Green Hill Solar Farm
EN010170

Appendix 16.2
BESS Fire Emissions Modelling

Prepared by: Arcadis Consulting (UK) Ltd

Date: May 2025

Document Reference: APP/GH6.3.16.2
APFP Regulation 5(2)(a)

Issue Sheet

Report Prepared for: Green Hill Solar Farm
DCO Submission

Appendix 16.2 BESS Fire Emissions Modelling

Prepared by
Name: Hannah Dennett Job title: Principal Air Quality Consultant
Approved by
Name: Stephen Pyatt Job title: Air Quality Technical Director

Revision	Date	Prepared by	Approved by
Original	03/04/2025	HD	SP

Introduction

Associated infrastructure for the Scheme such as Battery Energy Storage Systems (BESS) have the potential to cause air quality impacts in the rare result of a fire incident. Concentrations of carbon monoxide (CO), formaldehyde, hydrogen chloride (HCl), hydrogen cyanide (HCN), hydrogen fluoride (HF), ammonia (NH_3), nitrogen dioxide (NO_2) and particulates as a result of a BESS fire have been modelled using Atmospheric Dispersion Modelling Software (ADMS) to determine the effects of BESS fire emissions on human health.

A high-level visibility assessment has also been undertaken using the modelled particulates results to determine the effect of BESS fire emissions on visibility on the local road network to inform the Outline Battery Storage Safety Management Plan **(OBSSMP) [EN010170/APP/GH7.7]**.

The following sections outline the methodology used in the assessment and the modelled results.

Assessment Methodology

Relevant Guidance and Standards

Section 16.3 of Chapter 16: Air Quality provides an overview of the legislation and planning policy against which the Scheme has been considered for air quality.

The assessment has been undertaken with due consideration of the Environment Agency's 'Air emissions risk assessment for your Environmental Permit' guidance (Ref.1), which provides advice on assessing releases to air. Whilst this guidance is used for dispersion modelling for environmental permitting purposes, it includes useful general guidance on undertaking detailed modelling of emissions to air.

Given a potential BESS fire would be a relatively short-term incident, it is considered appropriate to compare predicted concentrations against Acute Exposure Guidance Levels (AEGLs), which have higher threshold concentrations than the national air quality objectives and are relevant to short term releases. AEGLs are expressed as concentrations of a substance above which it is predicted that the general population could experience, including susceptible individuals:

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

The occurrence of adverse health effects is not likely to occur in the general public at concentrations below the AEGLs. AEGLs have a range of exposure periods; ADMS uses hourly meteorological data, therefore the shortest time period that concentrations can be predicted over is one hour. As such, the 1-hour AEGLs have been used in this assessment. The AEGLs applicable to this assessment are presented in Table 1.

Table 1: 1-Hour AEGLs for the Modelled Pollutants (Ref.2)

Pollutant	Level 1 (ppm)	Level 2 (ppm)	Level 3 (ppm)
CO	NR*	83	330
Formaldehyde	0.9	14	56
HCl	1.8	22	100
HCN	2	7.1	15
HF	1	24	44
NH_3	30	160	1,100
NO_2	0.5	12	20

*NR = Not recommended due to insufficient data

There is no AEGL for particulates. As such, the Health and Safety Executive (HSE) Workplace Exposure Limit (WEL) (Ref.3) has been used for dust which is 4mg/m^3 for respirable dust. Whilst this is over an 8-hour reference period, it is considered appropriate for use in the assessment in lieu of any other limits.

The impact of the smoke plume on visibility has been calculated based on the mass concentration of particulate matter, using the following equation developed in the Principles of Smoke Management (Ref.4):

$S = K / \alpha_m m_p$

Where:

S = visibility through smoke (m)

K = proportionality constant; a value of 3 has been used in the assessment which is applicable to the observation of a non-light emitting object in smoke.

α_{m} = specific extinction coefficient (m^2/g); a value of 7.6 m^2/g has been used in the assessment. based on flaming combustion of wood and plastics (as opposed to smouldering which has lower α_m value)

m_p= mass concentration of particulate matter (g/m^3); value has been calculated using the modelled particulate matter less than 10 microns in diameter (PM_{10}) concentration associated with the BESS fire.

It should be noted that the visibility through smoke equation presented above is based on certain assumptions and therefore has inherent limitations, for example the extinction coefficient will depend on the particle size distribution and optical properties of the particulates. The output of the visibility calculations should therefore be treated with caution and used as a guide only.

Modelling Parameters

Input Data

Dispersion modelling has been undertaken using ADMS-Roads 5 (model version 5.0.0.1). ADMS-Roads 5 is a Gaussian plume air dispersion model used to model the air quality impact of road traffic and industrial sources. The model utilises hourly meteorological data in order to define conditions for plume rise, transport and diffusion. It estimates the concentration for each source and receptors combination for each hour of inputted meteorology and calculates user selected long-term and short-term averages.

The preferred location for the BESS is at Green Hill BESS as shown on **Figure 4.9 Illustrative Layout Plan Green Hill BESS [EN010170/APP/GH6.4.4.9]**, however BESS may also be located on Green Hill C as shown on **Figure 4.4.1 Illustrative Layout Plan Green Hill C_Option A [EN010170/APP/GH6.4.4.4.1]** and **Figure 4.4.2 Illustrative Layout Plan Green Hill C_Option B [EN010170/APP/GH6.4.4.4.2].** The final layout of the BESS compound will be determined during detailed design. The precise number of individual battery storage containers will depend upon the level of power capacity and duration of energy storage that the Scheme will require.

Worst case BESS fire locations (i.e. locations within the BESS Site closest to sensitive receptors) have been modelled as depicted in **Figure 16.4 BESS Fire Emissions Study Area, Receptors and Modelled BESS Locations**. The arrangement of the BESS has not been finalised, therefore the maximum extents of the potential BESS areas have been used as a worst case, as presented in **Figure 16.4 BESS Fire Emissions Study Area, Receptors and Modelled BESS Locations**.

Each of the modelled ten BESS fire locations have been modelled as an area source so that plume rise was factored into the model (the model does not allow for plume rise for volume sources). The area source dimensions have been based on the dimensions of one BESS enclosure (605.8cm wide and 259.1cm long).

Emissions data for BESS fires are limited. At the recommendation of the Scheme's Battery Safety and Testing Consultant, emissions data have been derived from the GridSolv Quantum Cube Bespoke Unit Testing Summary Report, prepared by Fire & Risk Alliance LLC for Wartsila North America, Inc. (Ref.5). The test fire was conducted using Large Format Prismatic (LFP) lithium iron phosphate battery modules; each module comprised 52 cells and each rack comprises eight modules, which is the same proposed battery set-up for the Scheme. Emissions from a test fire were measured using a probe approximately 3.35m above ground level. The maximum recorded concentrations are presented in Table 2. It should be noted that the report presents concentrations for other gases (such as carbon dioxide and methane), however, only gases considered the most harmful to human health have been considered in this assessment.

Table 2: Maximum Gas Concentrations Measured above the Initiating Unit

Gas	Maximum Concentration (ppm)
CO	3061.0
Formaldehyde	77.8
HCl	114.4
HCN	54.5
HF	575.6
NH_3	23.7
Nitric Oxide (NO)	59.4

Emissions data were not available in the report for particulates. As such, at the recommendation of the Scheme's Battery Safety and Testing Consultant, particulate emissions data were taken from the Axminster Energy Hub Plume Assessment Study prepared by DNV for Clearstone Energy (Ref.6). The assessment assumed that a battery unit fire is equivalent to a diesel fire for production of Particulate Matter (PM) and used a concentration of 0.25g/m^3. The height at which the concentration was measured was not reported, therefore the same height as that reported in the Quantum Cube Bespoke Unit Testing Summary Report (Ref.5) has been assumed (3.35m).

The Quantum Cube Bespoke Unit Testing Summary Report (Ref.5) did not report a maximum temperature at the sampling point. As such, the maximum recorded temperature from the roof of another test fire was utilised, at the recommendation of the Scheme's Battery Safety and Testing Consultant. The Sungrow Battery Energy Storage System (BESS) PowerTitan 2.0 Large Scale Burn Test Report prepared by DNV for Sungrow Power Supply Co., Ltd. (Ref.7) reported a maximum roof temperature of 914^{o}C. In lieu of any other suitable data, this was used for the temperature. Roof temperatures can reach 1300^{o}C during a fire; it is therefore considered that using a temperature of 914^{o}C is a conservative estimate as a higher temperature would be expected to increase buoyancy and aid dispersion.

When modelling a fire in ADMS, the height of the release should be the height of the flames. Maximum flame heights of around 4m were reported in the Sungrow Battery Energy Storage System (BESS) PowerTitan 2.0 Large Scale Burn Test Report (Ref.7). However, this exceeds the height of the sampling point, therefore the height of the release was assumed to be 3.35m (height of the sampling point). This is considered a conservative estimate as a higher release height would generally result in increased dispersion.

The plume rise is primarily buoyancy-driven rather than being mechanically expelled like a stack, as such a nominal value of 1m/s has been used for the velocity to activate the plume rise module (which would not activate if the velocity was zero).

Meteorological Data and Surface Characteristics

Meteorological data recorded at Bedford weather station was used for the air quality modelling as this was the closest, most appropriate station with good data capture for the desired time period. Bedford weather station is 13km east of the Scheme Order Limits. The station is situated in Bedford Aerodrome and is predominantly surrounded by open agricultural land. In accordance with the Environment Agency guidance (Ref.1), models have been run using five years of meteorological data, from 2020 to 2024 inclusive. The meteorological data was obtained from Air Pollution Services (APS) which provided hourly meteorological data for each year in ADMS format.

A surface roughness of 0.5m and minimum Monin-Obukhov length of 10m was used to represent the predominantly rural surroundings of the Scheme. These parameters, which are determined by land use, influence wind patterns and atmospheric turbulence affect pollution dispersion. These values were selected as they were judged to be most representative of the predominant land use dispersion characteristics across the study area.

Building and Terrain Inputs

Buildings can affect the observed dispersion pattern; buildings taller than 40% of the stack height and at a distance within 5 L from the stack (where L is the lesser of the building height and the maximum projected width) should be included in the model (Ref.8). The only building in the vicinity of the BESS Site would be the proposed GIS building. This would be approximately 15m by 40m and 12.5m in height. The maximum projected width of the building would be 42.7m (the diagonal measurement of the building). The height of the building is less than that (12.5m), as such, L would be 12.5m, and 5L would therefore be 62.5m. The minimum distance of the GIS building to the BESS Site would be approximately 70m, therefore this does not need including within the model as it is more than 62.5m from any of the BESS.

Terrain data have been incorporated into the model using 50m x 50m resolution terrain data from the Ordnance Survey (OS) OS Terrain 50 dataset. The terrain file covers the Scheme and its surroundings.

Derivation of Emission Rates

ADMS requires emissions data in the format of $g/m^2/s$ for area sources. The data presented in Table 2 are measured concentrations at a point 3.35m above ground level. Emission rates of $1g/m^2/s$ were used in the model, together with the parameters discussed above (summarised in Table 3).

Table 3: Parameters used to Derive Emission Rates for use in the Assessment

Parameter		Model Inputs
Area source geometry		605.8cm wide and 259.1cm long
Release height		3.35m
Velocity		1m/s
Temperature		914 ºC
Emission rate	CO	$1g/m^2/s$
	Formaldehyde	
	HCl	
	HCN	
	HF	
	NH_3	
	NO	
	PM_{10}	

The resulting concentrations were then compared with the measured concentrations to derive pollutant specific ratios. These ratios were applied to the preliminary emission rates ($1g/m^2/s$) to derive the emission rates that were used in the assessment. A test model was then set up using the derived emission rates to ensure that the predicted concentrations at the sampling point matched the measured concentrations. The derived emission rates used in the model are presented in Table 4.

Table 4: Derived Emission Rates used in the Assessment

Pollutant	Emission Rate ($g/m^2/s$)
CO	6.41
Formaldehyde	0.17
HCl	0.31
HCN	0.11
HF	0.86
NH_3	0.03
NO	0.13
PM_{10}	0.46

Background Concentrations

Defra predicted annual mean background maps provided in 1km x 1km grid squares (Ref.9) have been used to determine background pollutant concentrations for NO_2 and PM_{10} for each receptor location. Base year concentrations (2025) have been used as a worst case. Annual mean concentrations for CO and NH_3 were taken from the nearest background monitoring station for which data were available (Leeds Urban Background and Chilbolton Observatory for CO and NH_3, respectively) for 2024 (the latest available year) (Ref.9). Recent background concentrations were not available for HCl, HCN, formaldehyde and HF. However, it is considered that background concentrations of these pollutants would be negligible. In accordance with the Environment Agency guidance (Ref.1), it has been assumed that the short-term background concentration of a substance is twice its long-term concentration. As such, annual mean background concentrations were doubled to approximate the 1-hour background concentration. The 1-hour concentrations used in the assessment are presented in Table 5.

Table 5: Estimated 1-Hour Background Concentrations

Receptor	1-Hour Background Concentration ($\mu g/m^3$)							
	CO	Formaldehyde	HCl	HCN	HF	NH_3	NO_2	PM_{10}
Relan Lodge	270	-	-	-	-	5.8	12.8	24.9
Heidelberg Materials Aggregate	270	-	-	-	-	5.8	13.6	24.4
The Gatehouse	270	-	-	-	-	5.8	14.4	26.1
Bedlam Paintball	270	-	-	-	-	5.8	13.9	23.8
Grendon Hall	270	-	-	-	-	5.8	12.8	24.9

Receptor	1-Hour Background Concentration (µg/m³)							
	CO	Formaldehyde	HCl	HCN	HF	NH_3	NO_2	PM_{10}
Grendon C of E Primary School	270	-	-	-	-	5.8	12.8	24.9
Church Farm	270	-	-	-	-	5.8	12.8	24.9
81 Main Road	270	-	-	-	-	5.8	13.0	24.9
Appleby Barn	270	-	-	-	-	5.8	13.3	24.4
Highfield Lodge	270	-	-	-	-	5.8	13.3	24.4
Ashby Furse Farm	270	-	-	-	-	5.8	13.3	24.4
Beckworth Emporium	270	-	-	-	-	5.8	13.2	23.7
Sywell Aerodrome 1	270	-	-	-	-	5.8	13.3	24.2
Sywell Aerodrome 2	270	-	-	-	-	5.8	13.3	24.2
Wood Lodge Farm	270	-	-	-	-	5.8	13.2	23.7
Hardwick Grange Farm	270	-	-	-	-	5.8	13.1	24.5
Pastures Farm	270	-	-	-	-	5.8	13.6	24.4
Porters Lodge	270	-	-	-	-	5.8	13.6	24.4
PROW 1	270	-	-	-	-	5.8	13.2	23.7
PROW 2	270	-	-	-	-	5.8	13.2	23.7
PROW 3	270	-	-	-	-	5.8	13.2	23.7
PROW 4	270	-	-	-	-	5.8	13.3	24.4
PROW 5	270	-	-	-	-	5.8	13.3	24.4
PROW 6	270	-	-	-	-	5.8	13.6	24.4
PROW 7	270	-	-	-	-	5.8	13.6	24.4
PROW 8	270	-	-	-	-	5.8	13.1	24.9
PROW 9	270	-	-	-	-	5.8	13.1	24.9
PROW 10	270	-	-	-	-	5.8	12.8	24.9
PROW 11	270	-	-	-	-	5.8	12.8	24.9
Sywell Road 1*	-	-	-	-	-	-	-	23.7
Sywell Road 2*	-	-	-	-	-	-	-	23.7
Sywell Road 3*	-	-	-	-	-	-	-	23.7

Receptor	1-Hour Background Concentration (µg/m³)							
	CO	Formaldehyde	HCl	HCN	HF	NH_3	NO_2	PM_{10}
Station Road 1*	-	-	-	-	-	-	-	24.4
Station Road 2*	-	-	-	-	-	-	-	24.4
Station Road 3*	-	-	-	-	-	-	-	24.4
Station Road 4*	-	-	-	-	-	-	-	26.3
Station Road 5*	-	-	-	-	-	-	-	26.3
Station Road 6*	-	-	-	-	-	-	-	26.3
Station Road 7*	-	-	-	-	-	-	-	26.3

*Receptors only considered in visibility assessment, therefore only PM_{10} background required.

Unit Conversion

AEGLs are in ppm, whereas ADMS Roads uses µg/m³ and background concentrations are in µg/m³. To convert between the two units, the following equation was used:

Concentration (µg/m³) = molecular weight x concentration (ppb) ÷ 24.45

The molecular weights for each pollutant used in the assessment are as follows:

- CH_4 - 16.04;
- CO - 28.01;
- CO_2 - 44.01;
- Formaldehyde - 30.03;
- HCL - 36.46;
- HCN - 27.03;
- HF - 20.01;
- NH_3 - 17.03; and
- NO - 30.01.

PM_{10} concentrations were not converted to ppm, as it was not necessary (there is no AEGL for PM_{10}).

Receptors

Human receptors have been identified in the vicinity of the Scheme using Google Earth imagery and worst-case receptor locations have been selected. The receptor locations are presented in Table 6 and in **Figure 16.4 BESS Fire Emissions Study Area, Receptors and Modelled BESS Locations.**

Table 6: Receptor Locations

Receptor	X (m)	Y (m)	Z (m)	Distance to BESS Area (m)
Relan Lodge	487359	260425	1.5	504
Heidelberg Materials Aggregate	486121	261858	1.5	705
The Gatehouse	485985	261747	1.5	691
Bedlam Paintball	487289	262043	1.5	937
Grendon Hall	487975	260836	1.5	874
Grendon C of E Primary School	487837	260340	1.5	925
Church Farm	487858	260514	1.5	847
81 Main Road	488183	261052	1.5	1087
Appleby Barn	484704	268848	1.5	852
Highfield Lodge	484605	268532	1.5	751
Ashby Furse Farm	484070	268273	1.5	338
Beckworth Emporium	483531	268044	1.5	496
Sywell Aerodrome 1	482678	268758	1.5	885
Sywell Aerodrome 2	482805	268041	1.5	964
Wood Lodge Farm	483048	268259	1.5	635
Hardwick Grange Farm	484184	269784	1.5	1146
Pastures Farm	486444	261461	1.5	201
Porters Lodge	486213	261314	1.5	238
PROW 1	483513	268770	1.5	97
PROW 2	483498	268642	1.5	65
PROW 3	483402	268496	1.5	230
PROW 4	484360	268719	1.5	502
PROW 5	484333	268538	1.5	476
PROW 6	486286	261742	1.5	529
PROW 7	486710	261690	1.5	361
PROW 8	487528	261537	1.5	671

Receptor	X (m)	Y (m)	Z (m)	Distance to BESS Area (m)
PROW 9	487826	261096	1.5	754
PROW 10	487847	260792	1.5	756
PROW 11	487105	260555	1.5	254

Worst case locations on roads in the vicinity of the BESS Sites were selected for the visibility assessment, as detailed in Table 7 below.

Table 7: Visibility Assessment Locations

Receptor	X (m)	Y (m)	Z (m)	Distance to BESS Area (m)
Sywell Road 1	483398	268089	1.5	513
Sywell Road 2	483729	268100	1.5	431
Sywell Road 3	483934	268182	1.5	361
Station Road 1	486325	261270	1.5	123
Station Road 2	486416	261214	1.5	35
Station Road 3	486621	261060	1.5	35
Station Road 4	486804	260926	1.5	60
Station Road 5	486850	260892	1.5	23
Station Road 6	486915	260830	1.5	25
Station Road 7	486977	260770	1.5	36

A grid was also modelled at a resolution of 20m to ensure maximum concentrations were captured at the selected receptor locations.

Results

Human Health

The maximum modelled one-hour concentrations over the five modelled years for the worst-case BESS fire location for each sensitive receptor are summarised in Table 8. It should be noted that emissions data was available for NO rather than NO_2. However, there are no AEGLs available for NO and it states that *"AEGL values for nitrogen dioxide should be used for emergency planning"* rather than NO (Ref.2). As such, for the purposes of this assessment, it has been assumed that modelled NO concentrations are NO_2.

Table 8: Maximum Modelled One-Hour Concentrations

Receptor	Maximum Hourly Concentration								BESS Location where Maximum Concentration was Modelled
	CO (ppm)	Formaldehyde (ppm)	HCl (ppm)	HCN (ppm)	HF (ppm)	NH_3 (ppm)	NO_2 (ppm)	PM_{10} (mg/m³)	
Relan Lodge	0.81	0.02	0.03	0.01	0.15	0.01	0.02	0.07	BESS 9
Heidelberg Materials Aggregate	0.52	0.01	0.02	0.01	0.10	0.00	0.01	0.04	BESS 6
The Gatehouse	0.54	0.01	0.02	0.01	0.10	0.00	0.01	0.04	BESS 6
Bedlam Paintball	0.44	0.01	0.02	0.01	0.08	0.00	0.01	0.04	BESS 7
Grendon Hall	0.51	0.01	0.02	0.01	0.10	0.00	0.01	0.04	BESS 10
Grendon C of E Primary School	0.55	0.01	0.02	0.01	0.10	0.00	0.01	0.04	BESS 10
Church Farm	0.50	0.01	0.02	0.01	0.09	0.00	0.01	0.04	BESS 10
81 Main Road	0.48	0.01	0.02	0.01	0.09	0.00	0.01	0.04	BESS 8
Appleby Barn	0.41	0.01	0.02	0.01	0.08	0.00	0.01	0.03	BESS 2
Highfield Lodge	0.58	0.01	0.02	0.01	0.11	0.00	0.01	0.05	BESS 4
Ashby Furse Farm	1.51	0.04	0.06	0.03	0.28	0.01	0.03	0.12	BESS 2
Beckworth Emporium	0.72	0.02	0.03	0.01	0.14	0.01	0.01	0.06	BESS 3
Sywell Aerodrome 1	0.49	0.01	0.02	0.01	0.09	0.00	0.01	0.04	BESS 1
Sywell Aerodrome 2	0.43	0.01	0.02	0.01	0.08	0.00	0.01	0.04	BESS 1
Wood Lodge Farm	0.55	0.01	0.02	0.01	0.10	0.00	0.01	0.04	BESS 1
Hardwick Grange Farm	0.42	0.01	0.02	0.01	0.08	0.00	0.01	0.03	BESS 4
Pastures Farm	1.95	0.05	0.07	0.03	0.37	0.02	0.04	0.16	BESS 6
Porters Lodge	1.69	0.04	0.06	0.03	0.32	0.01	0.03	0.14	BESS 6
PROW 1	3.85	0.10	0.14	0.07	0.72	0.03	0.07	0.31	BESS 1
PROW 2	9.79	0.25	0.37	0.17	1.84	0.08	0.19	0.80	BESS 1
PROW 3	2.03	0.05	0.08	0.04	0.38	0.02	0.04	0.17	BESS 1
PROW 4	0.72	0.02	0.03	0.01	0.14	0.01	0.01	0.06	BESS 4
PROW 5	0.82	0.02	0.03	0.01	0.16	0.01	0.02	0.07	BESS 4
PROW 6	0.71	0.02	0.03	0.01	0.13	0.01	0.01	0.06	BESS 6

Receptor	Maximum Hourly Concentration								BESS Location where Maximum Concentration was Modelled
	CO (ppm)	Formaldehyde (ppm)	HCl (ppm)	HCN (ppm)	HF (ppm)	NH_3 (ppm)	NO_2 (ppm)	PM_{10} (mg/m³)	
PROW 7	1.08	0.03	0.04	0.02	0.20	0.01	0.02	0.09	BESS 5
PROW 8	0.48	0.01	0.02	0.01	0.09	0.00	0.01	0.04	BESS 10
PROW 9	0.48	0.01	0.02	0.01	0.09	0.00	0.01	0.04	BESS 10
PROW 10	0.59	0.01	0.02	0.01	0.11	0.00	0.01	0.05	BESS 10
PROW 11	1.72	0.04	0.06	0.03	0.32	0.01	0.03	0.14	BESS 9
Maximum	9.79	0.25	0.37	0.17	1.84	0.08	0.19	0.80	BESS 1

The modelled concentrations presented in Table 8 are the maximum 1-hour concentrations modelled over five years using worst case parameters for the BESS fire. The final column of the table indicates which BESS fire location resulted in the maximum pollutant concentrations at each receptor. The results indicate that the highest concentrations at a discrete receptor location were at PROW 2, resulting from a fire at the BESS 1 location.

The results in Table 8 present the concentrations resulting from a BESS fire only. Background concentrations have been added to the concentrations, where available, and the total concentrations are presented in Table 9.

Table 9: Maximum Modelled One-Hour Concentration including Backgrounds

Receptor	Maximum Hourly Concentration								BESS Location where Maximum Concentration was Modelled
	CO (ppm)	Formaldehyde (ppm)*	HCl (ppm)*	HCN (ppm)*	HF (ppm)*	NH_3 (ppm)	NO_2 (ppm)	PM_{10} (mg/m³)	
Relan Lodge	1.05	0.02	0.03	0.01	0.15	0.01	0.03	0.09	BESS 9
Heidelberg Materials Aggregate	0.75	0.01	0.02	0.01	0.09	0.01	0.02	0.07	BESS 6
The Gatehouse	0.77	0.01	0.02	0.01	0.10	0.01	0.02	0.07	BESS 6
Bedlam Paintball	0.67	0.01	0.02	0.01	0.08	0.01	0.02	0.06	BESS 7

Receptor	Maximum Hourly Concentration								BESS Location where Maximum Concentration was Modelled
	CO (ppm)	Formaldehyde (ppm)*	HCl (ppm)*	HCN (ppm)*	HF (ppm)*	NH_3 (ppm)	NO_2 (ppm)	PM_{10} (mg/m^3)	
Grendon Hall	0.74	0.01	0.02	0.01	0.10	0.01	0.02	0.07	BESS 10
Grendon C of E Primary School	0.79	0.01	0.02	0.01	0.10	0.01	0.02	0.07	BESS 10
Church Farm	0.73	0.01	0.02	0.01	0.09	0.01	0.02	0.07	BESS 10
81 Main Road	0.72	0.01	0.02	0.01	0.09	0.01	0.02	0.06	BESS 8
Appleby Barn	0.64	0.01	0.02	0.01	0.08	0.01	0.02	0.06	BESS 2
Highfield Lodge	0.82	0.01	0.02	0.01	0.11	0.01	0.02	0.07	BESS 4
Ashby Furse Farm	1.74	0.04	0.06	0.03	0.28	0.02	0.04	0.15	BESS 2
Beckworth Emporium	0.96	0.02	0.03	0.01	0.14	0.01	0.02	0.08	BESS 3
Sywell Aerodrome 1	0.73	0.01	0.02	0.01	0.09	0.01	0.02	0.06	BESS 1
Sywell Aerodrome 2	0.67	0.01	0.02	0.01	0.08	0.01	0.02	0.06	BESS 1
Wood Lodge Farm	0.78	0.01	0.02	0.01	0.10	0.01	0.02	0.07	BESS 1
Hardwick Grange Farm	0.65	0.01	0.02	0.01	0.08	0.01	0.02	0.06	BESS 4
Pastures Farm	2.19	0.05	0.07	0.03	0.37	0.02	0.05	0.18	BESS 6
Porters Lodge	1.93	0.04	0.06	0.03	0.32	0.02	0.04	0.16	BESS 6
PROW 1	4.08	0.10	0.14	0.07	0.72	0.04	0.09	0.34	BESS 1
PROW 2	10.03	0.25	0.37	0.17	1.84	0.08	0.20	0.82	BESS 1
PROW 3	2.27	0.05	0.08	0.04	0.38	0.02	0.05	0.19	BESS 1
PROW 4	0.96	0.02	0.03	0.01	0.14	0.01	0.02	0.08	BESS 4
PROW 5	1.06	0.02	0.03	0.01	0.16	0.01	0.03	0.09	BESS 4
PROW 6	0.94	0.02	0.03	0.01	0.13	0.01	0.02	0.08	BESS 6
PROW 7	1.31	0.03	0.04	0.02	0.20	0.02	0.03	0.11	BESS 5
PROW 8	0.72	0.01	0.02	0.01	0.09	0.01	0.02	0.06	BESS 10
PROW 9	0.72	0.01	0.02	0.01	0.09	0.01	0.02	0.06	BESS 10
PROW 10	0.83	0.01	0.02	0.01	0.11	0.01	0.02	0.07	BESS 10
PROW 11	1.95	0.04	0.06	0.03	0.32	0.02	0.04	0.17	BESS 9
Maximum	10.03	0.25	0.37	0.17	1.84	0.08	0.20	0.82	BESS 1

*Background concentrations not available

As indicated in Table 9, the predicted maximum one-hour PM_{10} concentrations were all well below the eight-hour WEL (4mg/m^3) and all other maximum one-hour concentrations were below AEGL level 2 (irreversible or other serious, long lasting health effects or an impaired ability to escape). In addition, all concentrations were below AEGL level 1 with the exception of HF, where there is an exceedance of AEGL level 1 along a PROW (PROW 2) when the BESS fire is located at a point closest to this location (BESS 1). This occurred when the wind direction was from the east; wind from this direction occurs 5.8% of the time, based on five years of met data. The likelihood of a fire occurring at a BESS is low, and the likelihood of a fire occurring at a BESS located close to the PROW when the wind is coming from the east is even lower. Additionally, should a fire occur in close proximity to the PROW, it is unlikely members of the public would be exposed for any significant period of time as it is expected that they would move away from a fire to ensure their safety. Modelling was undertaken using worst case parameters and the predicted concentrations are the maximum one-hourly concentrations over five modelled years. As such the effect of BESS fire emissions during the operational phase is predicted to be not significant.

Visibility

Table 10 Table 10 presents the predicted maximum one-hour PM_{10} concentrations at the modelled points along Station Road and the predicted visibility.

Table 10: Maximum Modelled One-Hour PM_{10} Concentrations With and Without Background and Predicted Visibility

Receptor	Maximum Hourly Concentration		BESS Location where Maximum Concentration was Modelled	Predicted Approximate Visibility (m)
	PM_{10} (µg/m³) without Background	PM_{10} (µg/m³) with Background		
Sywell Road 1	60.1	83.8	BESS 3	4710
Sywell Road 2	66.4	90.1	BESS 3	4381
Sywell Road 3	84.7	108.4	BESS 2	3641
Station Road 1	336.5	360.9	BESS 6	1094
Station Road 2	1611.3	1635.6	BESS 6	241
Station Road 3	1628.2	1652.6	BESS 7	239
Station Road 4	915.4	941.7	BESS 8	419
Station Road 5	2775.3	2801.6	BESS 8	141
Station Road 6	506.7	533.1	BESS 8	740
Station Road 7	1374.4	1400.7	BESS 9	282
Maximum Concentration	2775.3	2801.6	BESS 8	141

As indicated in Table 10, the highest PM_{10} concentrations are predicted along Station Road. The highest modelled concentration is at Station Road 5, where the visibility is predicted to be reduced to 141m as a result of smoke from BESS 8. Station Road is a national speed limit road (60mph). The typical braking distance is 73m for a car travelling at 60mph (Ref.10) which is lower than the predicted visibility. However, it should be noted that the equation used to determine visibility does not account for several factors such as smoke composition, humidity levels and light conditions, and assumptions have been made determining the variables and constant. Consequently, the visibility assessment should be treated as high level and, as a precaution, the following measure has been included in the OBSSMP:

- Should there be a BESS fire in close proximity to the road, site operator to determine wind direction and seek to close road if deemed necessary.

Uncertainty and Sensitivity

Uncertainty in dispersion modelling predictions can be associated with a number of different factors, including:

- Model uncertainty-due to model limitations;
- Data uncertainty-due to errors in input data, including emissions estimates, background estimates and meteorology; and
- Variability-randomness of measurements used.

Potential uncertainties in model results have been minimised as practicable and worst-case inputs used in the absence of definitive information. This encompassed the following:

- Choice of model - ADMS Roads is a commonly used atmospheric dispersion model and results have been verified through a number of studies to ensure predictions are as accurate as possible;
- Meteorological data - Modelling was undertaken using five years of meteorological datasets from the closest observation site to the Scheme. The highest concentrations predicted by the model over these five years were reported at the worst-case human receptors;
- Receptor locations - A Cartesian grid at a resolution of 20m and discrete receptors were included in the model in order to calculate maximum predicted concentrations throughout the assessment extents;
- Variability - All model inputs are as accurate as possible and worst-case conditions have been considered where necessary in order to ensure a robust assessment of potential pollutant concentrations.

It is considered that the use of the stated measures to reduce uncertainty and the use of worst-case assumptions when necessary has resulted in model accuracy of an acceptable level.

Assumptions and Limitations

The detailed modelling methodology has considered the following assumptions:

- It is assumed that each module consists of 52 cells, each rack contains eight modules, and each BESS contains ten racks totalling 3.7MWh;

- Modelling accounts for a steady burn as a result of deflagration of one BESS enclosure. It is assumed that the fire would be limited to one BESS enclosure;
- One BESS enclosure is assumed to be 2438mm in height, 6058mm wide and 2591mm long;
- It is assumed prismatic LFP batteries would be used;
- It is assumed that batteries are sealed by design so do not vent when in normal use and have no free electrolyte;
- It is assumed that the batteries will be controlled by charging management systems that will detect if a cell or battery is not operating correctly;
- It is assumed that there are no large buildings located on site in close proximity to the BESS cabinets that would affect dispersion;
- There is no AEGL for particulates. As such, the Health and Safety Executive (HSE) Workplace Exposure Limit (WEL) (Ref.3) has been used for dust which is $4mg/m^3$ for respirable dust. Whilst this is over an 8-hour reference period, it is considered appropriate for use in the assessment in lieu of any other limits;
- Visibility is affected not only by particulate concentrations, but by a range of factors including smoke composition, humidity levels, light conditions etc, therefore the visibility assessment is considered to be high level, as such detailed conclusions should not be drawn from the results;
- Emissions data for BESS fires are limited and have come from a range of sources. Worst case parameters have been used where possible;
- Emissions data were not available for particulates. As such, the assessment assumed that a battery unit fire is equivalent to a diesel fire for production of PM;
- A nominal value of 1m/s has been used for the velocity to activate the plume rise module;
- Emissions data was available for NO rather than NO_2. For the purposes of this assessment, it has been assumed that modelled NO concentrations are NO_2;
- There were no background concentrations available for HCl, HCN, formaldehyde and HF. However, it is considered that background concentrations of these pollutants would be negligible; and
- In accordance with the EA guidance (Ref.1), it has been assumed that the short-term background concentration of a substance is twice its long-term concentration. As such, annual mean background concentrations were doubled to approximate the 1-hour background concentration.

Mitigation

Prior to the commencement of construction of the BESS, Green Hill Solar Farm Ltd. will be required to prepare a Battery Storage Management Plan (BSMP). As part of the BSMP, the Applicant will take into account the latest good practices for battery fire detection and prevention, along with the emergency response plan, as guidance continues to develop in the UK and around the world. The following measures relating to air quality should be included:

- Notification of potentially affected residents including advice on the health effects of smoke and ways to reduce exposure (e.g. close windows and stay indoors);
- Notification of potentially affected members of the public to move to a cleaner air location;
- Cancellation of outdoor events and potentially moving affected residents to a cleaner air location; and
- Should there be a BESS fire in close proximity to the road, site operator to determine wind direction and seek to close the road if deemed necessary.

Conclusion

Based on the factors of distance to the nearest property and the anticipated short-term nature of a fire incident, the assessment concludes that there would not be significant effects at the closest receptor locations as a result of a BESS fire incident. The Emergency Response Plan (ERP) produced at the detailed design stage will incorporate all necessary emergency response procedures and actions based upon thermal runaway test data supplied by the BESS system provider.

References

Ref.1 Environment Agency (2025), Air emissions risk assessment for your Environmental Permit. Available at: https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit

Ref.2 Environmental Protection Agency (2025), Environment Protection Agency website. Available at: https://www.epa.gov/aegl/about-acute-exposure-guideline-levels-aegls

Ref.3 Health and Safety Executive (2020), EH40/2005 Workplace Exposure Limits. Available at: https://www.hse.gov.uk/pubns/books/eh40.htm

Ref.4 Klote, J. H. and Milke, J.A. (2002), Principles of Smoke Management

Ref.5 Wartsila North America, Inc (2023), Quantum Cube Bespoke Unit Testing Summary Report

Ref.6 Clearstone Energy (2024), Axminster Energy Hub Plume Assessment Study

Ref.7 Sungrow Power Supply Co., Ltd (2025), Sungrow Battery Energy Storage System (BESS) PowerTitan 2.0 Large Scale Burn Test Report

Ref.8 Department for Environment, Food and Rural Affairs (2022), Local Air Quality Management Technical Guidance LAQM.TG(22). Available at: https://laqm.defra.gov.uk/air-quality/featured/uk-regions-exc-london-technical-guidance/

Ref.9 Department for Environment, Food and Rural Affairs (2025), UK AIR. Available at: https://uk-air.defra.gov.uk/

Ref.10 UK Government (2025), The Highway Code. Available at: https://www.gov.uk/guidance/the-highway-code/general-rules-techniques-and-advice-for-all-drivers-and-riders-103-to-158