Longfield Solar Farm

Environmental Statement [PINS Ref: EN010118]

BESS Plume Assessment

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Longfield Solar Energy Farm Ltd

APFP Regulation 5(2)(a)

Planning Act 2008

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

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Executive Summary

1. Plume Assessment

1.1. Introduction

This assessment acknowledges that there may be concern regarding fire safety of battery systems and the possible impacts upon receptors.

This assessment should be read in conjunction with the Outline Battery Safety Management Plan (BSMP) and provides an assessment of the possible impact of a fire event within the BESS battery components.

This document provides an assessment of the potential **credible worst case** air quality impacts of a fire incident at the BESS Compound forming part of the Scheme.

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.

1.2. Background

1.2.1. Scheme Overview

The Scheme includes a BESS compound either side of the Longfield Substation to the north of Porters Wood as shown in the Works Plans submitted with the Application (Document Reference 2.2).

For the purposes of this document a Concept Design (ES 6.2 [Appendix 2A]) has been considered that uses a BESS system based upon LFP technology that is currently used on other sites being developed by the Applicant.

The Concept Design (ES 6.2 [Appendix 2A]) consists of the BESS Compound, enclosures and the associated transformers, circuit breakers and inverters. The BESS Compound, enclosures and auxiliary systems, such as cooling, Uninterrupted Power Supplies, fire detection and suppression systems, monitoring and control, will be designed in accordance with internationally recognised good practice guidance available at the time.

Once operational, the plant will be designed to operate unmanned with access required for maintenance only, and with a minimum operational life of 40 years.

This will allow the generated solar energy to be stored when demand is low and discharged to the electricity network at times of greatest demand.

1.2.2. Battery System Basic Architecture

The Concept Design (ES 6.2 [Appendix 2A]) of the BESS Compound has been selected based upon the current technology trends, where there has been a move from Lithium-Nickel-Manganese-Cobalt-Oxide (NMC) to Lithium Iron Phosphate (LFP) chemistries. The Concept Design (ES 6.2 [Appendix 2A]) is a system consisting of LFP cells.

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 guidance available at the time.

1.2.3. Battery System Failures

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.

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 fire.

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 whole BESS Compound site is addressed in this report.

1.3. Incident Impacts

A consequence analysis of the potential immediate effects of a fire or other incident event has been undertaken. This process is undertaken for all EDF Renewables BESS sites in the UK (EDFR are the major shareholder of the Applicant) and has been repeated for the Concept Design (ES 6.2 [Appendix 2A]) for the Scheme. The aim of the assessment is to understand the envelope of possible impacts of a BESS on the nearby receptors in an emergency situation; primarily the emergency responders and those in the surrounding area such as workers or local residents.

1.3.1. System location

Within the Order Limits, the selection of the location of the BESS Compound (Work No. 2 on the Works Plans) has been determined with consideration of a number of factors. The most pertinent factor being 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 an event occur. As such the closest property to the BESS Compound is approximately 440m away.

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).

1.3.2. Candidate System

The Concept Design (ES 6.2 [Appendix 2A]) electrochemistry is LFP, and modules from the Concept Design (ES 6.2 [Appendix 2A]) have been assessed to UL9450A Edition 2: Energy Storage Systems and Equipment. This determines the likelihood of a fire spreading within a battery system. The Concept Design satisfied the criteria at module level.

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.

It should be noted that LFP batteries do generate more Hydrogen Fluoride (HF) than NMC type cells, again a conservative approach.

In the event of a fire, the battery system and the transformers serving the BESS Compound will be automatically electrically isolated when a fire is detected within a container. However, the batteries within the containers will still hold charge in the event of a fire 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 Essex fire and rescue service with regards to the Scheme and this engagement has led to a number of design improvements.

Spatial protections built into the Concept Design (ES 6.2 [Appendix 2A]) via component grouping means that in the unlikely event that a fire should occur and all of the system design mitigations and preventative measures fail, it 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.

1.3.3. Methodology

To determine the impact of a fire event a number of **credible worst case scenarios** have been developed and modelled for the candidate battery system.

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 EDFR global team. EDFR 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.

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.

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.

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.

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 analysis does not consider all weather conditions (wind speed & direction and ambient temperature). A wind speed of 2 m/s has 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.

The analysis does not consider the effects of obstacles (man-made or natural) in the path of the releases.

1.3.4. Definitions

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.

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.

Worst case would be dependent on the assessment being made.

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.

For a fire, which as noted the candidate cells passed the UL9450a assessment at module level without igniting but to understand the possible worst case, it is assumed that the cells ignite and all are consumed. 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.

1.3.5. Parameters

1.3.5.1. Gas release.

To calculate the vent concentrations of a Concept Design (ES 6.2 [Appendix 2A]) cell, laboratory measurements of off-gasses are extrapolated to the system level.

Where the exact cell technology is known and reports are available this can be directly calculated. The Concept Design (ES 6.2 [Appendix 2A]) cell manufacturer has provided gas analysis from their UL9450A testing however this did not include HF evolution. Initially an assessment was made by reference to;

Literature – the volumes are in accordance with studies of similar technologies

Calculation from components using the MSDS for example; $LiPF_6$+H_2O -> LiF +POF_3+2HF

By comparison to other similar cell technology off-gas tests. Data has been collated from a number of cell manufacturers and from our own library of cell data. Some of this data is under NDA and so cannot be reproduced.

With regards the literature there were a range of values some an order of magnitude greater than others. Different chemistries are known to deliver different volumes and types of toxic gas. The values available had a reasonable range depending on the manufacturer , energy density and form factor. In the order of 20 to 200mg/Wh.

The calculation method was undertaken based upon the Material Safety Data Sheet (MSDS) of the candidate cell and found to be in the order of 80mg/Wh. This was anticipated to be an overestimate the quantities of HF produced but was used for initial modelling until more reliable data could be acquired. This figure has been superseded and is not used in this assessment.

As no HF off gas data was available for the candidate cell, as part of a wider battery safety research programme EDF, and The French National Institute for Industrial Environment and Risks (Ineris) undertook testing of the candidate LFP cell along with LFP cells of almost identical Wh capacity from two other manufacturers.

The cells were tested following a destructive protocol (UL9540a) leading to thermal runaway. These 3 cell types had very similar behaviours. Significantly there was no fire from any of the cells as per the original UL certification. A significant smoke emission was observed.

These fumes were analysed at the exit of the ventilation system a few meters from the cells. The testing programme is ongoing at the time of producing this report. However, the actual HF evolution data for the candidate cell has been released early to facilitate this report and was found to be around 40mg/Wh.

Therefore the assessment has been made using the 40mg/Wh figure.

This Concept Design (ES 6.2 [Appendix 2A]) 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 (H_2)
- Carbon Monoxide (CO)
- Hydrogen Fluoride (HF)
- Methane (CH_4)
- Ethylene (C_2H_4)
- Ethane (C_2H_6)
- Propylene (C_3H_6)

Note that Carbon Dioxide (CO_2) was not evaluated as it is not considered harmful in an open environment. <1%

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
- Hydrogen (most flammable/explosive)
- Ethylene (most flammable material that is heavier than air at STP – Standard Temperature & Pressure)

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 Outline BSMP submitted with the Application) is required to be submitted to the relevant local planning authority and approved, in consultation with the Health and Safety Executive, the Essex County Fire and Rescue Service and the Environment Agency. The Applicant must operate the BESS in accordance with the approved plan.

Further, pursuant to a requirement of the DCO, the detailed design of the BESS must be in accordance with the Outline - BSMP (which includes various safety requirements for the BESS design) and the Outline Design Principles. The Outline Design Principles contain controls over the BESS, which include: 1) that the chemistry of the BESS will be lithium ion, and 2) that an assessment will be undertaken, based on the detailed design for the BESS, to demonstrate that the risk of fire and impacts from such a fire will be no worse than as assessed in the plume assessment submitted with the Application.

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

1.3.5.2. Explosive gas volume

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.

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.

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

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.

1.3.5.3. Event Duration

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 to contain, giving an approximate duration for the release of gasses over 12 hours. 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.

1.3.6. Scenarios

It was assessed that the worst credible scenarios could be:

1. Release of Hydrogen Fluoride over 4 hours.
2. Release of Carbon Monoxide over 4 hours.
3. Instantaneous explosion of a ‘container’ of Hydrogen.
    a. The volume of hydrogen is calculated as the total volume of airspace in an enclosure replaced by the vent gasses in their component parts
4. Release of flammable Ethylene over 4 hours.
5. Fire inside the container resulting from ignition of Hydrogen

Meteorology

Site data was acquired along with atmospheric data for the assessment. In accordance with industry practice the following conditions were assumed:

D5 weather occurs frequently in the UK and is used to calculate the hazard range for daytime releases.

F2 weather which characterizes night time conditions, produce stable atmospheric conditions where dispersion is reduced and generally produces the greatest hazard range.

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

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

Preliminary analysis was conducted on both D5 and F2 conditions and final analysis was conducted on only the F2 conditions (greatest hazard range).

For the F2 conditions, due to the low wind speed and lack of turbulence, the cloud is anticipated to be less than 10m in width. 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.

1.3.7. Criteria

1.3.7.1. Toxic release impact assessment.

The modelling has been undertaken using both US Emergency Response Planning Guidelines/Public Health England and HSE guidance for both Specified Level of Toxicity (SLOT) and Significant Likelihood of Death (SLOD).

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

For an evenly distributed population, the number of fatalities resulting from a toxic release may be approximated by estimating the number of people inside the concentration contour leading to a SLOD Dangerous Toxic Load (DTL). This approximation results from the assumption that those people inside the SLOD contour who do not die (due to factors such as physiology, fitness levels, etc) will be balanced by an approximately equal number outside the SLOD contour who do die (again, due to factors such as physiology, state of health etc.)

Further, the number of people injured (serious and minor) by the release may be approximated by the number people estimated to be between the SLOD and SLOT DTL contours (i.e. the SLOT DTL contour is taken as a pragmatic limit for injuries).

It is conservatively assumed that the population is vulnerable both inside and outside, however in reality buildings provide a degree of protection against the effects of the release as compared to being outdoors. The level of protection is related to the rate at which air and toxic material enters the building and may be measured in air changes per hour (ACH). For the purposes of the models, the location of exposed persons and the integrity of the buildings has not been considered.

ERPGs are air concentration guidelines for single exposures to agents. They are intended for use as tools to assess the adequacy of accident prevention and emergency response plans, including transportation emergency planning, community emergency response plans, and incident prevention and mitigation

They are defined as follows:

- **ERPG-3** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
- **ERPG-2** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.
- **ERPG-1** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odour.

This is consistent with Chemical Industry Association (CIA) OBRA guidance levels which also identify suitable lower limits for thermal radiation and overpressure.

Table 4.1 Often applied Benchmarks for the hazard based approach.

Hazardous effect	Benchmark value below which no specific building safety measures are required	Basis
Explosion overpressure	30mbar(g)	Overpressures below 30mbar(g) are insufficient to cause structural damage or significant window glass hazards[33a]
Thermal radiation[19]	6.3 kW/m²	Radiation levels below 6.3kW/m² are taken as 'safe escape' (1% fatality 90 seconds exposure)
Flammable gas	LFL	Buildings outside LFL will not experience ingress of flammable gas above flammable concentrations
Toxic gas concentration	EPRG 3 or suitable equivalent*	Buildings outside these doses will not experience concentrations of concern from toxic gas ingress

** Available existing consequence modelling for sites may use alternative values. For example, in the UK, it is common for modelling to reference SLOT doses, which may also be suitable.*

For the scenarios the reference values are:

1. Hydrogen Fluoride
    a. ERPG-3 -50ppm
    b. ERPG-2 -20ppm
    c. ERPG-1 – 2ppm

According to HSE website "Toxicity Levels of Chemicals" HF has a SLOT of 1.2E+4 ppm/min therefore for a 240 min (4 hr) exposure the limit is 50 ppm i.e. the same as the ERPG-3 figure. The SLOD being 2.1E+4 ppm/min.

The 4h exposure is not linked to the duration of an event, but was selected to reflect a longer term exposure (again conservative) and align with the ERPG-3 value.

2. Carbon Monoxide
    a. ERPG-3 -500ppm
    b. ERPG-2 -350ppm
    c. ERPG-1 – 200ppm

Whereas in SLOT terms, 1 hour (60 min) would have a threshold of 669 ppm and a 4 hour (240 min) would have a threshold of 'only' 167 ppm

1.3.7.2. Toxic release findings

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.

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

The SLOT extent contour for a 4h exposure being around 60m from the source, which aligns with the ERPG-3 1h exposure limit. Due to the low wind speed and lack of turbulence the cloud is anticipated to be less than 10m in width. It should also be noted that the modelled plume remained well formed and showed a gradual rise to around 12m as it moves downwind, reducing the risk to people at ground level.

For Carbon monoxide the likely impact is modelled to be less than 50m.

As noted the location of the battery site was determined with our understanding of the risk of toxic plume and was sited to be as far as possible from any off site receptors, approximately 440m in any direction. Noting that the prevailing wind direction for the site is typically from the south-west 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.

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 defined in the Outline BSMP).

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.

The emergency response plan would also cover these eventualities;

- As would be the case in any fire event 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 PRoW to the southwest 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.

1.3.7.3. Flammable Release impact assessment.

The distance to reach the Lower Explosive Limit (LEL) of Ethylene (C_2H_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 LEL of Ethylene is 27,000 ppm in air.

To assist in the firefighting, 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/m_2 was selected. Radiation levels below this are taken as 'safe escape' with a 1% chance of fatality if exposed for 90 seconds.

1.3.7.4. Flammable Release Findings.

A jet type fire of the vented hydrogen has also been modelled with the threshold of 6.3kW/m2 being reached at a distance of 10m from the source. However this would be assessed on the ground during any event.

The model predicts that the LEL of Ethylene would extend less than 10m from the release point. This is considered to be secondary to the H2 risk considered.

1.3.7.5. Explosion impact assessment.

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.

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

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. For context 3.5kPa is approximately equivalent to a 160mph windspeed.

An extreme threshold of 15,000 pascals (15 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.

1.3.7.6. Explosion Findings.

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.

2. Summary

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.

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 Concept Design (ES 6.2 [Appendix 2A]) 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.

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.