Springwell Solar Farm

BESS Plume Assessment

EN010149/APP/7.19.2
Revision 2
Deadline 1
June 2025
Springwell Energyfarm Ltd

APFP Regulation 5(2)(a)
Planning Act 2008
Infrastructure Planning
(Applications: Prescribed Forms
and Procedure) Regulations 2009

Table of Contents

1. Introduction 2

1.1. Purpose of this document 2

2. Background 3

2.1. Proposed Development Overview 3

2.2. Battery System Basic Architecture 3

2.3. Battery System Failures 3

3. Incident Impacts 4

3.1. Overview 4

3.2. System Location 4

3.3. Example Design Used to Inform the ES 4

3.4. Methodology 5

3.5. Definitions 6

3.6. Parameters 7

3.7. Scenarios 9

3.8. Criteria 12

4. Summary 16

1. Introduction

1.1. Purpose of this document

1.1.1. This assessment acknowledges that there may be concern regarding the potential thermal runaway of the BESS (Battery Energy Storage System) and the possible impacts upon receptors. A thermal runaway event where a battery cell enters an uncontrolled self-heating state

1.1.2. This assessment should be read in conjunction with the **oBSMP (Outline Battery Safety Management Plan) [EN010149/APP/7.14.2]** and provides an assessment of the possible impact of a thermal runaway event within the BESS battery components as well as the impact of a possible thermal runaway.

1.1.3. This document has been updated at Deadline 1 to respond to the Examining Authority's First Written Questions, the First Issue Specific Hearing and discussions held to agree the **Draft Statement of Common Ground - UK Health Security Agency [EN010149/APP/8.6]**. The document references have not been updated from the original submission. Please refer to the **Guide to the Application [EN010149/APP/1.2]** for the list of current versions of documents.

1.1.4. This document provides an assessment of the potential credible worst case air quality impacts of a thermal runaway incident at the BESS Compound forming part of the Proposed Development.

1.1.5. The aim of the plume assessment is to understand possible impacts of the BESS Compound on the nearby receptors in an emergency situation; primarily the emergency responders and those in the surrounding area such as workers or local residents.

1.1.6. The Applicant has consulted the UK Health Security Agency (UKHSA) as part of the DCO process. An introductory meeting was held with the UKHSA 18 March 2025 to respond to the Relevant Representation letter and a follow up meeting was held 28 April 2025 where agreement was made on the **Statement of Common Ground – UK Health Security [EN010149/APP/8.6].** The Applicant and the UKHSA concur that at the detailed design stage (after battery system selection) a plume assessment would be commissioned based on atmospheric dispersion modelling; this would give an understanding of what would be emitted and the impact on Sensitive Receptors in comparison with air quality standards. This is secured through the **oBSMP (Outline Battery Safety Management Plan) [EN010149/APP/7.14.2]**. Some areas of clarity regarding the plume study were requested at this point and are contained herein.

2. Background

2.1. Proposed Development Overview

2.1.1. A summary of the description of the Proposed Development can be found in Section 3.1 of the **Environmental Statement (ES) Volume 1, Chapter 3: Proposed Development Description [EN010149/APP/6.1]**. The terminology used in this document is defined in the **Glossary [EN010149/APP/6.1]**.

2.2. Battery System Basic Architecture

2.2.1. The BESS parameters and therefore what is reflected in the **ES Volume 3, Appendix 3.1: Project Parameters [EN010149/APP/6.3]** for the BESS Compound have been selected based upon current technology market trends. Part of these trends is a move from Lithium-Nickel-Manganese-Cobalt-Oxide (NMC) to use Lithium Iron Phosphate (LFP) chemistries. The example design used to inform the ES uses LFP cells; a credible worst case scenario based on these trends has been reflected in this plume assessment.

2.2.2. Irrespective of eventual technology choice, the BESS Compound, enclosures and auxiliary systems, such as cooling, UPS, fire detection and suppression systems, monitoring and control, will be designed in accordance with internationally recognised good practice and guidance available at the time.

2.3. Battery System Failures

2.3.1. There are four main ways in which a lithium-ion cell might fail: thermal, electrical, mechanical and chemical. The causes of failure could include issues such as: manufacturing defects, overcharging, over-discharging, mechanical damage, overheating or abuse and short circuits; whether internal or external.

2.3.2. Regardless of the type of failure or the cause, the main potential hazard for consideration in this assessment is thermal runaway and ultimately, if not controlled, a significant flaming or explosive gas venting incident.

2.3.3. Other electrical systems which form part of the BESS Compound can carry conventional fire risks, however due to the extensive historic long-term deployment of other technology such as transformers, inverters and switchgear, these risks are regulated through longstanding industry guidance and codes. Therefore, only the battery technology component of the BESS Compound is addressed in this report.

3. Incident Impacts

3.1. Overview

3.1.1. A consequence analysis of the potential immediate effects of a thermal runaway or other incident event has been undertaken. This process is undertaken for all EDF Renewables BESS sites in the UK (EDF Renewables are a shareholder of the Applicant) and has been repeated for the example BESS design used to inform the ES. The aim of the assessment is to understand the envelope of possible impacts of a BESS thermal runaway event on the nearby receptors in an emergency situation; primarily the emergency responders and those in the surrounding area such as workers or local residents.

3.2. System Location

3.2.1. Within the Order Limits, the location of the BESS compound (Work No. 4 on the **Works Plans (EN010149/APP/2.3)**) has been determined with consideration of a number of factors. The most pertinent factor is that the selected site has tried to minimise the proximity to receptors of any nuisance, with the distance to properties maximised where possible. This has the benefit of reducing the visual and noise impact but also minimises any potential impacts on the local population should a thermal runaway event occur. As such the closest property to the BESS Compound is approximately 440m South East of the site.

3.2.2. These considerations are fed back into the design, with intolerable outcomes being identified and design changes implemented for appropriate mitigation. The findings of this process will then also be incorporated into the Emergency Response Plan (ERP) secured in the **oBSMP [EN010149/APP/7.14.2].**

3.3. Example Design Used to Inform the ES

3.3.1. The electrochemistry for the example design used to inform the ES and oBSMP is LFP. These modules have been assessed to UL9540A: Energy Storage Systems and Equipment. This determines the potential of a thermal runaway spreading within a battery system. The Concept Design satisfied the criteria at module level.

3.3.2. The module tests showed that during thermal runaway of a cell there was no fire and the thermal runaway did not propagate to the adjacent cells. Cell venting occurred leading to module venting. However for the purposes of this assessment it is conservatively assumed that the cells do ignite to understand the possible implications.

3.3.3. In the event of a thermal runaway, the battery system and the transformers serving the BESS Compound will be automatically electrically isolated when a thermal runaway is detected within a container. However, the batteries within the containers will still hold charge in the event of a thermal runaway even after the electrical system is isolated. As with any energy storage system, it will not be possible to immediately confirm that there is no residual risk from the energised batteries within the container. The Applicant are engaging with Lincolnshire Fire and Rescue Service with regards to the Proposed Development and this engagement has led to a number of design improvements.

3.3.4. Spatial protections built into the example design via component grouping, means that in the very unlikely event that a thermal runaway event should occur and all of the system design mitigations and preventative measures fail, the thermal runaway should be limited to the part of the system that is on fire. In this, the overall size of the battery system is inconsequential to the outcome and an event should be limited in size to only that equipment within a group, whether there are one or any number of groups.

3.4. Methodology

3.4.1. To determine the impact of a thermal runaway event a number of credible worst case scenarios have been developed and modelled for the example design used to inform the ES.

3.4.2. The possible scenarios "credible worst cases" have been developed by the Applicant based upon a number factors including literature, empirical data from BESS Compounds, fires globally, risk assessment, previous studies and the experience of the Applicant's global team. The Applicant has undertaken a number of BESS Compound end to end Risk Assessments / FMEA with a number of integrators across technologies allowing a deep understanding of BESS Compounds and their failure modes.

3.4.3. These scenarios are

- the release of toxic gas(es), without a fire event (as found during testing);
- a fire event;
- An explosion from the ignition of gasses.

3.4.4. The scope of the analysis is limited to evaluation of the worst credible toxic, flammable, thermal (radiant heat from a fire) and overpressure (from an explosion) effects of the most common chemicals released from cells inside a single container when venting under the most common weather conditions.

3.4.5. The analysis does not consider electrical system risks, other than as instigators for a BESS Compound event, as these risks are generally well known with longstanding industry guidance and codes.

3.4.6. The analysis does not consider the effects of smoke or particles created by a fire, nor does it consider the effects of projectiles or other debris released by an explosion. The BESS design would be capable of preventing / mitigating any deflagration events, which could be demonstrated through full scale destruction testing and rigorous consequence modelling as per - typical reports are listed below:

- NFPA 69 Explosion Prevention Compliance report
- Deflagration analysis report
- FDS gas ventilation analysis report

3.4.7. The analysis does not consider all weather conditions (wind speed & direction and ambient temperature). Wind speeds of 2 m/s & 5m/s have been used for analysis which is consistent with HSE guidance for consequence modelling as calm wind conditions generally produce the greatest hazard range, i.e. distance from source. Further wind data can be seen in “3.7 Scenarios”.

3.4.8. The analysis does not consider the effects of obstacles (man-made or natural) in the path of the releases, nor does it consider the height of the toxic or flammable clouds as the effects are predicted at ground level.

3.5. Definitions

3.5.1. **Credible** would be an event which although it will have mitigations to prevent occurrence could feasibly occur if the mitigations were to fail. For example several failures would have to occur for a bank to overcharge; these failures are deemed to be extremely unlikely. But we assume, to enable us to model the failure, that an overcharge situation of a bank to an extreme State of Charge (SOC) is credible, which in turn could lead to a thermal runaway.

3.5.2. It is deemed extremely unlikely to occur in the first instance with all of the protections in place. Therefore that this failure could happen on a number of banks simultaneously is not considered credible even with a failure of multiple protections, as if this were to happen, the whole system cannot fail simultaneously i.e. one part of the system will fail first, causing the rest of the system to shut down. i.e. at some point a protection will activate.

3.5.3. **Worst case** would be dependent on the assessment being made.

3.5.4. In the event of an explosion; the total volume of the enclosure would be considered to be filled with off-gas. i.e. it has displaced the normal atmosphere completely.

3.5.5. Even though the example cells passed the UL9450a assessment at module level without igniting, to understand the possible worst case, it is assumed that the cells ignite and all are consumed in a thermal runaway event. It is clear that this is an extremely conservative and almost incredible occurrence even without all of the other safety considerations but allows the worst case envelope to be defined.

3.6. Parameters

Gas release

3.6.1. To determine vent concentrations for an example cell, laboratory off-gas measurements are extrapolated to predict system-level emissions. Precise calculations are possible when detailed reports on the specific cell technology are available. The manufacturer of the Concept Design cell has supplied gas analyses from UL9540A testing. In the event of a venting incident, the gases listed in **section 3.6.3** may be released either fully or partially.

3.6.2. Data from cell provider indicates that the volume of HF released per unit or rack during testing was 82.56 litres. Therefore, the predicted HF release per compartment is estimated at 165.12 litres.

3.6.3. This example cell manufacturer data suggests a wide range of hydrocarbons are released during venting. However, only the most significant were evaluated (those with a predicted composition of more than 1% by volume) including:

- Hydrogen (H2);
- Carbon Monoxide (CO);
- Carbon Dioxide (CO2);
- Acetylene (C2H2);
- Propane (C3H6);
- Hydrogen Fluoride (HF);
- Methane (CH4);
- Ethylene (C2H4);
- Ethane (C2H6);
- Propylene (C3H6).

3.6.4. Note that Carbon Dioxide (CO2) was not evaluated as it is not considered harmful in an open environment. <1%

3.6.5. After initial analysis of these chemicals under different wind conditions and release volumes & durations, analysis focused on the following materials under F2 wind conditions:

- Hydrogen Fluoride;

- Carbon Monoxide;
- Methane.

3.6.6. The design of the BESS and its impacts are controlled in several ways. Prior to commencement of construction of the BESS, a Battery Safety Management Plan (in accordance with the **oBSMP [EN010149/APP/7.14]** submitted with the Application) is required to be submitted to the relevant local planning authority and approved, in consultation with the the Lincolnshire Fire and Rescue Service and the Environment Agency. The Applicant must operate the BESS in accordance with the approved plan.

3.6.7. Further, pursuant to a requirement of the DCO, the detailed design of the BESS must be in accordance with the oBSMP (which includes various safety requirements for the BESS design) and the **Design Commitments [EN010149/APP/7.4] and ES Volume 3, Appendix 3.1: Project Parameters [EN010149/APP/6.3]**. An assessment will be undertaken, based on the actual battery system chosen for the BESS, to demonstrate that the risk of thermal runaway and impacts from a fire will be no worse than as assessed in this **BESS Plume Assessment [EN010149/APP/7.19.2]**.

3.6.8. In this way, the Applicant can confirm that if the BESS constructed is different to that assessed in this plume assessment, its impacts in the event of a thermal runaway would be no worse than those assessed in this plume assessment, and therefore the risk to the local population would be very low.

3.6.9. A Layer of Protection Analysis (LOPA) has estimated the frequency of a cell venting event at approximately once every 7700 years (1.3x10-4 yr-1) for the example BESS array in the Proposed Development.

Explosive gas volume

3.6.10. The volume of the enclosure, less the volume of the material within it, is used as the maximum volume of explosive gas (in the cell vent concentrations). This assumes continuous cell(s) venting, without ignition, replacing the enclosure atmosphere until an explosion occurs.

3.6.11. A number of failures of protection systems would have to occur before and during the event. i.e., cell and module monitoring systems, system monitoring and gas detection systems.

3.6.12. It should be clear that with all of the mitigations in place this scenario is unlikely, and is considered to give an upper bound.

3.6.13. By the time of the construction it is also likely that any battery enclosure would have automatic fresh air venting to prevent any build-up of gasses.

Event Duration

3.6.14. Once the potential for gas release is determined, the impact of any release is then proportional to the duration of the release. The faster it is released the greater the potential impact. The exact nature of an event such as a thermal runaway is difficult to predict, therefore we have drawn on a number of laboratory fire tests and reviewed the timeline of a number of battery fires globally. Generally it has been observed that once ignited a grid scale battery enclosure typically tends to take around 12h for combustibles to be fully consumed, giving an approximate duration for the release of gasses over 12 hours.

3.6.15. To allow for uncertainty in the release rate and to allow for the unpredictable nature of an event we have modelled the release over 4 hours to give a credible worst case time duration and concentration of gasses, i.e. as the time of the release is proportional to the dilution this is a further conservative assumption.

3.7. Scenarios

3.7.1. It was assessed that the worst credible scenarios could be:

- Prolonged release of toxic Hydrogen Fluoride over periods of up to 4 hours.
- Prolonged release of toxic Carbon Monoxide over periods of up to 4 hours.
- Prolonged release of flammable Methane over periods of up to 4 hours.
- Instantaneous explosion of a compartment of Methane.
- Fire inside the compartment resulting from ignition of Methane.

Meteorology

3.7.2. Site data was acquired along with atmospheric data for the assessment. Wind data from the nearest weather station at RAF Waddington was taken from the CEDA website, with temperature and climate data for Waddington taken from the Met Office and 'Climate Data' websites respectively.

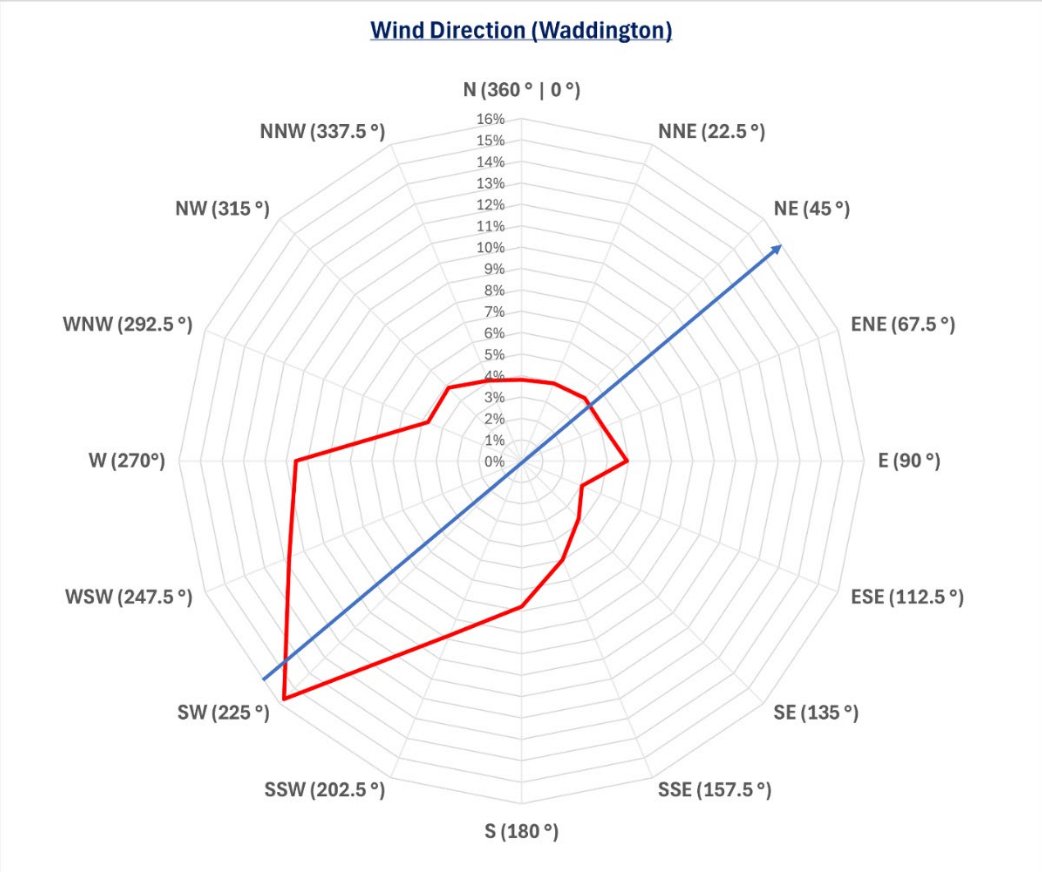
3.7.3. The key data is summarised as follows:

Average annual ambient temperature:	10.2 °C
Average annual humidity:	78 %
Prevailing wind direction:	230° or SW (South-Westerly)

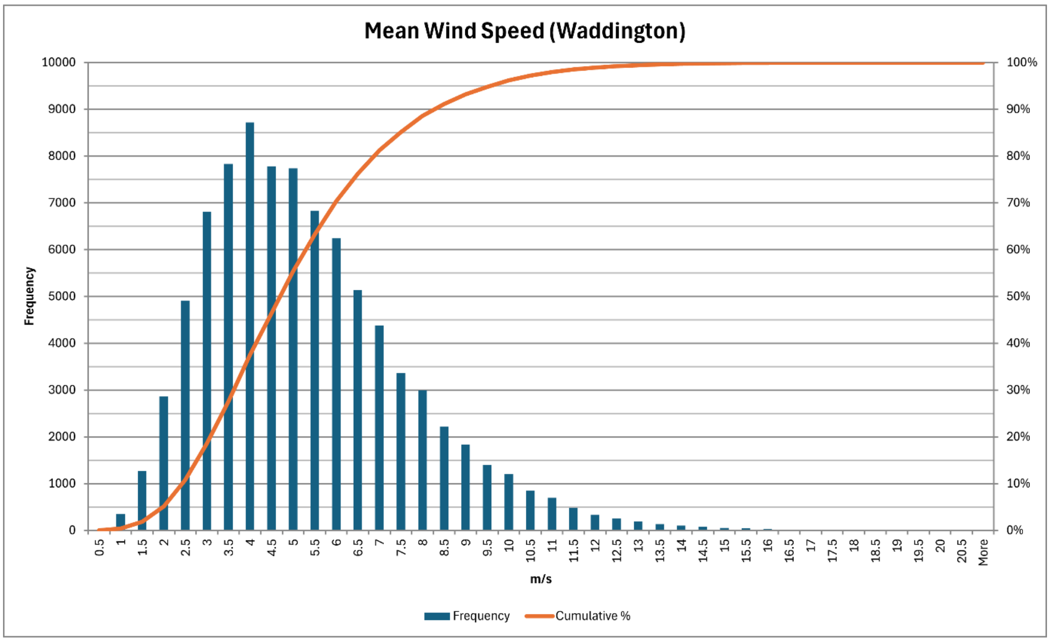
The plot shows the distribution of wind direction which has the following values:

Mean :	200°	(average)
Mode :	230°	(most common = prevailing)
Median :	220°	(middle)

3.7.4. The prevailing wind direction is show as a blue arrow on the radar diagram.



3.7.5. Average wind speed: 5 m/s (9.7 knots or 11.1 mph)



3.7.6. In accordance with industry practice the following conditions were assumed:

3.7.7. Still conditions (Pasquill-Gifford stability classification F2) tend to dominate the results of a toxic cloud release (since the low speed/turbulence does not contribute much dilution effect), however the more common D5 conditions have also been modelled (in PHAST) for HF releases as these are potentially the most harmful and therefore the impact of wind speed/stability on dispersion needs to be better understood.

3.7.8. These are derived from the Pasquill-Gifford stability classification method where the prefix letter refers to the stability class:

A. Very Unstable

B. Unstable

C. Slightly Unstable

D. Neutral

E. Slightly Stable

F. Stable

3.7.9. The suffix number refers to the wind speed in m/s.

3.7.10. Due to the low wind speed and lack of turbulence, the smoke plume is anticipated to be less than 6m in width at potentially irritating concentrations of 4.5 ppm. It should also be noted that the modelled plume remained well formed and showed a gradually rise as it moves downwind further reducing the risk to people at ground level.

3.8. Criteria

Toxic release impact assessment.

3.8.1. The modelling has been undertaken using both HSE guidance and Chemical Industries Association (UK) (CIA) for Specified Level of Toxicity (SLOT) and Significant Likelihood of Death (SLOD).

3.8.2. These are generally defined as follows:

- **SLOT** criteria reflect exposure conditions just on the verge of causing a low percentage of deaths (1% mortality) in the exposed population.
- **SLOD** criteria relates to the mortality of 50% of an exposed population.

Toxic release findings

3.8.3. For the toxic plume assessments the findings of the study have shown that the worst case impact of a toxic release varies dependent upon the prevailing wind direction and speed.

3.8.4. The modelling undertaken demonstrates that even when these barriers fail a significant impact beyond the Site is unlikely.

3.8.5. The SLOT extent contour for a 4h exposure being around 60m from the source. Due to the low wind speed and lack of turbulence the cloud is anticipated to be less than 6m in width. It should also be noted that the modelled plume remained well formed and showed a gradual rise to around 8m as it moves downwind, reducing the risk to people at ground level.

3.8.6. For Carbon monoxide, is it possible that members of the public could be harmfully impacted at less than 52m.

3.8.7. As noted the location of the battery site was determined with our understanding of the risk of toxic plume. It was sited to be as far as possible from any off site receptors, the nearest being approximately 440m south east of the Site. Noting that the prevailing wind direction for the site is typically south-westerly, the likelihood is that any plume would be more likely to move to the north-east. Therefore the likely impact on the general public, particular nearby residents is deemed to be very low.

3.8.8. This would leave only site operatives, emergency responders and passers-by at risk. These risks would be managed through an emergency response plan which will be put in place for the Site, as secured in the **oBSMP [EN010149/APP/7.14.2]**.

3.8.9. It should be noted that these worst case (distance travelled) plumes are very narrow, due to the low wind speed resulting in low turbulence. The plume will consist of not only the target gas but will be part of a larger plume of smoke, which site operatives and or passers-by are unlikely to remain within unless incapacitated.

3.8.10. The emergency response plan would also cover these eventualities;

- The duration of dwell for any site personnel, responder or member of the public will be controlled (minimized) to reduce the exposure time & concentration.
- This may include installation of visual e.g. beacons and/or audible e.g. klaxons alarms to alert onsite & offsite personnel of a venting event. The site is remote (with few members of the general public in the vicinity), therefore beacons/klaxons may be of limited value for those not aware of the hazards the site may present.
- This may include installation of a met mast or other relevant system on the site to measure wind speed and direction so that this can be shared in real-time with emergency responders and others to inform relevant and effective emergency response.
- As would be the case in any fire event, relevant nearby properties in the downwind direction would receive recommendations for people to remain indoors and keep doors and windows closed to further reduce any impact.
- A site cordon / exclusion zone would be in place;
- This may extend to the Public Rights of Way (PRoW) to the south however dwell times in the smoky plume would need to be reasonable for any impact on receptors and the smoke would serve to encourage people to avoid the area.
- The immediate downwind areas would be investigated for casualties.
- It is anticipated that the emergency response would take no more than a few tens of minutes to attend site, meaning that only incapacitated people in the immediate vicinity (within the site) would be at significant risk during this time. Discussions regarding the emergency response are ongoing; the ERP drafted with LFRS at the detailed design stage will fully address this type of emergency response scenario.
- The appropriate highways authorities would be alerted in the event of a thermal runaway (or other major incident) at the BESS location and take appropriate actions.

Flammable Release Impact Assessment

3.8.11. The distance to reach the Lower Explosive Limit (LEL) of Methane (CH_4) is predicted to evaluate the potential for a flammable release which may ignite after a time delay, thus presenting a threat to emergency response personnel in the vicinity. The 10% LEL of Methane is 93m in air.

3.8.12. To assist in the controlling of a fire and to understand the likely impact of a fire the CIA (Chemical Industries Association) guidelines for Occupied Buildings, the radiation threshold of 6.3 kW/m2 was selected. Radiation levels below this are taken as 'safe escape' with a 1% chance of fatality if exposed for 90 seconds.

Flammable Release Findings

3.8.13. A jet type fire of the vented hydrogen has also been modelled with the industry threshold of 6.3kW/m2 being reached at a distance of 5m from the source. However this would be assessed on the ground during any event as a precautionary measure.

3.8.14. The model predicts that the LEL of Methane would extend less than 5m from the release point. This is considered to be secondary to the H2 risk considered.

Explosion Impact Assessment

3.8.15. The effects of a vapor cloud explosion (VCE) depend on a number of factors. By default, the time of ignition is unknown, and it is assumed that the cloud is ignited by a flame or spark.

3.8.16. Although the site will be locally congested, there is a pressure release panel on each container and an uncongested explosion has been assumed.

3.8.17. The CIA guidelines for Occupied Buildings suggest an explosion overpressure threshold of 30 mbar as overpressures below this are insufficient to cause structural damage or significant window glass hazards. As the modelling software has a lower limit of 0.5 psi (~35 mbar ~3.5kPa) for calculating overpressure this has been used

3.8.18. An extreme threshold of 15,800 pascals (15.8 kPa) which may result in structural damage has also been considered. This is also around the pressure level that studies have shown that people can reasonably tolerate in an explosion.

Explosion Findings

3.8.19. The unconfined explosive potential has been modelled to be around 20m to reach the 3.5kPa value with the 15kPa being slightly less than 20m.

This would ensure that any explosive effects are contained within the site perimeter.

- This information will be used in the emergency response plan to assist the fire service in setting a safe operational distance during an event with an appropriate factor of safety.

4. Summary

4.1.1. With consideration of the findings against the outcomes of the reported BESS compound incidents both globally and in the UK it has been seen that the risk of fire and explosion is real and that generally our understanding of the real world outcomes appears to correlate with the modelling findings.

4.1.2. This plume assessment has considered the potential impacts from all types of battery failures, finding that in the occurrence of credible worst-case scenarios, nearby receptors are likely to remain unaffected relative to thresholds outlined in existing guidance. The arrangement and placement of the example design ensures receptors sensitive to the types of emergency situations associated with BESS failure are largely protected prior to implementation of specific emergency response planning or control systems, and deployment of these will only increase protection in these eventualities. However, to ensure safe management of emergency situations by onsite workers and emergency responders, an Emergency Response Plan will be developed and deployed prior to construction of the BESS facility.

4.1.3. All plume assessments all site specific and any comparison should only be for indicative purposes. As an example, plume assessments based on similar LFP battery systems to the system used in the Springwell plume assessment (utilising modelling parameters suggested by the UKHSA), were commissioned for the Cottam and West Burton DCO schemes in Lincolnshire. These plume assessments established that a single enclosure BESS fire would have an insignificant impact on off-site receptors. All BESS fire emissions were below AEGL-1 levels i.e. less than 1 PPM. The closest receptor in the Cottam plume study was 320 metres and the closest receptor in the West Burton study was 510 metres.

4.1.4. Therefore the Applicant considers that this document demonstrates a deep understanding of the risks of building and operating a large scale battery storage installation. It has been demonstrated that under day-to-day operation there is a low risk of an incident, and in the event of an incident the credible hazards are understood and have been evaluated at this concept design stage to demonstrate that the risk to the local population remains very low.

Springwell
Solar Farm

springwellsolarfarm.co.uk

Application Document Ref: EN010149/APP/7.19.2
Planning Inspectorate Scheme Ref: EN010149