WHITESTONE SOLAR FARM

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7.2: BESS Plume Assessment

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Glossary

Term	Meaning
ALOHA	A hazard modelling program which is part of the U.S. Environmental Protection Agency's software suite, that is widely used to plan for and to respond to chemical emergencies
Battery	A generic term for a single cell or a group of cells connected together electrically in series, in parallel or a combination of both.
Battery Energy Storage System	Electrochemical cells (lead acid, Li-ion, solid state batteries, flow batteries, etc.) linked together with control systems and associated housings, to form a facility that can store chemical energy and deliver the stored energy in the form of electricity.
Cabinet	A form of enclosure or part of a container, where doors or hatches enable direct access to equipment but a person cannot enter the enclosure.
Cell	The basic electrochemical unit, characterised by an anode and a cathode, used to receive, store, and deliver electrical energy
Concentration	The total mass or volume of a substance per unit volume of air. Typically expressed as milligrams per cubic metre or as parts per million (ppm).
Container	A form of enclosure where a door and internal walkway enables a person to enter the enclosure to access equipment.
Enclosure	The structure used to house racks of batteries, typically in the form of a container or a cabinet.
Energy Capacity	The amount of energy stored within the BESS, typically expressed in terms of electrical energy using units of kilowatt hour (KWh).
Emission	A substance released into the atmosphere.
Li-ion cell	A rechargeable cell that uses lithium ions as the primary component of its electrolyte
Module	A self-contained unit made up of multiple cells, insultation, connections and a housing.
Node	A point within a dispersion model output grid, that a predicted value is reported for.
Off-gassing	Venting of electrolyte vapours from a cell.
Power Output	The aggregate net electrical energy that a Battery Energy Storage System can provide, typically expressed in units of megawatts (MW) or gigawatts (GW)
Rack	A structure used to hold a group of modules.
Receptor	A component of the natural or man-made environment that is affected by an impact, including people.
State of charge	The ratio of present dischargeable energy storage capacity to the maximum dischargeable energy storage capacity, typically expressed as a percentage value.

Thermal barrier	A physical measure to slow the rate at which heat transfers between two parts of a BESS, i.e., a thermal insulating material or the use of an air-filled gap
Thermal runaway	The condition when an electrochemical cell increases its temperature through self-heating in an uncontrollable fashion and progresses when the cell's heat generation is at a higher rate than it can dissipate, potentially leading to off-gassing or fire.

Acronyms

Acronym	Meaning
BESS	Battery Energy Storage System
BS	British Standards
BS EN	British Standards European Norm
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EN	European Norm
ERP	Emergency Response Plan
FPRF	Fire Protection Research Foundation
FRS	Fire and Rescue Service
HBr	Hydrogen Bromide
HCl	Hydrogen Chloride
HCN	Hydrogen Cyanide
HF	Hydrogen Fluoride
IEC	International Electrotechnical Commission
LFP	Lithium Iron Phosphate
Li-Ion	Lithium-Ion
NFCC	National Fire Chiefs Council
NFPA	National Fire Protection Agency
NG	National Grid
NO_x	Nitrogen Oxides
ODEMP	Outline Decommissioning Environmental Management Plan
SO_2	Sulphur Dioxide
SOC	State of Charge
UL	UL Solutions

Units

Units	Meaning
hr	Hours
km	Kilometres
kV	Kilovolts

Units	Meaning
kW	Kilowatt
m	Metres
MW	Megawatts
ppb	Parts per Billion
s	Second
µg/m^3	Micrograms per cubic meter

1 EXECUTIVE SUMMARY

1.1.1 Battery Energy Storage Systems (BESS) designs that are compliant with the latest requisite safety standards integrate multiple layers of prevention and mitigation features to minimise the chances of a BESS failure incident (equipment failure / burning or gas venting thermal runaway scenario).

1.1.2 The selected BESS design will include integrated fire and explosion prevention and protection systems. Following key industry safety standards (e.g. NFPA 855, UL 9540, BS EN IEC 62933-5-2) and based on comprehensive UL 9540A (2025, 5th Edition) and / or 3rd party LSFT / full scale destruction testing. This testing involves burning the full BESS system to validate minimum safe equipment spacing distances and performance test active and passive mitigation systems integrated into the BESS design. This assessment aims to provide information on the likely impacts of toxic gas emissions from a BESS failure event based on the initial design information for the Whitestone Solar Farm ('the Proposed Development'), to ensure that fire, smoke, and any release of toxic gases does not significantly impact site operatives, first responders, and the local community.

1.1.3 For the purposes of Scheme safety documentation and studies a concept design has been considered that uses a BESS system based upon LFP lithium-ion battery technology that is currently used on many UK solar projects. This is considered to be a reasonable worst case for the purposes of the assessment in terms of BESS toxic gas emission potential (Hydrogen Fluoride production) and explosion risk (significant levels of hydrogen produced during thermal runaway).

1.1.4 In accordance with NFCC revised guidance, at the detailed design stage, a BESS system and detailed-design specific plume analysis study will be conducted to assess the environmental impact of a site incident to sensitive receptors within a 1 km radius. This analysis will ensure that toxic gas emissions to sensitive receptors arising from the detailed design of the Proposed Development remain below relevant public health exposure limit guidelines, when the battery system of a BESS enclosure is fully consumed (burnt out). Production of Particulate Matter (PM), and a visibility impact assessment on any transport links within a 1 km radius of the BESS compound, will also be included at that time.

1.1.5 This report considers the potential emissions that could be emitted from cells during a thermal runaway event and uses dispersion modelling to estimate the distance within which the Acute Exposure Guideline Level (AEGL-1) criteria would be achieved. This criterion is used by the UK Health Standards Agency to represent concentrations where exposure during an accidental fire would be unlikely to cause harm to people. The assessment considers potential pollutants and identifies Hydrogen Fluoride (HF) as the principal pollutant of concern.

1.1.6 The modelled scenarios demonstrate that the AEGL-2 and AEGL-3 criteria are achieved under calm and windy conditions at all off site locations. The AEGL-1 criteria is achieved at distances shorter than the distance to representative conditions in all directions under windy conditions and at all receptors apart from R4 under calm/low wind speed conditions. Estimated achievement of the AEGL-1 criteria under low wind conditions occurs prior to the boundary of the farm yard at R4 for an emission rate equivalent to 60% of all HF emissions from one cabinet and beyond the distance to residential receptors under a scenario with additional emissions from a second cabinet.

1.1.7 The short duration of a fire event, the limited scale of emissions and the unlikely nature of the event, mean that a significant effect is also highly unlikely for emissions of nitrogen oxides, sulphur dioxide and particulate matter or hydrocarbons at any receptor location.

2 INTRODUCTION

2.1.1 This Unplanned Emissions Assessment has been prepared on behalf of Whitestone Net Zero Ltd ('the Applicant') in relation to the Development Consent Order (DCO) Application for the construction, operation, maintenance, and decommissioning of Whitestone Solar Farm (hereafter referred to as the 'Proposed Development').

2.1.2 The Proposed Development involves the construction, operation and maintenance, and decommissioning of more than 100 MW of solar photovoltaic (PV) array, Battery Energy Storage System (BESS), onsite substations and supporting infrastructure, and grid connection infrastructure. The grid connection infrastructure would connect the Proposed Development to the National Grid at the new National Grid substation Brinsworth (Long Lane 400kV Substation), located east of Long Lane, Rotherham. National Grid have applied to Rotherham Metropolitan Borough Council for the development of this new substation which is intended by National Grid to be operational in time for the Proposed Development to connect in 2029. This substation is therefore not included in the Proposed Development and will be subject to a separate planning application taken forward by National Grid.

2.1.3 By its very nature a thermal event (the overheating of batteries or a fire) in part of the BESS is not an intended outcome from the use of the BESS. Considerable effort goes into designing and operating BESS units in a way that avoids any thermal event and thereby maintains the units in an operational condition, as described within the **Outline Battery Safety Management Plan (OBSMP) [EN0110020/APP/5.15]** submitted with the DCO Application. As such, these events are considered unlikely.

2.1.4 A fire is a 'possible' event for any development and there are regulatory requirements in place to ensure that the safety and environmental consequences of a fire have been considered and planned for. That work is normally finalised at the detailed design stage for a BESS scheme, after planning or development consent has been granted. This report aims to bridge the information gap at this stage and provide information of the likely magnitude of impacts of accidental (unplanned) emissions to air as the result of a thermal event at a BESS.

2.1.5 The scope of this study includes:

- A review of potential emissions to air from a thermal event within a single cabinet (main scenario) and for an event that results in a fire in multiple cabinets (sensitivity test);
- Consideration of the potential magnitude of emissions;
- Consideration of likely rates of dilution between potential emission locations and sensitive receptors located outside the Site; and
- Consideration of the likely consequences of emissions to air from the proposed BESS.

3 BACKGROUND

3.1.1 Battery technologies are used at renewable energy generation facilities to store electrical power so it can be supplied to the National Grid when it is most needed. Battery technologies can act as a standalone grid balancing service due to the intermittent nature of renewable energy generation supplying the grid which is the case here.

3.1.2 The BESS for the Proposed Development would consist of a compound and battery array at maximum capacity of 750 MW. Details of the design for the BESS elements, including the power and energy ratings, and the final enclosure dimensions and appearance, are currently in development and, therefore, the assessment has been based on maximum parameters which would not be exceeded (as set out in **ES Volume 1, Chapter 5: The Proposed Development [EN0110020/APP/6.5]**). This assessment is based on the following assumptions:

- The land parcel which would contain the BESS is 341m away from the nearest commercial properties and 470m away from the nearest residential properties.
- Included within the design, each enclosure would have:
  - Smoke, heat and gas detection and control systems;
  - Active ventilation to prevent build up of off-gases; and
  - Non-combustible walls, floor and ceiling, with a minimum internal fire resistance rating of up to 1 hour.

3.1.3 An **oBSMP [EN0110020/APP/5.15]** has been submitted with the DCO Application, which would be developed into a fully detailed battery safety management plan with input from the South Yorkshire Fire and Rescue Service (FRS). This is secured as a requirement of the **draft DCO [EN0110020/APP/3.1]**. The purpose of the **oBSMP [EN0110020/APP/5.15]** is to identify how the Applicant will use good industry practice to reduce risk to life, property, and the environment from a BESS failure event. The document provides a summary of the safety related information requirements which will be provided in advance of construction of the BESS. These details are not repeated here but have been built into the modelling assumptions used.

4 GUIDANCE AND STANDARDS

4.1.1 The Planning Practice Guidance for Renewable and Low Carbon Energy[1] encourages Local Planning Authorities to consider guidance produced by the National Fire Chiefs Council (NFCC). The NFCC BESS Guidance[2] applies to BESS in open air environments with an energy capacity of 1MWh or greater and is therefore relevant for the Proposed Development.

4.1.2 The NFCC guidance intends to help reduce the fire exposure risk to the public and emergency responders as far as reasonably practicable. The guidance encourages relationships between Fire and Rescue Services, developers, and planners, to help assess risk and form effective emergency response plans. The guidance outlines the need to consider safety in design, have effective battery management systems in place, including alerts for battery fault and combustible gas detectors. The guidance further outlines the need for means of containment, suitable thermal barriers, and emergency plans. The guidance also emphasises the need for each potential Site to be considered individually.

4.1.3 The selected BESS design will include integrated fire and explosion prevention and protection systems following key industry safety standards (e.g. NFPA 855, UL 9540, BS EN IEC 62933-5-2) and based on comprehensive UL 9540A (2025, 5th Edition) and/or 3rd party LSFT/full scale destruction testing. This testing involves burning the full BESS system to validate minimum safe equipment spacing distances and performance test active and passive mitigation systems integrated into the BESS design. A BESS system and site-specific Emergency Response Plan (ERP) will be developed at the detailed design stage, based on national and international best practice measures.

4.1.4 Section 3 of the **oBSMP [EN0110020/APP/5.15]** references the guidance documents and standards considered by the Applicant that have been used to inform the design of the Proposed Development. There is currently limited UK specific guidance for BESS, however the Applicant has incorporated good practice from around the world.

5 EMISSIONS FROM INCIDENT FIRES

5.1 Potential Sources of Emissions to Air

5.1.1 For the purposes of this document, a concept design has been considered that uses a BESS system based upon lithium iron phosphate (LFP) lithium-ion battery technology that is currently used on the majority of UK solar projects in development. This is considered a reasonable worst case for the purposes of the assessment in terms of safety (toxic and explosive gas production risks).

5.1.2 The general arrangement for BESSs is to have 'cells' grouped into 'modules' (sometimes called 'packs') and a number of modules housed on shelves within a 'rack'. The racks are housed in a cabinet that takes the form of a metal, fireproof enclosure, with front opening doors. There is not a set number of cells which constitute a module, modules within a rack, or cabinets within a container – these will vary by manufacturer. The latest designs favour 3 or 4 cabinets within one container for the larger units.

5.1.3 LFP cells have a risk of 'thermal runaway' if manufacturing defects are present, or in situations of overcharging, overheating, or mechanical damage.

5.1.4 Thermal runaway results in the release of gases, including flammable gases which may then go on to produce a fire, giving rise to a range of organic and inorganic air pollutants. This situation is true of any incident fire and sets of emission factors have been collated by the Environment Agency[3] for incident fires involving automobiles, buildings, and waste materials, for example. A standardised set of emission factors for BESS is not currently available from the Environment Agency.

5.1.5 A few recent studies have investigated the toxic gas constituents of fires in general[4] and lithium-ion battery fires specifically in controlled test environments[5,6]. It has been established that lithium-ion battery fires may produce carbon monoxide (CO), hydrogen cyanide (HCN), hydrogen chloride (HCl), hydrogen bromide (HBr), hydrogen fluoride (HF), sulphur dioxide (SO_2), NO_X (nitrogen oxides), hydrocarbons, and particulate matter. The prevalent gas production mainly comprises CO, CO_2, hydrogen and hydrocarbon gases, with most of the toxic gases referenced generally only detected as trace elements.

5.1.6 The UK has air quality objectives and targets to protect public health from exposure to air pollutants including NO_x when present as nitrogen dioxide (NO_2), particulate matter (size fractions PM_{10} and $PM_{2.5}$), SO_2, CO and hydrocarbons. These objectives and targets are mostly based on long averaging periods, such as 24hr mean concentrations and annual mean concentrations. A single event, only lasting a few hours, is incapable of materially effecting such long-term average concentration values, used to measure ongoing exposure from the combined contributions of background and local emissions sources. Even short-term objectives, such as the hourly mean concentration of NO_2 is based on a percentile of hourly values that can be exceeded a small number of times per year.

5.1.7 The short duration of a fire event, the limited scale of emissions and the unlikely nature of the event, mean that a significant effect is highly unlikely for emissions of NO_x, NO_2, SO_2, CO, particulate matter or hydrocarbons at any receptor location. HCN concentration can become elevated in close proximity to any fire, especially within enclosed spaces, but is rapidly dispersed and oxidised as it travels downwind of the fire. BESS fires do not present HCN risks in ambient air to first responders that are any greater than for any other form of building or vehicle fire.

5.1.8 Emissions of HCl, HBr and HF are possible, with emissions of HCl and HBr being much smaller in magnitude than HF, and so HF is used in this assessment to represent these substances.

5.1.9 Further, in 2016, a U.S. based organisation, The Fire Protection Research Foundation (FPRF), conducted a full scale (100 kWh) BESS test fire[7] that included gas sample measurements from batteries subjected to external and internal ignition tests. This provided further evidence that CO and HF are produced in such cases. Elevated concentrations of CO were detected in the first 30 minutes of the test and this decreased to near zero during the main period of self-sustaining combustion, which is not unexpected for a fire occurring outdoors, and HF was detected at concentrations > 100 ppm (i.e., over range for the detector used) after 30 minutes and then for the duration of the fire.

5.1.10 HF is the primary emission of concern for this assessment. Based upon the studies described above, it is likely to be present within a BESS fire at concentrations of concern at distances of more than a few tens of metres from the fire. It is also highly toxic. It is considered that HF has the greatest potential for harm compared to other products of combustion and therefore modelling of HF represents worst case impacts and modelling of other pollutants is not required.

5.1.11 It is noted that HF is formed by the decomposition of the fluoride-containing electrolyte and/or its atmospheric reaction with the hydrogen released due to the thermal runaway. The production of HF therefore depends both on the quantity of electrolyte within the battery cells and the specific conditions of the thermal runaway/fire. Although the mechanism is not certain, it has also been found that the state of charge (SOC) influences HF production, with cells burnt at 100% SOC found to produce less HF than those burnt at lower SOC. The concentration of HF is also dependent on the total length of the incident with a shorter, fiercer fire likely to be associated with higher peak HF concentrations than a longer one.

5.1.12 In theory, it would be possible to base a dispersion model on the concentration of HF measured in the plume near to the BESS during a whole unit test firing. However, there are serious limitations with such an approach, primarily arising from the large variation in HF concentrations that have been reported in the literature[8]. There is also substantial variation in concentration over time during the same test. For example, one test firing[9] reported a very large amount of variation in measured concentrations for HF from sample to sample, ranging from 575 mg/m^3 down to the low tens of mg/m^3. The peak concentrations are short lived and infrequent events, typically lasting seconds. Such peak values are not representative of conditions that occur over the timescales of relevance to this assessment, which uses criteria that are 10 minute mean and 1 hour mean concentration values. The use of mean values in air quality standards takes into account the presence of values being higher than the mean value for the time period. The use of the peak values measured over a few seconds as a basis for assessment would be overly conservative. Data with sufficient granularity to enable the mean concentration over a relevant time period to be calculated from short term measurements are not captured during standard fire tests.

5.1.13 The Electrical Power Research Institute (EPRI)[10] is a research Institute in the U.S. that provides technical research for its corporate membership, which are mostly electricity generation companies. In 2024, it published a review of Lessons Learned from Air Plume Modelling of Battery Energy Storage System Failure Incidents). Of particular relevance to this report are the following findings:

- Staking multiple conservative assumptions in dispersion model studies, even if not 'worst case' (i.e. conservative and improbable) can result in unrealistically conservative results;
- Based on 67 GW and 150 GWh of Li-ion BESS deployed to end of 2023 and 85 cell failure incidents from those units, a cell failure rate of less than 0.1% was observed. This is 1 incident per 1.76 GWh deployed. Only a small fraction of those cell failures would then develop into fires. The implication is that the likely number of fire incidents at a BESS of less than 1GWh is less than 1 incident during its operational lifetime; and
- Consideration of the proportion of the time when meteorological conditions would give rise to potential impacts at actual receptors is a useful approach to establish how often an exposure pathway is present under real world conditions.

5.1.14 EPRI has collated best practice in the dispersion modelling of emissions from BESS fires[11] and have noted that where UL 9540 A emission data is not available, an appropriate emission factor for HF emissions would be in the range of 0.4 g to 1.5g of HF per kilogram of battery weight. An increasing number of modules and whole cabinets have demonstrated during testing that no fire propagation occurs beyond the tested module. Therefore, this assessment assumes that any incident could be limited to a single module (Section 6) or could include multiple modules (Section 7).

5.1.15 Example emissions are calculated here based upon a single module containing 104 cells[12]. Taking a conservative estimate of weight based upon the total container weight (which also includes non-battery material), it is estimated that this module weighs 895 kg, which using the worst-case weight-based emissions factor equates to 1.3 kg of HF. An alternative calculation (excluding non-battery weight) would give a cell weight of 5.7 kg each, resulting in a total battery weight of 593 kg, equating to 0.9 kg of HF.

5.1.16 An alternative approximation is based around the emissions per Wh, with findings from one small scale test[13] of 20-200 mg/Wh. This method is considered less reliable than the EPRI method as it is less well proven at scale, although experience indicates that the lower end of the range is more appropriate at the larger scale, therefore the same example single module of 104.5 kWh capacity equates to 2.1 kg of HF.

5.1.17 These example HF content values are similar to values used in some previous DCO environmental impact assessments[14] where values of 2 kg of HF content have been cited based on the more limited data available at that time.

5.1.18 In summary, the use of emission factors based on the HF content of battery systems remains the most defensible approach for dispersion modelling. As the volume of available test reports grows, the design of BESS is changing to meet the requirements of fire safety tests, resulting in increased use of smaller fireproof cabinets to restrict fires to smaller number of battery modules than was the case ten years ago. The approach taken in this assessment is that a 2 kg of HF content per incident (based upon only one module experiencing thermal runaway i.e. no module-to-module propagation) remains a reasonable central estimate, with a 50% higher and lower sensitivity test scenario to reflect uncertainties in module composition (in terms of number of cells, battery weight, and energy capacity), and state of charge. However, in recognition that these estimates are becoming increasingly conservative as technology develops, a low HF content scenario of 0.5 kg of HF has also been included.

5.1.19 At the detailed design stage further modelling can be done to consider the thermal risk from the fire, based on an understanding of combustible materials released in a fire for the selected make and model of equipment and such modelling can also include a plume assessment to confirm that the density of smoke or pollutant concentrations remain in keeping with fire and rescue service expectations.

5.2 Assessment Criteria

5.2.1 The UK Health Security Agency (UKHSA) (formerly Public Health England (PHE)) publish Incident Management guidance for specific air pollutants including HF[15]. These documents summarise the physical and chemical properties of the substance and the hazard they pose to human health. Internationally recognised best practice emergency response guidelines are reported by UKHSA.

5.2.2 Emergency response planning guideline (ERPG) values, that start at ERPG-1 and increase in concentration to ERPG-3, have been defined by the American Industrial Hygiene Association[16]. They are described below:

- ERPG-1: the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects.
- EPRG-2: 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 that could impair an individual's ability to take protective action.
- ERPG–3: 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.

5.2.3 Acute exposure guideline level (AEGL) values have been defined by the US Environmental Protection Agency[17] based on slightly different criteria:

- AEGL-1: Above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
- AEGL-2: Above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- AEGL-3: Above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

5.2.4 The values adopted as being most protective of receptors (or the most conservative in terms of likely impacts on receptors) surrounding the Proposed Development are listed in

5.2.5 **Table 5-1**. Concentrations of 1 ppm and 2 ppm of HF gas are equivalent to 0.82 mg/m^3 and 1.64 mg/m^3 respectively. The time periods used for ERPG and AEGL are based on different considerations, but for the purposes of this assessment they represent a maximum concentration value in a 10-minute period. These concentration values are also valid at an averaging time of 1 hour, which is the resolution of the meteorological data used in this assessment.

Table 5-1 Summary of Emergency Response Criteria

Substance	EPRG-1 Value (ppm)	Time period for EPRG	AEGL-1 (ppm)	Time Period AEGL
HF	2	10 minutes & up to 1 hour	1	10 minutes & up to 8 hours

5.2.6 The most conservative criteria, the AEGL-1 of 1ppm has been chosen as the relevant assessment criteria for this assessment.

6 MAIN SCENARIO (ONE CABINET FIRE EVENT)

6.1 Introduction to Dispersion and Dilution

6.1.1 Any gaseous pollutants emitted from a BESS would be transported from the BESS towards receptor locations by the air movements occurring at the time of the emission to air. These movements are determined by the direction of the wind and the amount of turbulent mixing of the air as it blows towards the receptor location. Differences in the temperature of the plume of air containing the emission and the surrounding air can also affect the vertical movement of the pollutants. To help understand the minimum rates of dilution likely to occur to pollutant concentrations as they disperse from the source of the emission to receptor locations, the dispersion has been modelled.

6.2 Modelling Approach

6.2.1 This scenario considers the indicative BESS plant with a container that comprises 6 separate cabinets and each cabinet containing 8 modules. In this scenario, it is assumed that a fire develops within one cabinet and does not progress to adjoining cabinets. This scenario assumes that the fire emits to the atmosphere through the vent of the container.

6.2.2 The dispersion modelling was conducted using the U.S. Environmental Protection Agency's ALOHA software (version 5.4.7) to simulate the atmospheric dispersion of thermal plume. The model was configured as a continuous elevated release with a duration of one hour, consistent with the peak hourly emissions from a fire, while meteorological and surface parameters were defined according to the site conditions. The model assessed downwind HF concentrations, with particular focus on the maximum distance to the AEGL-1 threshold (1 ppm) to evaluate potential off-site exposure risks. The overall approach followed established practices for emergency response and hazard assessment[18,19]. The model output report, detailing input parameters and corresponding results are provided in Appendix A.1 for a fire event under low wind speeds and the same fire event during high wind speeds.

6.3 Emission Parameters

6.3.1 The effective release height applied in ALOHA was estimated through a signified plume-rise analysis based on the empirical relations developed by Briggs[20].The total energy of the involved portion of the system was determined from its rated capacity, assuming that only a portion of the stored energy contributes to the flaming phase of combustion[21]. A convective fraction of 70% of the total heat-release rate was adopted in accordance with standard fire plume modelling practice[22]. The resulting effective release heights were then used as source parameters in the ALOHA dispersion simulations.

6.3.2 As the exact emissions from the BESS cannot be meaningfully estimated at present, the modelling is based on emissions that have been modelled as a volume source, at a nominal emission rate of 1µg/m^3/s. This approach establishes the pattern of dispersion and dilution, that can be scaled up to consider any other emission rate value.

6.3.3 A number of assumptions have been made to the model to ensure the assessment approach is precautionary and provides an upper estimate of likely outcomes. Near source temperatures in excess of 300°C can be reasonably expected to be present, which would result in the plume rising rapidly, reducing near-ground concentrations. However, the emission is not from a stack or open fire, but from a vent and the source is a volume of air adjacent to the vent with an elevated concentration. This assessment has assumed a volume source with no initial vertical momentum and the temperature has been modelled as if it was emitted at ambient air temperature. These two assumptions represent a very conservative approach in terms of dispersion modelling as they remove the vertical momentum of the emission and consequently the predicted near ground level concentrations from the model are considerably higher than would be experienced under real world conditions, as the plume has been modelled without that initial vertical momentum caused by the fire.

6.4 Meteorology

6.4.1 The dispersion of emissions from a point source is largely dependent on atmospheric stability and turbulent mixing in the atmosphere, which in turn are dependent on wind speed and direction, ambient temperature, cloud cover and the friction created by buildings and local terrain.

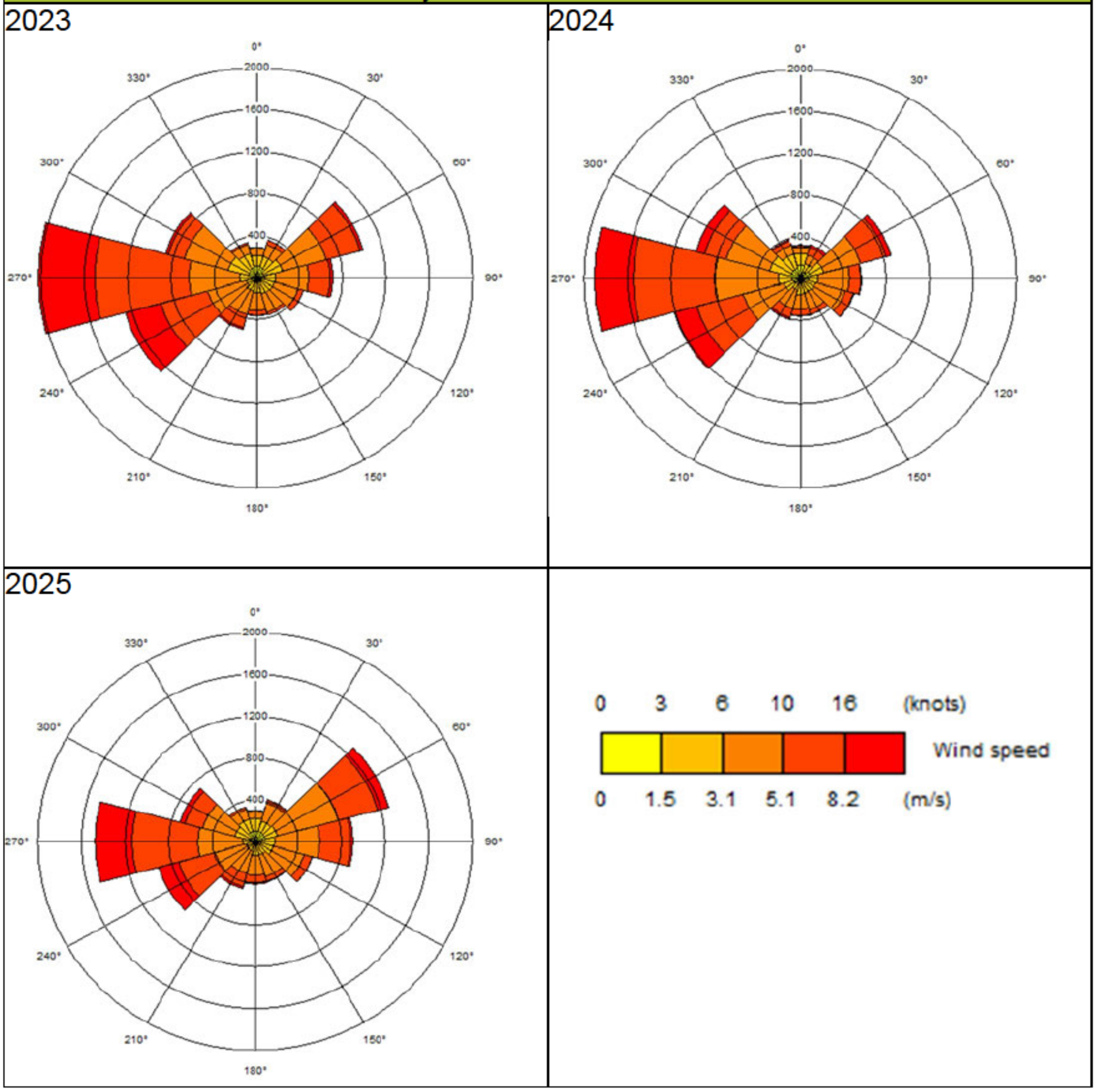
6.4.2 Actual observed hourly sequential meteorological data is available for input into dispersion models, and it is important to select data as representative as possible for the Site that is modelled. This is usually achieved by selecting a meteorological station as close to the Site as possible, although other stations may be used if the local terrain and conditions vary considerably, or if the station does not provide sufficient data. For point sources, such as stacks, the Environment Agency recommends the use of five years of the recent available meteorological data be used in modelling assessments to ensure that all typical weather conditions are considered within the modelling.

6.4.3 Three years of hourly sequential data from Sheffield City meteorological observation station for the years 2023 - 2025 were analysed to determine representative conditions for the low wind speed and high wind speed dispersion simulations. Meteorological data for Sheffield City for the years 2020 – 2022 were not usable due to a significant portion of meteorological data for these years being missing. The 5th percentile of wind speed and air temperature was used to represent calm, low-dispersion conditions, while the 95th percentile values were used to represent windy, high-dispersion conditions. These percentiles capture the lower and upper extremes of local meteorology, providing conservative and contrasting boundary cases for assessing potential plume behaviour and HF dispersion.

6.4.4 The meteorological site is located approximately 5.2km west of the Proposed Development. The meteorological conditions at Sheffield City are considered representative of those experienced at the Proposed Development.

6.4.5 The wind-roses for Sheffield City meteorological data are shown in **Plate 5-1**.

Plate 5-1: Wind-roses for Sheffield City



6.5 Receptors

6.5.1 Four receptors have been identified as being the nearest receptors to the Proposed Development in the northerly, easterly, southernly, and westerly directions.

6.5.2 The details of the receptors are shown in **Table 6-1** below, and in **Figure 6-1**.

Table 6-1: Receptors

Receptor Number	Receptor Name	X	Y	Distance from BESS
R1	Royds Moor Farm	446482	390060	866m north of BESS
R2	Manor Farm, Morthen	447442	389271	811m east of BESS

R3	Main Street, Ulley	446396	387596	1,410m south of BESS
R4	Upper Whiston Farm	446032	388989	341m west of BESS

6.6 Likely Consequences of Battery Emissions from One Cabinet

6.6.1 **Table 6-2** show the maximum distance between the BESS and surrounding receptors for which HF concentrations would achieve the AEGL-1 value of 1 ppm. The same distances are also illustrated in **Figure 6-1**.

6.6.2 In **Figure 6-1** the green 'cones' represent the 30º wind direction sector that meteorological data was used for in model calculations. A central line extending from the nearest battery cabinet to the receptor is labelled with the distance. A yellow line illustrates the maximum distance beyond which the AEGL-1 criteria (1ppm) for short term exposure to HF is achieved.

6.6.3 The results confirm that HF concentrations would fall below the AEGL-1 value at all residential receptor locations under both calm/low wind speed and windy weather conditions. The farmyard areas near receptor R4 would also experience concentrations below the AEGL-1 criteria, but some areas of farmland and users of the M1 could experience HF concentrations above the HF criteria value. Workers on the farmland would have the ability to move away from the fire and thereby minimize exposure to HF and other emissions. Users of the M1 would be exposed for a very short period if passing the site at motorway speeds and would be present for considerably less than 10 minutes.

6.6.4 The AEGL-2 and AEGL-3 values for HF are predicted to be achieved at all locations under all conditions.

Table 6-2: AEGL-1 Achievement Distances

Scenario	Meteorological conditions	Effective Release Height (m)	Distance to AEGL-1 (m)
One-cabinet fire, calm, low dispersion conditions, R1 receptor	5th Percentile (calm): Ambient Temperature: -6.2ºC Wind speed: 1.5m/s	6.5	206
One-cabinet fire, windy, high-dispersion conditions, R1 receptor	95th Percentile (windy): Ambient Temperature: 21.0ºC Wind speed: 7.2 m/s	4.6	Achieved at all distances
One-cabinet fire, calm, low dispersion conditions, R2 receptor	5th Percentile (calm): Ambient Temperature: 2.0ºC Wind speed: 1.5 m/s	6.5	206
One-cabinet fire, windy, high-dispersion conditions, R2 receptor	95th Percentile (windy): Ambient Temperature: 21.0ºC Wind speed: 8.2 m/s	4.5	Achieved at all distances
One-cabinet fire, calm, low dispersion conditions, R3 receptor	5th Percentile (calm): Ambient Temperature: -1.0ºC Wind speed: 1.0 m/s	7.2	271
One-cabinet fire, windy, high-dispersion conditions, R3 receptor	95th Percentile (windy): Ambient Temperature: 16.0ºC Wind speed: 4.6 m/s	5.0	Achieved at all distances
One-cabinet fire, calm, low dispersion conditions, R4 receptor	5th Percentile (calm): Ambient Temperature: 2.0ºC Wind speed: 1.5 m/s	6.5	206
One-cabinet fire, windy, high-dispersion conditions, R4 receptor	95th Percentile (windy): Ambient Temperature: 21.0ºC Wind speed: 8.2 m/s	4.5	Achieved at all distances


BESS Receptors
Whitestone BESS and SS Area
AEGL-1 criteria achieved under high wind speed scenario
AEGL-1 criteria achieved under low wind speed scenario
Distance to AEGL-1 (m)
Source to Receptor
R1
R2
R3
R4
866
811
341
1410
M1
High Street
Whiston Parish Church Cricket Club
Moorhouse Lane
The Green
Pleasley Road
Morthen Lane
York Lane
Well Lane
Field Lane
Brampton Lane
Penny Hill Lane
Ulley Brook
Ulley Reservoir Country Park
Main Street
Ulley
Reservoir Road
Whiston
0 100 200 300 400 500
Meters
N
SCALE: 1:10,000
SIZE: A3
APPLICATION: EN0110020
DATE: 17/04/2026
VERSION: A01
DRAWN: SL
CHECKED: EU
APPROVED: GG
Whitestone Solar Farm
Environmental Statement
Figure 6.1
Unplanned Hydrogen Fluoride (One Cabinet)
Sheet 1 of 1
Reference: EN0110020/APP/6.19
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 - Regulations 5(2)(a)
AECOM
WHITESTONE
solar farm

7 MULTI-CABINET FIRE SCENARIO (SENSITIVTY TEST)

7.1 Modelling Approach

7.1.1 This assessment approach considers the same indicative BESS plant as considered in Section 6, with a container that comprises 6 separate cabinets and each cabinet containing 8 modules. In this scenario, it is assumed that a fire develops within a cabinet and progresses to adjoining cabinets. It takes time for the fire to progress, meaning that as the fire develops in one cabinet, combustion has already occurred for part of the preceding cabinet. The peak hourly emission rate is considered to be equivalent to the potential emissions of 60% of the total HF from first cabinet and 40% of the total HF from the second cabinet. This is a conservative approach as it assumes all potential emissions from all modules are released.

7.1.2 This scenario requires the structure of the cabinets to fail allowing the fire to extend beyond the cabinet emitting directly to atmosphere, rather than through the vent as would occur for the one module event scenario. This represents a conservative assumption, as it implies a substantial overlap in emissions from multiple cabinets and assumes that a significant proportion of the total HF inventory is released within a single hour. In practice, the involvement of multiple cabinets is considered to be highly unlikely due to the design and safety features incorporated within BESS installations, which act to limit fire propagation between cabinets. This is important as a fire with temperatures in the range of 1200ºC to 1500ºC will cause the air above the fire to rise. This phenomenon is taken into account by calculating the ‘effective height of release’, which is the height the plume rises before the dispersion model calculates the downwind dispersion. Under calm conditions the effective height of release is calculated to be 10m and this is reduced to 5m during windy conditions.

7.1.3 The model output report, detailing input parameters and corresponding results are provided in **Appendix A.1** for a fire event under low wind speeds and the same fire event during high wind speeds.

7.2 Emission Parameters

7.2.1 The effective release height applied in ALOHA was estimated through a simplified plume-rise analysis based on the empirical relations developed by Briggs[23]. The calculation used the convective heat-release rate derived from experimentally measured combustion energy for LFP cells[24], which was estimated to be approximately 3.3 MW for a two-cabinet fire. The total energy of the involved portion of the system was determined from its rated capacity, assuming that only a portion of the stored energy contributes to the flaming phase of combustion[25]. A convective fraction of 70% of the total heat-release rate was adopted in accordance with standard fire plume modelling practice[26]. The resulting effective release heights were then used as source parameters in the ALOHA dispersion simulations.

7.3 Meteorology

7.3.1 Three years of hourly sequential data from Sheffield City meteorological observation station for the years 2023 to 2025 were analysed to determine representative conditions for the low wind speed and high wind speed dispersion simulations. The 5th percentile of wind speed and air temperature was used to represent calm, low-dispersion conditions, while the 95th percentile values were used to represent windy, high-dispersion conditions. These percentiles capture the lower and upper extremes of local meteorology, providing conservative and contrasting boundary cases for assessing potential plume behaviour and HF dispersion.

7.4 Likely Consequences of Battery Emissions from Two Cabinets

7.4.1 **Table 7-1** show the maximum distance between the BESS and surrounding receptors for which HF concentrations would achieve the AEGL-1 value of 1 ppm for each of the directions towards receptors listed in **Table 6-1**.

7.4.2 The results confirm that HF concentrations would achieve the AEGL-1 value at a maximum distance of 555 m from the source under calm conditions in a southernly directions, and within 164 m from the source under windy weather conditions in a southernly direction. This is due to more vigorous mixing resulting in a more rapid dilution of the plume under windy conditions. The AEGL-2 and AEGL-3 values for HF are predicted to be achieved at all locations under calm or windy conditions.

Table 7-1: AEGL-1 Achievement Distances

Scenario	Meteorological conditions	Effective Release Height (m)	Distance to AEGL-1 (m)
Multi-cabinet fire, calm, low dispersion conditions, R1 receptor	5th Percentile (calm): Ambient Temperature: -6.2ºC Wind speed: 1.5m/s	8.7	451
Multi-cabinet fire, windy, high-dispersion conditions, R1 receptor	95th Percentile (windy): Ambient Temperature: 21.0ºC Wind speed: 7.2 m/s	5.9	121
Multi-cabinet fire, calm, low dispersion conditions, R2 receptor	5th Percentile (calm): Ambient Temperature: 2.0ºC Wind speed: 1.5 m/s	8.7	446
Multi-cabinet fire, windy, high-dispersion conditions, R2 receptor	95th Percentile (windy): Ambient Temperature: 21.0ºC Wind speed: 8.2 m/s	5.7	112
Multi-cabinet fire, calm, low dispersion conditions, R3 receptor	5th Percentile (calm): Ambient Temperature: -1.0ºC Wind speed: 1.0 m/s	9.7	555
Multi-cabinet fire, windy, high-dispersion conditions, R3 receptor	95th Percentile (windy): Ambient Temperature: 16.0ºC Wind speed: 4.6 m/s	6.6	158
Multi-cabinet fire, calm, low dispersion conditions, R4 receptor	5th Percentile (calm): Ambient Temperature: 2.0ºC Wind speed: 1.5 m/s	8.7	446
Multi-cabinet fire, windy, high-dispersion conditions, R4 receptor	95th Percentile (windy): Ambient Temperature: 21.0ºC Wind speed: 8.2 m/s	5.7	112

8 CONCLUSION

8.1.1 The potential emissions from a fire within the battery energy storage system have been considered and modelling undertaken for the principal pollutant of concern, which is hydrogen fluoride gas (HF). The modelling estimates the distance that the AEGL-1 criteria would be achieved under different meteorological conditions, along a line from the nearest battery cabinet to representative receptor locations. A calm or low wind speed condition and a high wind speed condition are considered. The HF emissions rate used represents the foreseeable, but unlikely event in which emissions equivalent to 60% of all potential HF emissions from all modules in a single cabinet are emitted in one hour.

8.1.2 **Figure 6-1** illustrates the distances at which the AEGL-1 criteria are achieved under conditions that blow the plume towards 4 representative receptors (R1 to R4). Under windy conditions the AEGL-1 value is achieved at all off-site locations. Under calm/low wind speed conditions the AEGL-1 criteria is achieved well before the distance at which any receptor, except for R4, is located. At R4, the AEGL-1 value is achieved at the edge of the farmyard and before the plume reaches any residential receptor on the farm or within the wider village.

8.1.3 Any workers on agricultural land or users of public rights of way that were closer to the fire when it started would be able to move back to a safer distance and thereby avoid exposure to elevated concentrations of all air pollutants.

8.1.4 For the two-cabinet (highly conservative) scenario, the modelling has been repeated using an emission rate that is equivalent to 60% of all potential HF emissions from all modules in a first cabinet and 40% of all potential HF emissions from a second cabinet, being emitted in a single hour. This scenario takes no account of fire fighting actions to limit the spread of the fire and no account of the feasibility of the required progression of the fire across two cabinets being possible within the time period of 1 hour.

8.1.5 The estimated distances at which the AEGL-1 value is predicted to be achieved at all representative receptors (R1-R3), except for R4 remains smaller than the distance to the receptors under windy and calm/low wind speed conditions. Under windy conditions the AEGL-1 criteria is achieved within the distance to the farm yard boundary, but under calm conditions it is not. The AEGL-2 and AEGL-3 criteria are achieved at all distances from the source of emissions under both calm and windy conditions.

8.1.6 The expected HF emissions will be checked against the assumptions in this report at detailed design stage once the make, model and layout of the BESS is known. Consequence modelling will be undertaken at that time to demonstrate that the risks associated with an unplanned fire would not exceed the effects outlined in this report or cause any significant adverse health effects to the local community.

A.1 Aloha Run Reports

One cabinet Scenario under calm wind conditions

R1 receptor - 1 Cabinet - Calm/low wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 0.48 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: 0.51 atm
  Ambient Saturation Concentration: 520,385 ppm or 52.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 1.5 meters/second from S at 10 meters
  Ground Roughness: open country          Cloud Cover: 5 tenths
  Air Temperature: 2° C                   Stability Class: E
  No Inversion Height                     Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 1.76 kilograms/hr        Source Height: 6.5 meters
  Release Duration: 60 minutes
  Release Rate: 29.3 grams/min
  Total Amount Released: 1.76 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 206 meters --- (1 ppm = AEGL-1 [60 min])
```

R2 receptor- 1 Cabinet - Calm/low wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 0.48 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: 0.51 atm
  Ambient Saturation Concentration: 520,385 ppm or 52.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 1.5 meters/second from W at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 2° C                  Stability Class: E
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 1.76 kilograms/hr       Source Height: 6.5 meters
  Release Duration: 60 minutes
  Release Rate: 29.3 grams/min
  Total Amount Released: 1.76 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 206 meters --- (1 ppm = AEGL-1 [60 min])
```

R3 receptor- 1 Cabinet - Calm/low wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 0.49 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                 Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: 0.46 atm
  Ambient Saturation Concentration: 460,824 ppm or 46.1%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 1 meters/second from N at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: -1° C                 Stability Class: E
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 1.76 kilograms/hr       Source Height: 7.2 meters
  Release Duration: 60 minutes
  Release Rate: 29.3 grams/min
  Total Amount Released: 1.76 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 271 meters --- (1 ppm = AEGL-1 [60 min])
```

R4 receptor- 1 Cabinet - Calm/low wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 0.48 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: 0.51 atm
  Ambient Saturation Concentration: 520,385 ppm or 52.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 1.5 meters/second from E at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 2° C                  Stability Class: E
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 1.76 kilograms/hr       Source Height: 6.5 meters
  Release Duration: 60 minutes
  Release Rate: 29.3 grams/min
  Total Amount Released: 1.76 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 206 meters --- (1 ppm = AEGL-1 [60 min])
```

One cabinet Scenario under windy conditions

R1 receptor- 1 Cabinet - High wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 1.19 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                   Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 7.2 meters/second from S at 10 meters
  Ground Roughness: open country          Cloud Cover: 5 tenths
  Air Temperature: 21° C                  Stability Class: D
  No Inversion Height                     Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 1.76 kilograms/hr        Source Height: 4.6 meters
  Release Duration: 60 minutes
  Release Rate: 29.3 grams/min
  Total Amount Released: 1.76 kilograms
  Note: This chemical may flash boil and/or result in two phase flow.
     Use both dispersion modules to investigate its potential behavior.

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: LOC is not exceeded --- (1 ppm = AEGL-1 [60 min])
```

R2 receptor- 1 Cabinet - High wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 1.36 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 8.2 meters/second from W at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 21° C                 Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 1.76 kilograms/hr       Source Height: 4.5 meters
  Release Duration: 60 minutes
  Release Rate: 29.3 grams/min
  Total Amount Released: 1.76 kilograms
  Note: This chemical may flash boil and/or result in two phase flow.
     Use both dispersion modules to investigate its potential behavior.

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: LOC is not exceeded --- (1 ppm = AEGL-1 [60 min])
```

R3 receptor- 1 Cabinet - High wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 0.78 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: 0.88 atm
  Ambient Saturation Concentration: 888,107 ppm or 88.8%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4.6 meters/second from N at 10 meters
  Ground Roughness: open country        Cloud Cover: 5 tenths
  Air Temperature: 16° C                Stability Class: D
  No Inversion Height                   Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 1.76 kilograms/hr      Source Height: 5 meters
  Release Duration: 60 minutes
  Release Rate: 29.3 grams/min
  Total Amount Released: 1.76 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: LOC is not exceeded --- (1 ppm = AEGL-1 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
```

R4 receptor- 1 Cabinet - High wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 1.42 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: 0.51 atm
  Ambient Saturation Concentration: 520,385 ppm or 52.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 8.2 meters/second from E at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 2° C                  Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 1.76 kilograms/hr       Source Height: 4.5 meters
  Release Duration: 60 minutes
  Release Rate: 29.3 grams/min
  Total Amount Released: 1.76 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: LOC is not exceeded --- (1 ppm = AEGL-1 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
```

Multi cabinet Scenario under calm conditions

R1 receptor- 2 Cabinet - Calm/low wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 0.43 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: 0.61 atm
  Ambient Saturation Concentration: 614,254 ppm or 61.4%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 1.5 meters/second from S at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 6.2° C                Stability Class: E
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 5.85 kilograms/hr       Source Height: 8.7 meters
  Release Duration: 60 minutes
  Release Rate: 97.5 grams/min
  Total Amount Released: 5.85 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 451 meters --- (1 ppm = AEGL-1 [60 min])
```

R2 receptor- 2 Cabinet - Calm/low wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 0.48 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                   Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: 0.51 atm
  Ambient Saturation Concentration: 520,385 ppm or 52.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 1.5 meters/second from W at 10 meters
  Ground Roughness: open country          Cloud Cover: 5 tenths
  Air Temperature: 2° C                   Stability Class: E
  No Inversion Height                     Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 5.85 kilograms/hr        Source Height: 8.7 meters
  Release Duration: 60 minutes
  Release Rate: 97.5 grams/min
  Total Amount Released: 5.85 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 446 meters --- (1 ppm = AEGL-1 [60 min])
```

R3 receptor- 2 Cabinet - Calm/low wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 0.49 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: 0.46 atm
  Ambient Saturation Concentration: 460,824 ppm or 46.1%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 1 meters/second from N at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: -1° C                 Stability Class: E
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 5.85 kilograms/hr       Source Height: 9.7 meters
  Release Duration: 60 minutes
  Release Rate: 97.5 grams/min
  Total Amount Released: 5.85 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 555 meters --- (1 ppm = AEGL-1 [60 min])
```

R4 receptor- 2 Cabinet - Calm/low wind speed

```
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 0.48 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: 0.51 atm
  Ambient Saturation Concentration: 520,385 ppm or 52.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 1.5 meters/second from E at 10 meters
  Ground Roughness: open country          Cloud Cover: 5 tenths
  Air Temperature: 2° C                   Stability Class: E
  No Inversion Height                     Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 5.85 kilograms/hr        Source Height: 8.7 meters
  Release Duration: 60 minutes
  Release Rate: 97.5 grams/min
  Total Amount Released: 5.85 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 446 meters --- (1 ppm = AEGL-1 [60 min])
```

Multi cabinet scenario under windy conditions

R1 receptor- 2 Cabinet - High wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 1.19 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 7.2 meters/second from S at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 21° C                 Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 5.85 kilograms/hr       Source Height: 5.9 meters
  Release Duration: 60 minutes
  Release Rate: 97.5 grams/min
  Total Amount Released: 5.85 kilograms
  Note: This chemical may flash boil and/or result in two phase flow.
     Use both dispersion modules to investigate its potential behavior.

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 121 meters --- (1 ppm = AEGL-1 [60 min])
```

R2 receptor- - 2 Cabinet - High wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 1.36 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 8.2 meters/second from W at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 21° C                 Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 5.85 kilograms/hr       Source Height: 5.7 meters
  Release Duration: 60 minutes
  Release Rate: 97.5 grams/min
  Total Amount Released: 5.85 kilograms
  Note: This chemical may flash boil and/or result in two phase flow.
     Use both dispersion modules to investigate its potential behavior.

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 112 meters --- (1 ppm = AEGL-1 [60 min])
```

R3 receptor- 2 Cabinet - High wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 0.78 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: 0.88 atm
  Ambient Saturation Concentration: 888,107 ppm or 88.8%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4.6 meters/second from N at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 16° C                 Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 5.85 kilograms/hr       Source Height: 6.6 meters
  Release Duration: 60 minutes
  Release Rate: 97.5 grams/min
  Total Amount Released: 5.85 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 158 meters --- (1 ppm = AEGL-1 [60 min])
```

R4 receptor- 2 Cabinet - High wind speed

```
SITE DATA:
  Location: WHITESTONE SOLAR FARM, UNITED KINGDOM
  Building Air Exchanges Per Hour: 1.36 (unsheltered single storied)
  Time: January 1, 2025  0800 hours ST (user specified)

CHEMICAL DATA:
  Warning: HYDROGEN FLUORIDE can react with water and/or water vapor.  This
  can affect the evaporation rate and downwind dispersion.  ALOHA cannot
  accurately predict the air hazard if this substance comes in contact with
  water.
  Chemical Name: HYDROGEN FLUORIDE
  CAS Number: 7664-39-3                  Molecular Weight: 20.01 g/mol
  AEGL-1 (60 min): 1 ppm   AEGL-2 (60 min): 24 ppm   AEGL-3 (60 min): 44 ppm
  IDLH: 30 ppm
  Ambient Boiling Point: 19.3° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 8.2 meters/second from E at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 21° C                 Stability Class: D
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Direct Source: 5.85 kilograms/hr       Source Height: 5.7 meters
  Release Duration: 60 minutes
  Release Rate: 97.5 grams/min
  Total Amount Released: 5.85 kilograms
  Note: This chemical may flash boil and/or result in two phase flow.
     Use both dispersion modules to investigate its potential behavior.

THREAT ZONE:
  Model Run: Gaussian
  Red   : LOC is not exceeded --- (44 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Orange: LOC is not exceeded --- (24 ppm = AEGL-2 [60 min])
  Note: Threat zone was not drawn because
     the ground level concentrations never exceed the LOC.
  Yellow: 112 meters --- (1 ppm = AEGL-1 [60 min])
```

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