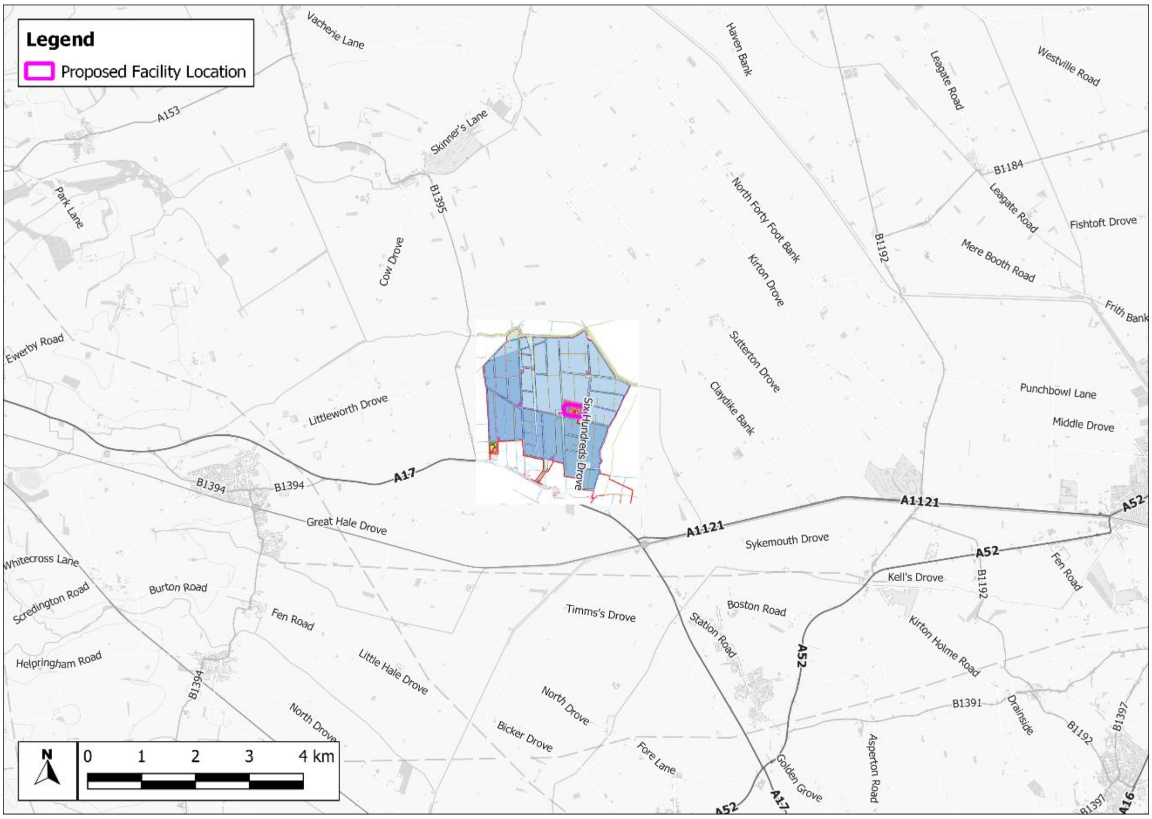


Figure notes: Contains OS data © Crown copyright and database right (2023).

Modelling Overview.

Concentrations of hydrogen fluoride (HF) have been predicted. Three different years (2017, 2018 and 2019) have been utilised to take account of variations in meteorology, taking the maximum results from any of the years to provide a conservative assessment.

The Model.

Concentration contributions associated with the Proposed Facility have been predicted across the local area using the Atmospheric Dispersion Modelling System (ADMS) suite of tools developed and validated by Cambridge Environmental Research Consultants.

ADMS-5 is used extensively throughout the UK for regulatory compliance purposes and Local Air Quality Management (LAQM) and is accepted as an appropriate tool by local authorities and the Environment Agency (EA). Version 5.2.4 of the model has been used for modelling of the combustion plant emissions.

The model requires a range of input parameters which are discussed below.

Modelled Receptors.

The model output locations are often referred to as receptors, although in some cases the locations may not represent locations of relevant exposure. For ease, this study uses the phrase receptor to represent the modelled output location.

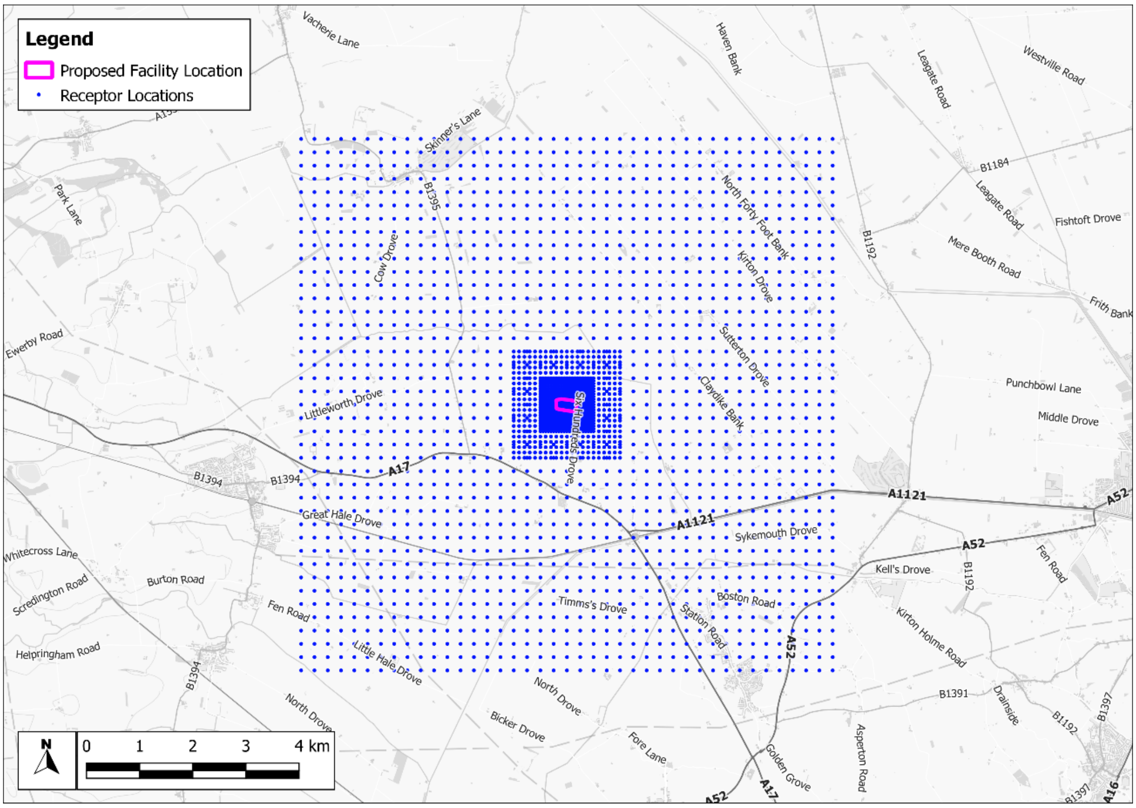
Pollutant concentrations have been predicted across a nested grid of receptors covering a 10x10 km area surrounding the Proposed Facility. The receptor grid has been modelled at a height of 1.5 m above ground level. The extent of this modelled grid defines the 'Study Area'. The Study Area is considered appropriate to consider the impacts on both human-health and sensitive ecological receptors.

The nested cartesian grid has the spacing of:

- 5x5 m within 100 m of the emissions source;
- 25x25 m within 250 m of the emissions source;
- 50x50 m within 500 m of the emissions source;
- 100x100 m within 2 km of the emissions source; and
- 250x250 m within 5 km of the emissions source.

These receptor locations are shown in Figure 5.

Figure 5: Gridded Receptor locations in relation to the Proposed Facility



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Meteorology and surface characteristics.

Meteorology

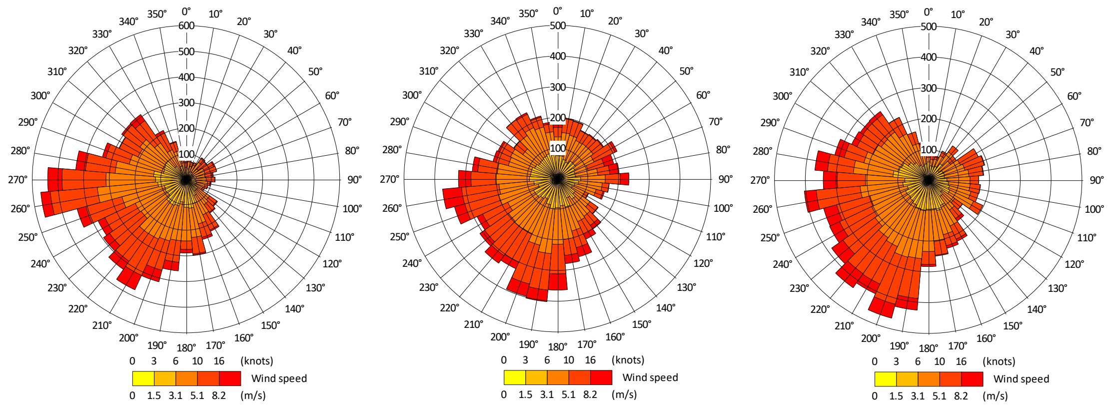
The dispersion model includes a meteorological pre-processor developed by the UK Met Office to calculate values of meteorological parameters in the boundary-layer. The pre-processor requires a set of meteorological parameters on an hour-by-hour basis: wind speed, wind direction, temperature and cloud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

It is important to use meteorological data which is representative of the conditions within the Study Area. There are a limited number of sites in the UK where this data is measured and recorded. As an alternative to observational data, numerical weather prediction (NWP) prognostic data for the meteorological conditions at the Proposed Facility are available. APS have produced NWP data across the entire UK at a 3x3 km resolution using the widely accepted Weather Research and Forecasting (WRF) Model and reanalysis data (data which includes measured observational information). Wind roses showing the frequency of wind speeds and directions for the 3x3 km grid which the Proposed Facility is located within, for the years of 2017 to 2019 are shown in Figure 6.

Following a review of the available datasets, it is considered that data from the NWP model for the specific site location is likely to be most representative of the conditions in the study area and this has been used in the study.

To account for the annual meteorological variation three years of meteorological data has been used in the model.

Figure 6: Windrose of Wind Speed and Direction for Each Year from 2017 (Left) to 2019 (Right) of Numerical Weather Prediction (NWP) data for the 3x3 km grid square covering the Proposed Facility Location



Surface Characteristics

In addition to the meteorological data, the model requires values to be set for a number of meteorological related parameters, for both the area the meteorological data represents and the Study Area. Land-use and surface characteristics have an important influence in determining turbulent fluxes and, hence, the stability of the boundary layer and atmospheric dispersion. Details of the parameter values used in the modelling are provided in Table 2 below.

Surface roughness length used within the model represents the aerodynamic effects of surface friction and is defined as the height at which the extrapolated surface layer wind profile tends to zero. This value is an important parameter used by the built-in meteorological pre-processor of ADMS to interpret the vertical profile of wind speed and estimate friction velocities which are, in turn, used to define heat and momentum fluxes and, consequently, the degree of turbulent mixing. Surface roughness values for different land-use classifications have been specified. Accounting for differences between the area the data represents and the Study Area, is essential. Due to the size of the model domain, a variable surface roughness file has been used within the model based on the spatially variable land-uses and the equivalent roughness values from the dataset. Figure 7 shows the values used across the modelled domain. For the NWP data, surface roughness is calculated based on land-use up to 1,000 m from the centre point of the modelled grid cell and is an inverse distance weighted geometric mean and predominantly based on grassland.

Figure 7: Modelled Surface Roughness

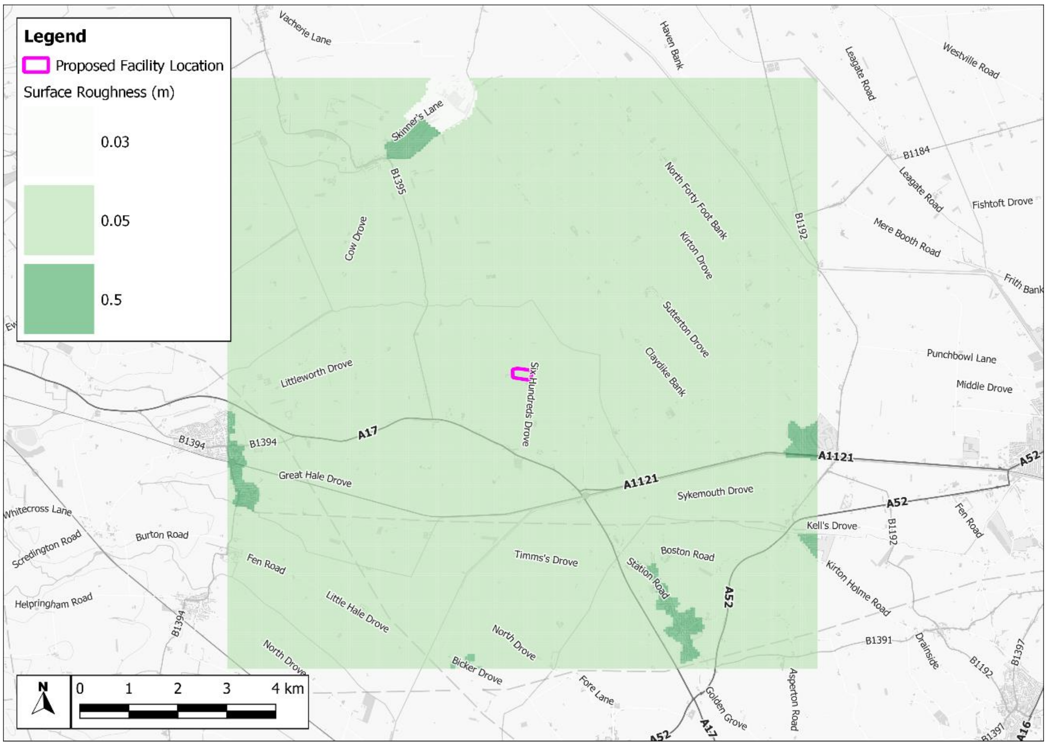


Figure notes: Contains OS data © Crown copyright and database right (2023).

The surface albedo is the ratio of reflected to incident shortwave solar radiation at the surface of the earth. This varies depending on the land use, and thus area-weighted average albedos have been derived for the meteorological data area and the dispersion site study area and used in the models. Albedo values have been associated with the different land uses. For this study, Albedo has been calculated based on land-use up to 5,000 m from the centre point (both the Proposed Facility and NWP grid centre) and is an arithmetic mean. The mean includes an inverse distance weighting for distances over 1,000 m.

The Priestley-Taylor parameter is a parameter representing the surface moisture available for evaporation. A Priestley-Taylor parameter of 1 has been set in the model.

The CERC user guide explains that "*the Monin-Obukhov length provides a measure of the stability of the atmosphere. In very stable conditions in a rural area its value would typically be 2 to 20 m. In urban areas, there is a significant amount of heat generated from buildings and traffic, which warms the air above the town/city*". For large urban areas this is known as the urban heat island. It has the effect of preventing the atmosphere from ever becoming very stable. Minimum Monin-Obukhov (M-O) length can be defined in the model to account for the urban heat island effect which is not represented by the meteorological data. Minimum M-O ratio is calculated based on land-use up to 5,000 m from the centre point (both the Proposed Facility location and the NWP grid centre) and is a geometric mean. The mean includes an inverse distance weighting for distances over 1,000 m.

Table 2: Meteorological Parameters Values Used in the Model

Parameter	Dispersion Site Value	NWP Grid Value
Latitude (°)	52.99	n/a
Surface roughness (m)	n/a[a]	0.037
Surface albedo	0.24	0.24
Minimum Monin-Obukhov length (m)	10.002	10.006
Priestley-Taylor parameter	1	1

Table notes:

a, This value has not been utilised in the model since a variable surface roughness file has been used instead.

Terrain

The effects of complex topography on atmospheric flows can result in elevated pollutant concentrations. These effects are most pronounced when the terrain gradient exceeds 1 in 10, i.e. a 100 m change in elevation per 1 km step in horizontal plane. The local terrain data is based on Ordinance Survey Terrain 50 data and shown in Figure 8. Terrain covering the study area has been used in the modelling.

Figure 8: Modelled Terrain

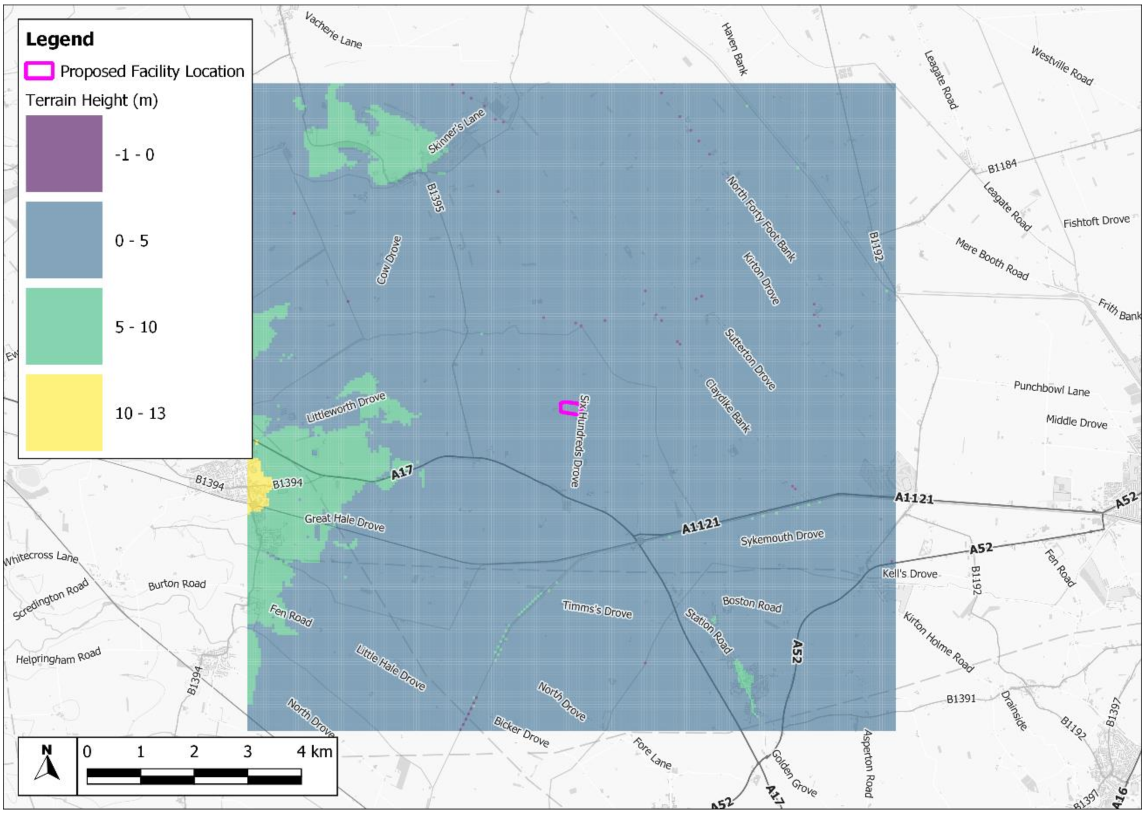
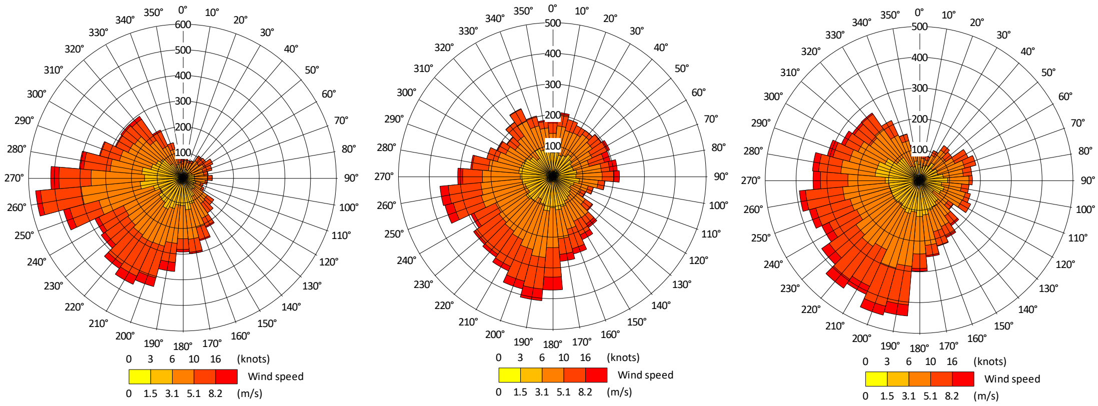


Figure notes: Contains OS data © Crown copyright and database right (2023).

Processed Meteorological Data

The meteorological parameters alter the meteorological data inputted into the model to reflect conditions at the dispersion site (the Study Area). For example, if the dispersion site has a higher surface roughness value than the NWP grid cell, then the model will reduce the wind speed at the dispersion site to reflect this. Figure 9 shows the processed meteorological data of frequency of wind speeds and directions from 2017 to 2019.

Figure 9: Windrose of Wind Speed and Direction for Each Year from 2017 (Left) to 2019 (Right) of modelled meteorological data at the Proposed Facility Location



Battery Fire Modelling.

This preliminary modelling study has used a single volume source to represent the emission source. Other source types such as point sources and jet sources will need to be modelled for sensitivity test once greater detail is known about the plans. Within the model, the single volume source has been modelled to represent all of the batteries. The location and extent of the volume source within the Proposed Facility is shown in Figure 10.

Figure 10: Source Location

Table 3 presents the parameters utilised in the model for the source. It has been assumed that the fire would start in one battery and then gradually spread from one battery to the next until all are burnt. Although there may be more than one battery on fire at any one time, the emission rate for HF is expected to peak at approximately 5 mg/s. Larsson et al. (2017) has demonstrated that this emission rate only lasts for a short period of several minutes, with the average over a 15-minute period being lower. When considering that multiple batteries could be on fire simultaneously to some extent, the emission rate is expected to remain below 5 mg/s on average over a 15-minute period. Although high temperatures occur during battery fires, the temperature when peak emissions occur has previously been demonstrated to be around 300˚C and has thus been used in the modelling.

Table 3: Modelled Source Parameters

Parameter	Value
Exhaust temperature (˚C)	300
Source height (m)[a]	3
Mid-level release height (m)	1.5
Source volume (m^3)	223,409
HF emission rate (mg/s)[b]	5
Table notes: [a]Source height estimated from assumed container height. [b]Based on the emission rates presented in Larsson et al. (2017)	

Assessment Percentiles

The percentile for the pollutant used within the assessment is provided in Table 4. The percentile presented has been calculated following the EA's hypergeometric distribution approach and it represents a 1% probability risk of there being one exceedance of a 15-minute assessment criteria based on the batteries being on fire for a period of 15 hours. The exact duration of the potential fire is not known at this stage, largely due to the number of batteries being unknown. To provide a preliminary assessment, it has been assumed that there are up to 200 batteries at the Proposed Facility and that five batteries would be on fire simultaneously at any point in time, with each battery burning for a period of 3 hours.

Table 4: Assessment Percentiles

Pollutant	Time Period	Concentration and the number of exceedances allowed per year	Assessment Percentiles
Hydrogen Fluoride (HF)	15-minute Mean	Up to one exceedance	99.75^{th} percentile

Glossary.

ADMS	Atmospheric Dispersion Modelling System
APS	Air Pollution Services
EA	Environment Agency
HF	Hydrogen Fluoride
LAQM	Local Air Quality Management
M-O	Monin-Obukhov
NWP	Numerical Weather Prediction
WRF	Weather Research and Forecasting
μg/m^3	Microgrammes per cubic metre

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Appendix 2 - Professional Experience.

Christelle Escoffier (Hoare Lea), PhD, BSc (Hons), AMIEnvSc, MIAQM, MIES

Christelle Escoffier (MsEng. Msc. PhD MIES MIAQM) is a senior associate and technical lead for air quality group with Hoare Lea. She is a Full Member of the Institution of Environmental Sciences and the Institute of Air Quality Management. She graduated with a Master in Science Diploma from Paris VI University, France and holds a Doctor of Philosophy degree in Physical Oceanography, Meteorology and Environment, from the same University.

In her twenty-two years of professional experience, she has managed and delivered air quality services for a wide range of industries in the United Kingdom (UK), the United States of America (USA) and the Middle East. Her portfolio of experience comprehends projects for diverse sectors from road transport, planning and development, wastewater and waste, oil and gas to power (energy centres, landfill gas plant, power reserve facilities, gas-fired and oil-fired combustion turbine stations). Christelle has in-depth knowledge of atmospheric dispersion models. She has delivered dispersion modelling training courses to government agencies, academic, industrial and commercial professionals worldwide since 2005.

Lauren Buchanan (Hoare Lea), MSc, BSc (Hons), AMIEnvSc, MIAQM

Lauren is a Senior Air Quality Consultant at Hoare Lea. She is an Associate Member of the Institution of Environmental Sciences and a Member of the Institute of Air Quality Management. She has worked on a range of projects gaining experience in many different aspects of air quality assessment, including monitoring and detailed dispersion modelling of dust, odour, roads and industrial emissions for a variety of sectors and to fulfil Local Air Quality Management (LAQM) duties on behalf of Local Authorities. Lauren has undertaken air quality assessments for permit requirements and planning applications, including stand-alone reports, Environmental Impact Assessments, Habitats Regulations Assessments and Development Consent Orders.

Dr Austin Cogan, MPhys (Hons) PhD CEnv MIEnvSc MIAQM

Dr Cogan is Director and cofounder of APS, is a Chartered Environmentalist and has nearly 15 years' experience in environmental sciences. Austin has extensive experience of odour, air quality and dust assessments for a range of industries as well as services for local authorities, including Clean Air Zone and micro-simulation modelling. He is also an international expert in the field of climate change, having monitored greenhouses gases globally, published numerous scientific papers and presented at conferences internationally. He has also been involved in guidance development, most recently the IAQM’s indoor air quality guidance.

Dr Claire Holman, BSc (Hons), PhD CSci CEnv FIEnvSc FIAQM

Dr Holman is a Director of APS, has nearly 40 years of experience and has advised national governments in Europe, Asia and Africa, as well as the European Commission on a range of strategic air quality and climate change issues. Claire has contributed to the development of IAQM and EPUK professional guidance, is former chair of the institute, has been a member of a Government air quality review group, and advised the Department for Transport on their cleaner vehicles and fuels research programme.

Kieran Laxen, MEng (Hons) MIEnvSc MIAQM

Mr Laxen is a Director and Cofounder of APS and has nearly 15 years' experience in the field of air quality. Kieran is an active member of the IAQM committee and currently Vice Chair. He has extensive experience of air quality monitoring and is a leading UK expert in the assessment of power generating facilities for both permitting and planning applications. He has been a stakeholder in Defra's and the Environment Agency's consultations into implementing the MCPD and Specified Generator Controls.

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