EAST CLAYDON GREENER GRID PARK

Statkraft UK LTD

Report no.: 10511146-RMC-IE-04, Rev. 0
Document no.: 2432714
Date: 2025-04-25

Project name:	East Claydon Greener Grid Park	DNV Services UK Limited Energy Systems
Report title:	Fire Safety Strategy	Risk Management Consultancy
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Date of issue:	2025-04-25	
Project no.:	10510680	
Organization unit:	Risk Management Consultancy	
Report no.:	10511146-RMC-IE-04, Rev. A	
Document no.:	2432714	

Applicable contract(s) governing the provision of this Report:

Framework #4600001487, Call Off #4500470611

Objective:

This document is the Fire Safety Strategy for Statkraft UK LTD's proposed Greener Grid Park in East Claydon, UK.

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Keywords BESS, Safety, Risk Management

Rev. no.	Date	Reason for issue	Prepared by	Verified by	Approved by
A	2025-04-22	Draft issue	J. Holt	J. Singh	J. Singh
0	2025-04-25	Formal issue	J. Holt	J. Singh	J. Singh

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EXECUTIVE SUMMARY

This report has been commissioned by Statkraft UK LTD ('Statkraft') to accompany a full detailed planning application for the development of a Greener Grid Park in East Claydon, UK. The development will comprise energy storage and grid balancing equipment and associated infrastructure including access, drainage, landscaping and other incidental works.

This report contains the Fire Safety Strategy prepared by DNV for the East Claydon Greener Grid Park Battery Energy Storage System (BESS) component. The Fire Safety Strategy defines those fire safety features that will be included at the Greener Grid Park and demonstrates the high standards of safety integral to its design. The project has strived to reduce the potential for accidents to the lowest practicable level and actively promotes a safety and sustainability culture at all stages of the development. Specifically:

Statkraft has actively addressed the requirements of the National Fire Chief Council's (NFCC) 2023 guidance for battery energy storage systems. The design and safety measures have been discussed with Buckinghamshire Fire and Rescue Service (BFRS) as part of pre-application consultation:

- Firewater will be available from underground water tanks and suitable to provide firewater at a rate of 1,900 L/min over two hours;
- The battery containers will be equipped with suitable Battery Management System (BMS), fire detection and suppression equipment such to prevent, control, and mitigate the risk of thermal runaway;
- The battery containers will be spaced to prevent propagation or spread of any potential fire, supported through industry standard fire propagation testing (UL 9540A) and further Large Scale Fire Test (LSFT);
- The site access will be suitable for emergency service vehicles and provide unobstructed access to all equipment for firefighting;
- In the unlikely case of fire on site, the BFRS will be recommended to observe a controlled burn whereby firewater is only applied for boundary cooling purposes in alignment with NFCC and BESS supplier recommendations. A sustainable drainage system and attenuation pond will prevent firewater runoff and any potential environmental damage;

The safety features embedded in the design and operating procedures are based on current goo engineering practice and the most relevant industry standards and codes. These will minimise the fire risk at the installation to As Low as Reasonably Practicable (ALARP);

The risk to personnel and first responders in an unlikely event of a major fire will be managed effectively through an Emergency Response Plan (ERP) prepared in collaboration with the BFRS;

The risk to the general public is considered negligible due to the location and design of the site.

GLOSSARY OF TERMS

Term	Description
ACOP	Approved Codes of Practices
ALARP	As Low As Reasonably Practicable
BESS	Battery Energy Storage System
BFRS	Buckinghamshire Fire and Rescue Service
BMS	Battery Management System
BS	British Standard
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations
EMS	Energy Management System
ER	Employers Requirement
ERP	Emergency Response Plan
ESS	Energy Storage System
FRS	Fire and Rescue Service
IEC	International Electrochemical Commission
HSE	Health and Safety Executive
IP	Ingress Protection
LEL	Lower Explosive Limit
LFP	Lithium Iron Phosphate
LSFT	Large Scale Fire Test
NFCC	National Fire Chief's Council
NFPA	National Fire Protection Agency
NMC	Nickle Manganese Cobalt Oxide
OEM	Original Equipment Manufacturer
SSRI	Site Specific Risk Information
SuDS	Sustainable Drainage System
TMS	Thermal Management System
UL	Underwriters Laboratory

1 INTRODUCTION

1.1 Proposed Development

On behalf of Statkraft UK LTD ('Statkraft'), a full detailed planning has been submitted for the development of a Greener Grid Park, comprising a Battery Energy Storage System (BESS), synchronous compensators, associated infrastructure, landscaping, and access in East Claydon UK. The Greener Grid Park is located on Land North of East Claydon Road, RG24 7AL within the local authority of Buckinghamshire Council.

The proposed layout is presented in Figure 1 below.

Figure 1: East Claydon Greener Grid Park - Site Layout Plan

1.2 Document Scope

This document presents the Fire Safety Strategy prepared by DNV for the East Claydon Greener Grid Park. The Fire Safety Strategy provides an overview of potential fire risks associated with the BESS component of the development, and demonstrates the engineering controls, stakeholder consultation processes, and design aspects implemented to prevent, control and mitigate the fire hazards.

The Fire Safety Strategy has been prepared in line with the *NFCC Grid Scale Battery Energy Storage System Planning – Guidance for FRS* (Ref. /1/) published in 2023, and defines those features which will be included to ensure compliance. The Fire Safety Strategy also includes reference to globally recognised standards NFPA 855 and UL 9540A to further qualify design and layout features.

2 SAFETY REQUIREMENTS

2.1 Statutory Requirements in England and Wales

The East Claydon Greener Grid Park will be subject to the legislative requirements stated in the UK Statutory Instruments. The relevant regulations to which new developments must conform concern Health and Safety, Fire Risk, Electrical Safety and Construction Management. The following apply in England and Wales:

1. *Health and Safety at Work etc. Act 1974* (Ref. /2/)
2. *The Regulatory Reform (Fire Safety) Order 2005* (Ref. /3/)
3. *The Building Regulations 2010 (as applicable in parts)* (Ref. /4/)
4. *Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002* (Ref. /5/)
5. *Electricity at Work Regulations 1989* (Ref. /6/)

Other legislations also apply; hence this list is not to be considered comprehensive.

2.2 Applicable Standards and Approved Codes of Practice (ACOPs)

In the UK there is no standard, or set of standards, that have been adopted into legislation to specifically demonstrate proper fire safety in design, installation, and testing for sites including battery energy storage. However, a number of standards and guidance documents have become routine, and favoured across the industry. The main standards and guidance documents applicable to the BESS at the East Claydon Greener Grid Park are:

1. **NFCC Grid Scale Battery Energy Storage System planning – Guidance for FRS** (Ref. /1/)

   In the UK the NFCC has published guidance for the FRS regarding planning considerations for new battery energy storage systems. The guidance includes a number of design and operational safety recommendations in line with international standards and learnings from BESS fire incidents worldwide.

   The NFCC guidance is currently the most widely used reference by UK planning authorities in assessment of fire safety at new developments.

2. **NFPA 855 Standard for the Installation of Stationary Energy Storage Systems** (Ref. /7/)

   NFPA 855 is an international safety standard for the installation of energy storage systems. Globally NFPA 855 is considered the most well referenced standard for BESS design safety. It has been adopted by planning authorities worldwide, including the UK as guidance for issue permitting in BESS. The standard is considered the de-facto standard for BESS developments in the USA.

3. **UL 9540A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems 4th Edition** (Ref. /8/)

   UL 9540A is the industry standard test methodology for evaluating the resistance to fire propagation in the event of BESS thermal runaway. The test is designed to emulate real-world thermal runaway, it involves the deliberate initiation of thermal runaway to prove the units' limits with respect to fire propagation. UL 9540A is the dominant methodology utilised worldwide for assessing propagating fire risk in BESS. It is referenced by both the NFCC and NFPA as a means to demonstrate site safety with respect to equipment separation distances.

3 FIRE STATEMENT

In this section, compliance aspects of the East Claydon Greener Grid Park with the NFCC's guidance for battery storage are defined and demonstrated. This section has been structured as such to mirror the order of requirements introduced by the NFCC to maximise comparability between the documents for the reader.

In each subsection, relevant excerpts from the NFCC guidance are quoted, followed by compliance statements for the East Claydon Greener Grid Park. Table 1 provides a summary of the headline compliance aspects. A layout plan highlighting the safety features integrated into the site design is further included in Appendix A: Fire Strategy Layout.

Table 1: NFCC Compliance Summary

NFCC Requirement	East Claydon Greener Grid Park	Compliance
Information Requirements	Detailed site information package will be prepared and made availat to the BFRS.	☑
System Design and Construction	Statkraft are committed to ensuring the highest level of safety in th selected BESS solution. Design and construction aspects at the E Claydon Greener Grid Park have been specifically assessed in line with the recommendations from the NFCC.	☑
Testing	The BESS technology selected will be tested in line with UL 9540A and a Large Scale Fire Test (LSFT) to demonstrate suitability of the BE container positioning to prevent fire spread.	☑
Design	The East Claydon Greener Grid Park will utilise a BESS solution from recognised battery unit provider. The adopted BESS solution w equipped with design features in line with the recommendations of t NFCC.	☑
Detection and Monitoring	The selected BESS shall be equipped with a BMS which enact protection, monitoring, and control functionality over the battery systen The BESS will further be equipped with internal fire detection syste monitoring heat and smoke evolution. Where deemed nece through risk analysis or manufacturer's recommendations, combustible gas detectors will also be installed.	☑
Suppression Systems	Integration of an internal fire suppression system will be int through liaison with a competent system designer and the manufacturer Statkraft will assess the need for fire suppression based on a risk analysis, considering demonstrable safety features in the BESS. Where deeme required any suppression system will be based on either aero: water-based fire suppressants.	☑

NFCC Requirement	East Claydon Greener Grid Park	Compliance
Deflagration Preventing and Venting	The BESS enclosures will include suitable measures for exp protection informed through design risk studies. Explosion protec systems will be designed and selected in consultatio equipment manufacturer and their efficacy demonstrated with suitable evidence.	☑
Site Access	The site will be equipped with adequate access routes and in roadways to provide unobstructed access to the battery enclosures f firefighting. Swept path analysis has been completed to demonstrate the suitability of the internal roadways for fire service vehicles.	☑
Access Between BESS Units and Unit Spacing	Spacing around the BESS units will be based on a data-driven and evidence-backed approach. The selected BESS will be tested in line with UL 9540A and an LSFT to demonstrate suitability of the minim clearance to prevent fire spread; that is that any thermal runaway ever will be shown not to propagate between enclosures.	☑
Distance from BESS Units to Occupied Buildings and Site Boundaries	There will be no occupied buildings on site. The battery units will be clear from the site boundary by at least 25 m.	☑
Site Conditions	Vegetation will be cleared within 10 m of BESS units in line wit requirements of the NFCC.	☑
Water Supplies	The site will include underground water tanks sized to accommodat 228,000 L of stored water. This is directly in line with recommendatior for the NFCC for provision of firewater supply equivalent to 1,900 L/mi deluge over a period of two-hours.	☑
Signage	The site will be equipped with suitable electrical and battery signage and any other relevant information to suitably inform persons o relevant hazards and emergency procedures.	☑
Risk Management Plan	A Risk Management Plan will be prepared for the East Claydon Greener Grid Park in line with recommendations from the NFCC.	☑
Emergency Response Plan	An Emergency Response Plan (ERP) will be developed using guidanc from the UK Health and Safety Executive (HSE), NFPA 855 and prevailing legislation in the *Regulatory Reform (Fire Safety) Order 2005*. The ERP will be developed in collaboration with the BFRS to allow effective and safe emergency response.	☑

NFCC Requirement	East Claydon Greener Grid Park	Compliance
Environmental Impacts	The site will include a sustainable drainage system designed to capture and contain any contaminated firewater runoff. The philosop capture of firewater runoff will follow the NFCC guidance, such that ar firewater runoff or otherwise will be captured and containec attenuation ponds across the site. The drainage system will be equipped with suitable lining and control valves to eliminate risk of discharge the local environment.	☑
Recovery	Post incident recovery will be included as part of the ERP. At the end c the project life, or following any incident the BESS will be decommissioned in line with The Waste Batteries and Accumul Regulations.	☑

3.1 Information Requirements

NFCC Requirement:

Grid scale BESS should form part of FRS planning in accordance with arrangements required under section 7(2)(d) of the Fire and Rescue Services Act (2004). Site Specific Risk Information (SSRI) should be made available to crews in the form of an effective Emergency Response Plan. Details of any site access arrangements, such as key codes, should be provided to the FRS.

East Claydon Greener Grid Park Compliance: As introduced in section 4, Statkraft have engaged the BFRS, for pre-application consultation regarding the proposed development.

As part of ongoing consultation Statkraft will ensure that a suitable firefighting strategy is agreed with the BFRS, and develop a comprehensive ERP with their input. All relevant Site Specific Risk Information (SSRI) shall be included and accounted for in the ERP and documentation package developed specially for the project.

3.2 System Design and Construction

NFCC Requirement:

This information should be provided to the FRS:

1. *The battery chemistries being proposed (e.g. Lithium-ion Phosphate (LFP), Lithium Nickel Manganese Cobalt Oxide (NMC))*
2. *The battery form factor (e.g. cylindrical, pouch, prismatic)*
3. *Type of BESS e.g. container or cabinet*
4. *Number of BESS containers/cabinets*
5. *Size/capacity of each BESS unit (typically in MWh)*
6. *How the BESS units will be laid out relative to one another.*
7. *A diagram / plan of the site.*
8. *Evidence that site geography has been taken into account (e.g. prevailing wind conditions).*
9. *Access to, and within, the site for FRS assets*
10. *Details of any fire-resisting design features*
11. *Details of any:*
    - *a. Fire suppression systems*
    - *b. On site water supplies (e.g. hydrants, EWS etc)*
    - *c. Smoke or fire detection systems (including how these are communicated)*
    - *d. Gas and/or specific electrolyte vapour detection systems*
    - *e. Temperature management systems*
    - *f. Ventilation systems*
    - *g. Exhaust systems*
    - *h. Deflagration venting systems*
12. *Identification of any surrounding communities, sites, and infrastructure that may be impacted as a result of an incident.*

East Claydon Greener Grid Park Compliance: Statkraft will prepare a site-specific information package including all relevant technical and design considerations required by the NFCC. The information package will be made available to the BFRS. It is noted, in the planning phase where equipment supply contracts are not yet in place, specific details regarding battery technology and safety features are not confirmed. Statkraft are committed to ensuring the highest level of safety in their selected BESS solution.

The adjoining sections in this document define those safety features which are committed by Statkraft, in line with the NFCC requirements.

3.3 Testing

NFCC Requirement:

Details of any evidence based testing of the system design should be requested, for example, results of UL 9540A testing.

East Claydon Greener Grid Park Compliance: The BESS technology selected will be tested in line with UL 9540A (Ref. /8/) as well as a Large Scale Fire Test (LSFT) to demonstrate suitability of the BESS container positioning to prevent fire spread. At request, the results of testing will be made available to the BFRS for review.

The commissioning of the site will follow the guidance of the OEM. This will include functional checks of all safety systems. Initial testing will take place at the OEM's factory, where a Factory Acceptance Test (FAT) will be performed to verify that key components of the BESS are operational and safe for transit. Upon arrival, a Post Delivery Inspection (PDI) will be conducted to confirm that no damage has occurred during the shipping process followed by a Site Acceptance Test (SAT) to confirm operability.

3.4 Design

NFCC Requirement:

Design features should be made clear. These may include:

- *Rack layout and setup*
- *Thermal barriers and insulation*
- *Container layout and access arrangements*

East Claydon Greener Grid Park Compliance: Statkraft will prepare a site-specific information package including all relevant technical and design considerations required by the NFCC. The site will utilise a BESS solution from a recognised battery unit provider and deliver BESS in line with defined Employer's Requirements (ERs). Specific features will include:

- Lithium Iron Phosphate (LFP) battery technology arranged as cells, modules, racks and purpose built non-walk-in outdoor enclosures;
- Suitably Ingress Protection (IP) rated enclosures to protect against water and particulate damage;
- Electrical control and protection equipment, Battery Management System (BMS) and Temperature Management System (TMS) to maintain the battery units within their safe operating envelope;
- Appropriate auxiliary fire detection, suppression and explosion protection systems.

Such provisions are discussed throughout this document, in line with guidance from the NFCC.

3.5 Detection and monitoring

NFCC Requirement:

An effective and appropriate method of early detection of a fault within the batteries should be in place, with immediate disconnection of the affected battery / batteries. This may be achieved automatically through the provision of an effective Battery Management System (BMS) and / or a specific electrolyte vapour detection system.

Should thermal runaway conditions be detected then there should be the facility in place for the early alerting of emergency services.

Detection systems should also be in place for alerting to other fires that do not involve thermal runaway (for example, fires involving electrical wiring).

East Claydon Greener Grid Park Compliance: The selected BESS shall be equipped with BMS which enacts protection, monitoring, and control functionality over the battery system. The BMS will ensure the battery cells are maintained with their safe-operating-envelope, and in case of deviation from operating norms (e.g. voltage, temperature, state of charge), will be able to enact safety functions autonomously to prevent fault or failure, including thermal runway. This will include functionality to derate the battery system on detection of any unsafe operating condition, and the ability to disconnect, shutdown, and isolate the system in case of further deviation or critical failure. Fire detection systems will be installed within the BESS enclosures and at critical equipment on site to detect other fires that do not involve thermal runaway.

Both the BMS and fire detection systems will be interfaced with a site wide Energy Management System (EMS) and a 24/7 remote monitoring system. The EMS and remote monitoring system will be integrated with all site equipment and provide a real time view of the plant status and presence of any faults or failures. In case thermal runaway or fire is detected, the systems will raise high priority alarms to remote operating personnel and activate local audible and visual alarms to alert any persons on or nearby to the site. The operating personnel will be properly trained to respond to thermal runaway and/or fire event, and will contact the FRS as appropriate. Specific procedures for responding to thermal runaway, fire, and other emergency events shall be defined in the ERP.

NFCC Requirement:

Continuous combustible gas monitoring within units should be provided. Gas detectors should alarm at the presence of flammable gas (yes / no), shut down the BESS, and cause the switchover to full exhaust of the ventilation system. Sensor location should be appropriate for the type of gas detected e.g. hydrogen, carbon monoxide, volatile organic compounds.

External audible and visual warning devices (such as cabinet level strobing lights), as well as addressable identification at control and indicating equipment, should be to linked to:

1. Battery Management System (when a thermal runaway event is identified)

2. Detection and suppression system activation

East Claydon Greener Grid Park Compliance: The BESS will be equipped with internal fire detection systems, monitoring heat and smoke evolution. Where deemed necessary, through risk analysis or manufactu recommendations, combustible gas detectors will also be installed. The detection systems will provide early warning of a fire event and enact immediate power down of any compromised unit

Local audible (sounder) and visual (beacon) alarms will be strategically located around the site to alert any persons present of the event of fire or thermal runaway. The audible and visual alarm systems will be interfaced with the BMS, fire detection and fire suppression functions, as relevant, to activate accordingly.

3.6 Suppression Systems

NFCC Requirement:

Suitable fixed suppression systems should be installed in units in order to help prevent or limit propagation between modules.

Where it is suggested that suppression systems are not required in the design, this choice should be supported by an evidence based justification and Emergency Response Plan that is designed with this approach in mind (for example, risk assessed controlled burn strategies, and external sprinkler systems).

The choice of a suppression system should be informed by liaison with a competent system designer who can relate the system choice to the risk identified and the duration of its required activation. Such a choice must be evidence based.

East Claydon Greener Grid Park Compliance: Any internal fire suppression system will be specified by a competent system designer appointed by the manufacturer. Statkraft will ensure the need for fire suppression is assessed based on a risk analysis, considering demonstrable safety features in the BESS (e.g. beneficial testing results in line with UL 9540A) and emergency response strategy for the site.

Where deemed required, any suppression system will be selected based on assessment of its efficacy. At the time of reporting, the most common methods of fire suppression are based on either aerosol of water based suppressants. In case the industry moves to favour a method other than aerosol or water based suppressant, Statkraft may consider such solutions providing ample demonstration of efficacy and safety.

3.7 Deflagration Prevention and Venting

NFCC Requirement:

BESS containers should be fitted with deflagration venting and explosion protection appropriate to the hazard. Designs should be developed by competent persons, with design suitability able to be evidenced. Exhaust systems designed to prevent deflagration should keep the environment below 25% of Lower Explosive Limit (LEL).

Flames and materials discharged as a result of any venting should be directed outside to a safe location and should not contribute to any further fire propagation beyond the unit involved or present further risk to persons. The likely path of any vented gasses or materials should be identified in Emergency Response Plans to reduce risk to responders.

Explosion / deflagration strategies should be built into the emergency plan such that responders are aware of their presence and the impact of their actions on these strategies.

Where emergency ventilation is used to mitigate an explosion hazard, the disconnect for the ventilation system should be clearly marked to notify personnel or first responders to not disconnect the power supply to the ventilation system during an evolving incident.

East Claydon Greener Grid Park Compliance: The BESS enclosures will include suitable measures for explosion protection informed through design risk studies. Explosion protection systems will be installed in alignment with NFPA 855 (Ref. /7/), which can include NFPA 68-compliant deflagration control systems (Ref. /10/), and/or NFPA 69-compliant explosion prevention systems with gas detection (Ref. /11/), and/or other engineered solutions, where validated to be effective through testing. The design of the explosion protection system will be evidence-based and informed by manufacturer analysis and recommendation.

As per guidance from the NFCC:

> Any exhaust system shall keep the environment below 25% of Lower Explosive Limit (LEL).

Deflagration vents will be directed to a safe location and likely path of any vented gasses or materials identified and included in the ERP.

Where emergency ventilation systems are used, disconnect systems will be clearly marked.

All relevant information regarding explosion protection shall be included in the ERP.

3.8 Site Access

NFCC Requirement:

Suitable facilities for safely accessing and egressing the site should be provided. Designs should be developed in close liaison with the local FRS as specific requirements may apply due to variations in vehicles and equipment.

This should include:

At least 2 separate access points to the site to account for opposite wind conditions / direction.

Roads / hard standing capable of accommodating fire service vehicles in all weather conditions. As such there should be no extremes of grade.

A perimeter road or roads with passing places suitable for fire service vehicles.

Road networks on sites must enable unobstructed access to all areas of the facility.

Turning circles, passing places etc size to be advised by FRS depending on fleet

East Claydon Greener Grid Park Compliance: The East Claydon Greener Grid Park will be accessed from East Claydon Road (south) via a private internal access road. From the main entrance to the site firefighting crews may access the BESS compounds through movement toward the east or west.

To ensure safe site access in emergency circumstance the main site entrance is suitably set back from BESS containers to ensure FRS personnel avoid exposure to any smoke or toxic off-gassing as a result of BESS fire. To verify the safe setback distance, a Plume Dispersion Study has been prepared for the East Claydon Greener Grid Park. The findings demonstrate immediate danger from heat flux, smoke and toxic gases which may be evolved as a result of a BESS fire are confined to the immediate surroundings of the BESS only. The complete Plume Dispersion Study is available in Appendix B: Plume Dispersion Study.

The site will benefit from internal roadways designed in line with *BS 9999 Fire safety in the design, management and use of buildings* (Ref. /12/) such that emergency services will have unobstructed access to all areas of the facility for firefighting. The width and sizing of the roadways have been determined according to guidance from *The Building Regulations, Fire Safety Approved Document B* (Ref. /13/) and verified through swept path analysis completed based on the dimensions of typical fire service vehicles.

The site will further include a number of emergency pedestrian egress gates positioned strategically to ensure suitable means of escape from all site areas. As part of routine maintenance procedures and inspections, Statkraft will ensure all access and egress routes are clear of debris and obstructions.

3.9 Access Between BESS Units and Unit Spacing

NFCC Requirement:

In the event of a fire involving a BESS unit, one of the primary tactics employed will be to prevent further unit to unit fire spread. Suitable access for firefighters to operate unimpeded between units will therefore be required. This should allow for the laying and movement of hose lines and, as such, access should be free of restrictions and obstacles. The presence of High Voltage DC Electrical Systems is a risk and their location should be identified. Exclusion zones should be identified.

A standard minimum spacing between units of 6 metres is suggested unless suitable design features can be introduced to reduce that spacing. If reducing distances a clear, evidence based, case for the reduction should be shown.

Any reduction in this separation distance should be design based by a competent fire engineer. There should be consideration for the fire separation internally and the total realistic load of fire. Proposed distances should be based on radiant heat flux (output) as an ignition source.

The NFCC does not support the stacking of containers / units on top of one another on the basis of the level of risk in relation to fire loading, potential fire spread, and restrictions on access

East Claydon Greener Grid Park Compliance: Spacing around the BESS units will be based on a data-driven and evidence-backed approach. Stacked container solutions will not be employed.

Test standard UL 9540A is the dominant methodology utilised worldwide for assessing propagating fire risk in BESS and is referenced by both the NFCC and NFPA as a means to demonstrate site safety with respect to separation distances.

The selected BESS will be tested in line with UL 9540A as well as a Large Scale Fire Test (LSFT) to demonstrate suitability of the minimum clearance to prevent fire spread; that is that any thermal runaway event will be shown not to propagate between enclosures.

3.10 Distance from BESS Units to Occupied Buildings and Site Boundaries

NFCC Requirement:

Individual site designs will mean that distances between BESS units and occupied buildings / site boundaries will vary. Proposed distances should take into account risk and mitigation factors. However, an initial minimum distance of 25 metres is proposed prior to any mitigation such as blast walls. Reduction of distances may be possible in areas of lower risk (e.g. rural settings). Where possible buildings should be located upwind.

East Claydon Greener Grid Park Compliance: The East Claydon Greener Grid Park will be operated via a remote control centre. The site will be normally unmanned and only accessed routinely for maintenance and inspection activities. The buildings on site are hence considered unoccupied. The NFCC does not prescribe clearance distance for BESS to unoccupied buildings. NFPA 855 requires that battery units must observe clearance of 3 m from all buildings regardless of occupation. This may be reduced to 0.9 m where qualified by fire testing in line with UL 9540A. Statkraft will observe minimum spacing to buildings in line with NFPA 855's 3 m basic requirement.

Regarding spacing to site boundary, the East Claydon Greener Grid Park adheres recommendation from the NFCC for clearance from battery containers of 25 m. It is further noted, the site is located in a rural location such that there are no regularly occupied buildings or otherwise within 250 m of the BESS compound. The Plume Dispersion Study prepared for the site has shown that residential areas and road receptors are sufficiently distant from the BESS enclosures, such that they will not be subject to any immediate and significant hazard from simulated fires in terms of heat flux, visibility, or toxicity.

3.11 Site Conditions

NFCC Requirement:

Sites should be maintained in order that, in the event of fire, the risk of propagation between units is reduced. This will include ensuring that combustibles are not stored adjacent to units and access is clear and maintained. Areas within 10 metres of BESS units should be cleared of combustible vegetation and any other vegetation on site should be kept in a condition such that they do not increase the risk of fire on site. Areas with wildfire risk or vegetation that would result in significant size fires should be factored into this assessment and additional cleared distances maintained as required.

East Claydon Greener Grid Park Compliance: Vegetation within 10 m of BESS units will be cleared to limit risks of fire propagation. To maintain site conditions, Statkraft will develop a vegetation management plan for the operational phase of the project to ensure routine cutback / removal. Any other combustible materials (e.g. maintenance consumables) will not be stored adjacent to battery units and will be housed in dedicated areas.

3.12 Water Supplies

NFCC Requirement:

Water supplies will depend on the size of the installation. In the majority of cases, initial firefighting intervention will focus on defensive firefighting measures to prevent fire spread to adjacent containers. As a result, proposals for water supplies on site should be developed following liaison with the local fire and rescue service taking into account the likely flow rates required to achieve tactical priorities. This should also take account of the ability of / anticipated time for the fire and rescue service to bring larger volumes of water to site (for example through the provision of High Volume Pumps).

IP ratings of units should be known so that risks associated with boundary cooling can be understood.

As a minimum, it is recommended that hydrant supplies for boundary cooling purposes should be located close to BESS containers (but considering safe access in the event of a fire) and should be capable of delivering no less than 1,900 litres per minute for at least 2 hours. Fire and rescue services may wish to increase this requirement dependant on location and their ability to bring supplementary supplies to site in a timely fashion.

Water supply for any automatic suppression system will be covered by the relevant standard / design depending on which system chosen as appropriate for the risk. For manual water, amounts should come from performance based requirement rather than a reference to a code, unless it can be proven that the code specifically covers BESS. Regarding water storage tanks, volumes will again need to be informed on a performance-based need. Isolation points should be identified.

Any static water storage tanks designed to be used for firefighting must be located at least 10 metres away from any BESS container / cabinet. They must be clearly marked with appropriate signage. They must be easily accessible to FRS vehicles and their siting should be considered as part of a risk assessed approach that considers potential fire development/impacts. Outlets and connections should be agreed with the local FRS. Any outlets and hard suction points should be protected from mechanical damage (e.g. through use of bollards).

East Claydon Greener Grid Park Compliance: Access to firewater will be readily available on site through permanently installed underground water tanks sized to accommodate 228,000 L of stored water. This is directly in line with recommendations from the NFCC for provision of firewater supply equivalent to 1,900 L/min deluge over a period of two-hours.

Positioning of the water tank will be underground such to avoid any risk of damage in case of fire or mechanical impact (e.g. from construction activity or vehicles). Access for hose attachments will be readily accessible to the first responders in line with recommendation from the BFRS and will be clearly marked with appropriate signage.

3.13 Signage

NFCC Requirement:

Signage should be installed in a suitable and visible location on the outside of BESS units identifying the presence of a BESS system. Signage should also include details of:

- *Relevant hazards posed*
- *The type of technology associated with the BESS*
- *Any suppression system fitted*
- *24 / 7 Emergency Contact Information*

Signs on the exterior of a building or enclosure should be sized such that at least one sign is legible at night at a distance of 30 metres or from the site boundary, whichever is closer.

Adherence to the Dangerous Substances (Notification and Marking of Sites) Regulations 1990 (NAMOS) should be considered where the total quantity of dangerous substances exceeded 25 tonnes.

East Claydon Greener Grid Park Compliance: The site will be equipped with suitable electrical safety signage and any other relevant information to suitably inform persons of relevant hazards and emergency procedures. All relevant requirements from the NFCC will be adhered to. Signage features will include:

- Information board at the main site entrance providing contact details of Statkraft alongside a 24/7 emergency freephone number;
- Clearly indicated entries / exits in case access is required by emergency services or for emergency escape;
- Safety hazards including indicating operating voltages, arc flash labels, suppression agents, and demarcation zones;
- Battery specific labels including enclosed cell technology (LFP);
- Emergency stop and safety critical power supplies (e.g., emergency ventilation signage informing personnel / first responders to not disconnect the power during an evolving incident).

3.14 Risk Management Plan

NFCC Requirement:

A Risk Management Plan should be developed by the operator, which provides advice in relation to potential emergency response implications including:

- *The hazards and risks at and to the facility and their proposed management.*
- *Any safety issues for firefighters responding to emergencies at the facility.*
- *Safe access to and within the facility for emergency vehicles and responders, including to key site infrastructure and fire protection systems.*
- *The adequacy of proposed fire detection and suppression systems (e.g., water supply) on-site.*
- *Natural and built infrastructure and on-site processes that may impact or delay effective emergency response.*

East Claydon Greener Grid Park Compliance: A Risk Management Plan will be prepared for the East Claydon Greener Grid Park. The Risk Management Plan will include all those aspects required by the NFCC and include details and findings from the safety assessment carried out by Statkraft to systematically identify and assess all hazards and risks which may be present.

3.15 Emergency Response Plan

NFCC Requirement:

An Emergency Response Plan should be developed to facilitate effective and safe emergency response and should include:

- *How the fire service will be alerted*
- *A facility description, including infrastructure details, operations, number of personnel, and operating hours.*
- *A site plan depicting key infrastructure: site access points and internal roads; firefighting facilities (water tanks, pumps, booster systems, fire hydrants, fire hose reels etc); drainage; and neighbouring properties.*
- *Details of emergency resources, including fire detection and suppression systems and equipment; gas detection; emergency eye-wash and shower facilities; spill containment systems and equipment; emergency warning systems; communication systems; personal protective equipment; first aid.*
- *Up-to-date contact details for facility personnel, and any relevant off-site personnel that could provide technical support during an emergency.*
- *A list of dangerous goods stored on site.*
- *Site evacuation procedures.*
- *Emergency procedures for all credible hazards and risks, including building, infrastructure and vehicle fire, grassfire and bushfire*

East Claydon Greener Grid Park Compliance: An ERP will be developed using guidance from the UK Health and Safety Executive (HSE), NFPA 855 and prevailing legislation in the *Regulatory Reform (Fire Safety) Order 2005*. The ERP will be developed with the BFRS to allow effective and safe emergency response. All provisions from the NFCC regarding emergency response will be included in the ERP as relevant.

3.16 Environmental impacts

NFCC Requirement:

Suitable environmental protection measures should be provided. This should include systems for containing and managing water runoff. System capability/capacity should be based on anticipated water application rates, including the impact of water based fixed suppression systems.

Sites located in flood zones should have details of flood protection or mitigation measures.

East Claydon Greener Grid Park Compliance: Sustainable drainage system (SuDS) at the East Claydon Greener Grid Park has been designed for safe containment and disposal of any contaminants arising from BESS firefighting activities. Philosophy for capture of firewater runoff will follow the NFCC guidance, such that any firewater runoff or otherwise will be captured and contained in attenuation ponds across the site. The drainage system will be equipped with suitable lining and control valves to avoid discharge to the local environment. Where any firewater is captured, safe disposal will be ensured via contract with third party specialist contractor.

3.17 Recovery

NFCC Requirement:

The operator should develop a post-incident recovery plan that addresses the potential for reignition of BESS and de-energising the system, as well as removal and disposal of damaged equipment.

East Claydon Greener Grid Park Compliance: Post incident recovery will be included as part of the ERP introduced in section 3.15. At the end of the project life, or following any incident the BESS will be decommissioned in line with The Waste Batteries and Accumulators Regulations (Ref. /15/).

4 BUCKINGHAMSHIRE FIRE RESCUE SERVICE CONSULTATION

4.1 Pre-Application Consultation

The designated fire authority for the East Claydon Greener Grid Park is the Buckinghamshire Fire and Rescue Service (BFRS). Statkraft recognises the importance of early engagement with the Local Fire and Rescue Service in the development of a BESS facility. This collaboration is of mutual interest and aims to:

- Ensure that Statkraft is aware of the firefighting provisions necessary for the BFRS to manage a BESS fire and is able to integrate these into the design.
- Confirm that the BFRS understands the nature of BESS fires and is confident and competent in safely managing them;
- Ensure that a suitable firefighting strategy is agreed upon between Statkraft and the BFRS, alongside a comprehensive Emergency Response Plan (ERP);

Statkraft has engaged with the BFRS to ensure they are informed of the proposed development. Fire safety considerations, in line with NFCC guidance for battery storage (Ref. /1/), were discussed during a teleconference held on 14 February 2025. During this meeting, the BFRS raised no objections to the proposed development.

It was agreed that formal written feedback will be provided by the BFRS following their review of the detailed planning documents.

4.2 Continued Engagement

Statkraft will continue to engage with the BFRS throughout the planning, construction and operational phases of the project. In particular:

- The agreed firefighting strategy and emergency response procedures will be regularly reviewed and updated in collaboration with the BFRS, reflecting developments in legislation, standards, and best practices as well as learnings from the wider BESS industry;
- The BFRS will be invited to attend and contribute toward risk studies and safety workshops carried out post planning consent;
- The BFRS will be provided with a complete document package for the site, including but not limited to:
    - Site specific risk information in the form of an Emergency Response Plan (ERP); in accordance with Section 7(2)(d) of the *Fire and Rescue Services Act (2004)* (Ref. /9/);
    - Information on site access arrangements such as key codes;
    - Battery details: battery chemistries and form factor;
    - BESS details: type and number of BESS units, size / capacity, layout, site plan;
    - Evidence showing consideration of site geography;
    - Details on site access for FRS assets;
    - Details on the site surroundings; e.g., communities, sites, infrastructure that may be at risk in the event of an incident;
    - Details of any fire suppression systems, firewater supplies, smoke or fire detection, gas detection, temperature management systems, ventilation, exhaust systems and deflagration venting systems;
    - Details of any evidence-based testing e.g. results of UL 9540A testing (Ref. /8/);

Statkraft will welcome site surveys throughout the construction and operational phases of the project to ensure the BFRS are well versed with the equipment arrangements and access controls.

5 CONCLUSIONS

This document contains the Fire Safety Strategy for Statkraft's proposed Greener Grid Park, in East Claydon UK. The contents demonstrate the inherent safety features implemented by the design in line with industry best practice, guidance, and appropriate regulation, minimise the risk of fire on site, and the mitigating features employed to reduce impact if such an event should occur. Through a rigorous assessment of safety, Statkraft has demonstrated a risk aware approach to the proposed development, wherein the primary focus throughout the project lifecycle is safety and protection of the local environment:

Statkraft has actively addressed the requirements of the National Fire Chief Council's guidance for battery energy storage systems.

The safety features embedded in the design and operating procedures are based on current goo engineering practice and the most relevant industry standards and codes (UL 9540A, NFPA 855). These minimise the fire risk at the installation to As Low as Reasonably Practicable (ALARP).

The risk to personnel and first responders in an unlikely event of a major fire will be managed effectively through an ERP.

The design and safety measures will be discussed, developed, and agreed with the BFRS.

The risk to general public is negligible due to the location and design of the site.

REFERENCES

/1/ National Fire Chief's Council, 'Grid Scale Battery Energy Storage System planning – Guidance for FRS', 2022.

/2/ UK Public General Acts, 'Health and Safety at Work etc. Act', 1974

/3/ UK Statutory Instruments, 'No 1541 The Regulatory Reform (Fire Safety) Order, 2005

/4/ UK Statutory Instruments, 'No 2214 The Building Regulations', 2010.

/5/ UK Statutory Instruments, 'No 2276 The Dangerous Substances and Explosive Atmospheres Regulations', 2002

/6/ UK Statutory Instruments, 'No 635 The Electricity at Work Regulations', 1989

/7/ National Fire Protection Agency, 'NFPA 855 Standard for the Installation of Stationary Energy Storage Systems', 2023

/8/ Underwriters Laboratories, 'UL9540A Test Method for Evaluating Thermal Runaway Fire Propagation Battery Energy Storage Systems 4th Edition'; 2022.

/9/ UK Public General Acts, 'Fire and Rescue Services Act', 2004.

/10/ National Fire Protection Agency, 'NFPA 68 Standard on Explosion Protection by Deflagration Ver Systems', 2024

/11/ National Fire Protection Agency, 'NFPA 69 Standard on Explosion Prevention Systems', 2023

/12/ British Standards Institute, 'BS 9999 Fire safety in the design, management and use of buildings', 201

/13/ HM Government, 'The Building Regulations 2010 Fire Safety Approved Document B 2019 edition incorporating 2020 and 2022 amendments – for use in England', 2022

/14/ The Energy Institute (EI), 'Guidance Model Code of Safe Practice Part 19: Fire precautions at petroleum refineries and bulk storage installations' 2023

/15/ UK Statutory instruments '2009 NO. 890 The Waste Batteries and Accumulators Regulations 2009, 2009.

APPENDIX A

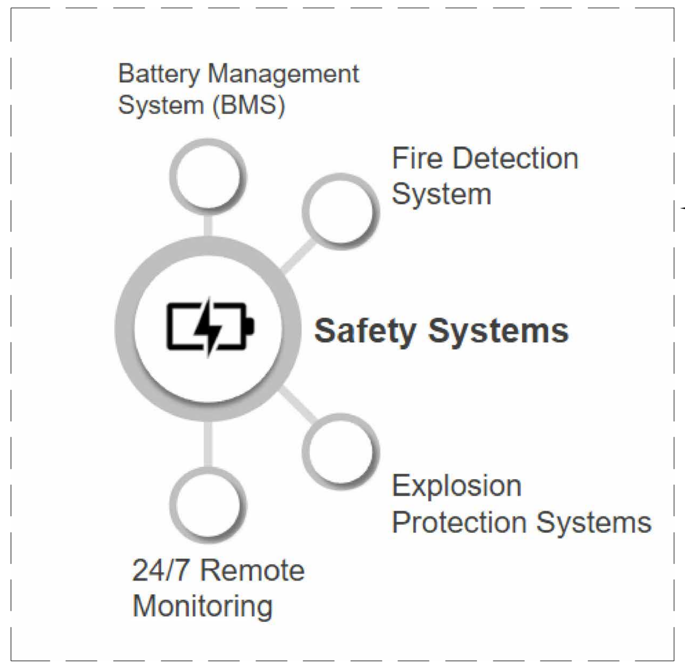
Fire Strategy Layout

A1

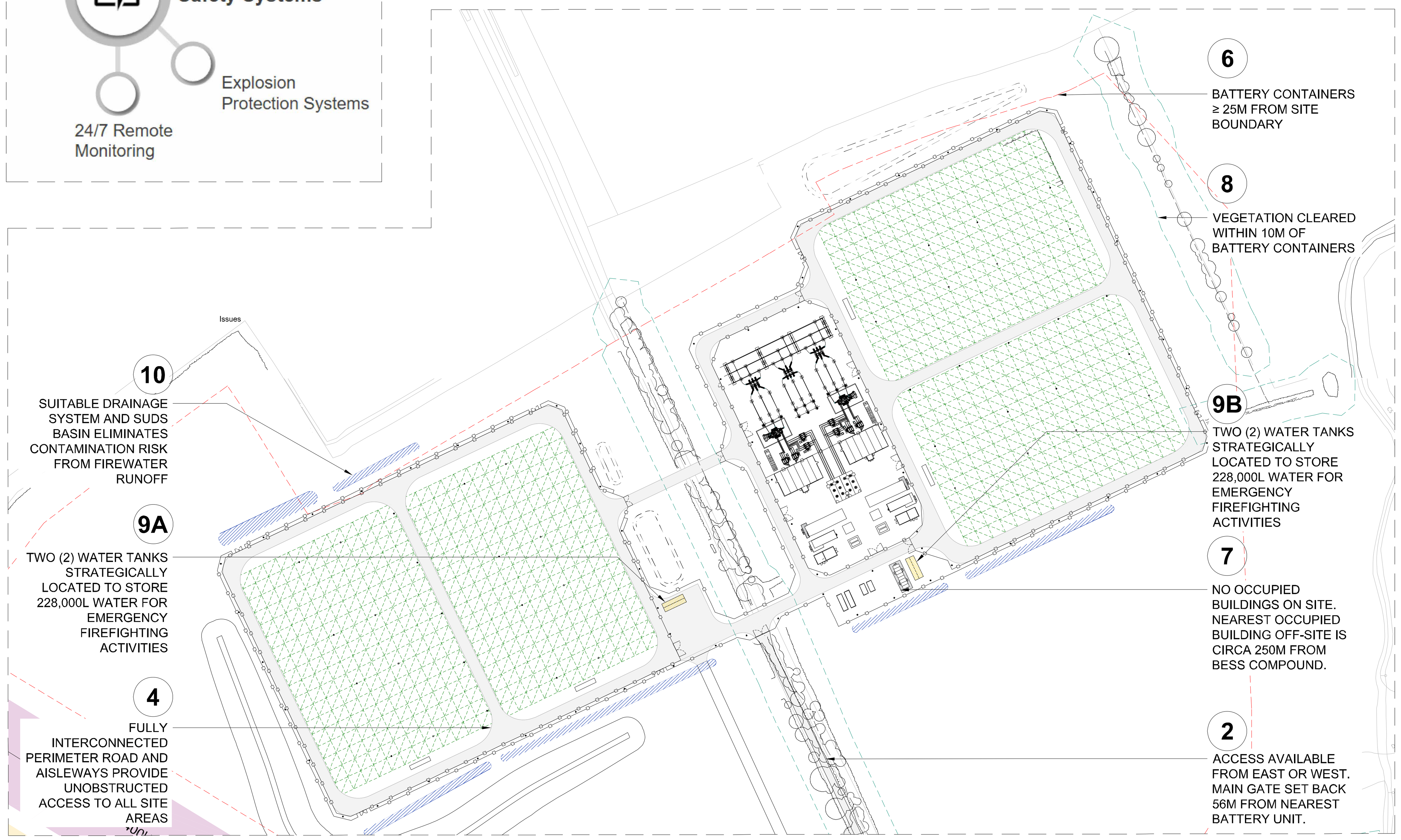
BESS Battery Energy Storage Site Design Guidance for FRS Checklist			
Ref Number	Guidance Description for BESS Energy Storage Design	Complies	Notes
1	Battery storage systems should be designed to prevent fire, including appropriate detection, control, and mitigation measures.	Yes	Battery storage containers will be equipped with industry recognised safety systems including: BMS, Fire Detection System, Fire Suppression System, Explosion Prevention and 24/7 Remote Monitoring.
2	Site should include two access routes to accommodate varying wind conditions.	Yes	Site can be accessed via the main gate entering into the east or west compounds. 'Junction point' is sufficiently clear from the nearest battery container to mitigate risk of harm to first responders from any off-gassing or fire event.
3	Site road networks should provide unobstructed, access to all site areas and suitable to accommodate fire service vehicles	Yes	Fully interconnected roadways permit access to all site areas. Swept pass analysis completed for fire service vehicles.
4	Site should include a perimeter road with suitable passing places	Yes	Perimeter road encircles site, fully interconnected roadways enable multi-vehicle access and manoeuvrability
5	Spacing of battery units should be 6m unless a clear, evidence based, case for the reduction is shown	Yes	Minimum battery container spacing to be based on industry standard UL 9450A and LSFT testing. Exemplar: 2.7m.
6	Spacing of battery units should be 25m from site boundaries	Yes	Battery units will be spaced > 25m from the site boundaries in all locations
7	Spacing of battery units should be 25m from occupied buildings	Yes	No occupied buildings on site. Nearest occupied building off-site is circa 250m from BESS compound.
8	Areas within 10 metres of BESS units should be cleared of combustible vegetation	Yes	Vegetation will be cleared with 10m of all battery units.
9	Firewater supplies equivalent to 1,900 L/min over 2-hours	Yes	Two (2) water tanks will provide 228,000 L emergency firewater supplies capable of 1,900 L/min flow over 2-hours
10	Suitable environmental protection measures should be provided. including systems for containing and managing water runoff.	Yes	Sustainable drainage system (SuDS) and attenuation ponds will be provided with 726,000L and 1,443,000L capacity to capture any contaminated firewater runoff for safe disposal .
N/A	A site-specific risk information pack should be generated and shared with the Fire and Rescue Services (FRS)	Yes	Statkraft will work alongside the FRS to provide all relevant information relating to site layout, risk factors and firefighting arrangements. Site specific information package, risk management plan and emergency response plan shall be prepared in collaboration with and approved by the FRS.
N/A	Risk management plan should be developed which provides advice in relation to potential emergency response implications		
N/A	Emergency response plan should be developed to facilitate effective and safe emergency response		

EAST CLAYDON GREENER GRID PARK HAS BEEN DESIGNED IN CLOSE ACCORDANCE WITH THE RECOMMENDATIONS SET OUT BY THE FIRE CHIEF COUNCIL AND IN PARTICULAR WITH REFERENCE TO THE DOCUMENT 'GRID SCALE BATTERY ENERGY STORAGE SYSTEM PLANNING – GUIDANCE FOR FRS'
THE PURPOSE OF THIS PLAN IS TO DEMONSTRATE THE CONSIDERATIONS AND COMPLIANCE OF THE DESIGN WITH THIS GUIDANCE.

THIS PLAN IS TO BE READ IN CONJUNCTION WITH THE PROPOSED SITE LAYOUT PLAN REF: STA008-PL-01



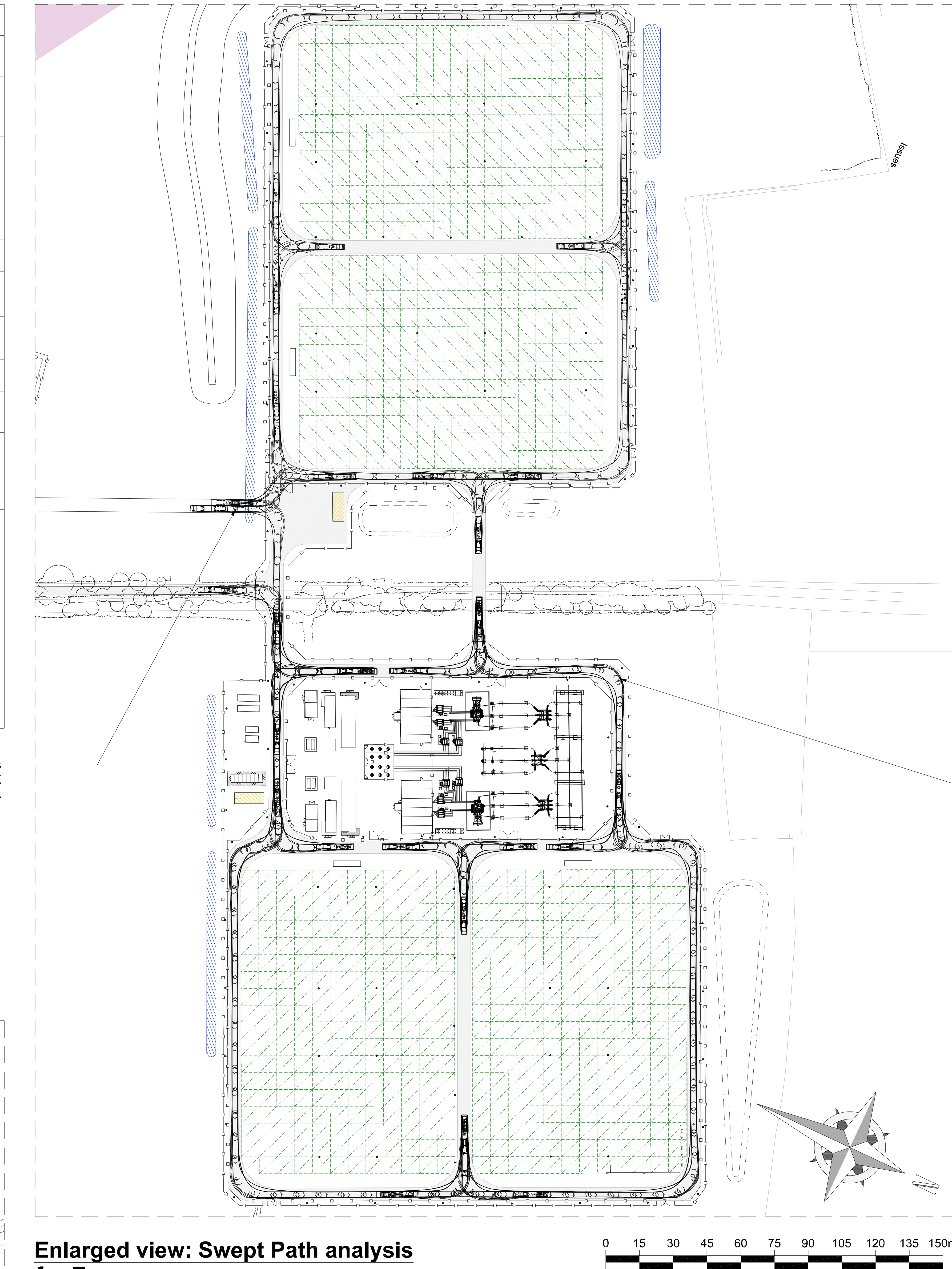
1 TIER 1 BESS SOLUTION EQUIPPED WITH LATEST INDUSTRY STANDARD SAFETY AND PROTECTION SYSTEMS



Fire Strategy Plan

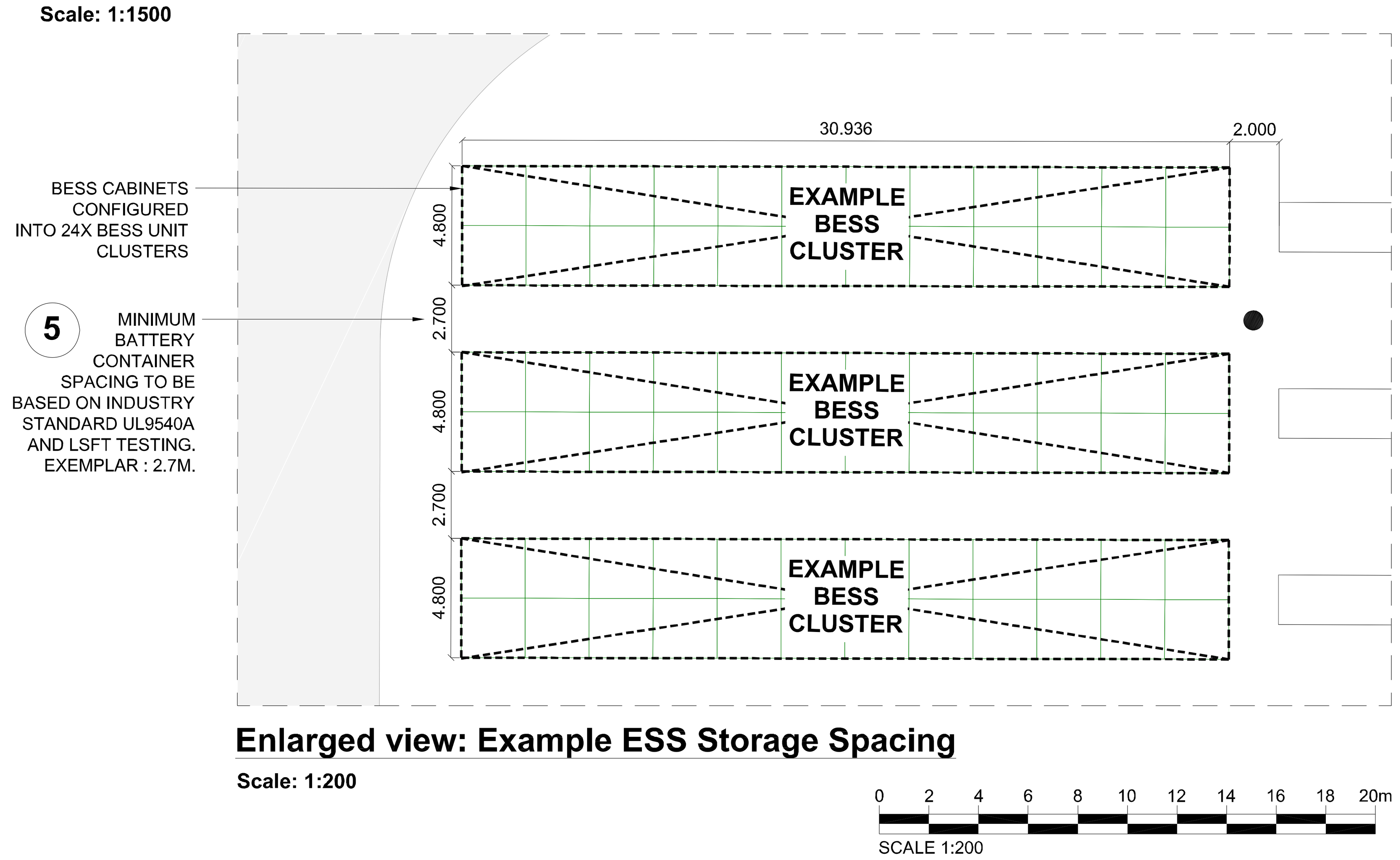
Scale 1:2000

TEMPORARY CONSTRUCTION ACCESS IS SUITABLE FOR FIRE RESCUE SERVICE ACCESS FOR DURATION OF SITE BUILD.



Enlarged view: Swept Path analysis for Emergency access

Scale: 1:1500



Enlarged view: Example ESS Storage Spacing

Scale: 1:200

All dimensions to be confirmed on site prior to commencement of work. Scale for planning purposes only

Revisions:

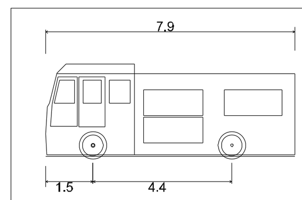
Revision	Date	Revision Notes	Drawn	Inspected
01	13.11.24	First Issue	OB	TM
02	06.12.24	Drainage Revised	OB	TM
03	19.12.24	Titleblock Amended	OB	TM
04	03.01.25	Layout Amended	OB	TM
05	13.02.25	Layout and Titleblock Amended	OB	TM
06	04.03.25	Bund Added, Track and Vehicle Tracking Amended	JTC	RL
07	11.04.25	Layout Amended	OB	RL
08	16.04.25	Layout Amended	OB	RL
09	25.04.25	Table Amended	JM	RL

LEGEND:

25M BATTERY OFFSET

10M OFFSET FROM VEGETATION

3 ACCESS AND TRACKS DESIGNED FOR FIRE RESCUE SERVICE. SWEPT PATH ANALYSIS CONDUCTED USING THE FOLLOWING VEHICLE SPEC:



Pumping Appliance	
Overall Length	7.900m
Overall Width	2.500m
Overall Body Height	3.300m
Min Body Ground Clearance	0.140m
Track Width	2.500m
Lock to lock time	4.00s
Kerb to Kerb Turning Radius	7.750m

Project:

East Claydon Greener Grid Park

Client:

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Status:

PLANNING

Drawing Title:

East Claydon Fire Strategy Plan

Drawn:	Checked:	First Issued:
OB	TM	13.11.2024
Project Code: STA008	Drawing Number: FS-01	
Sheet Size: A1	Scale: A.N	Revision: 09

APPENDIX B

Plume Dispersion Study

EAST CLAYDON GREENER GRID PARK

Statkraft UK LTD

Report no.: 1051146-RMC-IE-03, Rev. 0
Document no.: 2569057
Date: 2025-04-25

Project name:	East Claydon Greener Grid Park	DNV Services UK Limited
Report title:	Plume Dispersion Study	London SHE Risk
Customer:	Statkraft UK LTD, 19th Floor 22 Bishopsgate London EC2N 4BQ United Kingdom	5th Floor Vivo Building Vivo Building 30 Stamford Street SE1 9LQ
Customer contact:	Statkraft UK LTD	London
Date of issue:	2025-04-25	United Kingdom
Project no.:	10511146	Tel: +44 (0)20 3186 4000
Organisation unit:	London SHE Risk	GB 440 60 13 95
Report no.:	1051146-RMC-IE-03, Rev. 0	
Document no.:	2569057	

Applicable contract(s) governing the provision of this Report:

Framework #4600001487, Call Off #4500470611

Objective:

This document is the Plume Dispersion Study for Statkraft UK Ltd's proposed Greener Grid Park in East Claydon, UK.

[redacted]

Callum Davis Junior Consultant	Diyar Yalcin Senior Consultant	Jasjeet Singh Senior Principal Consultant

[redacted]

Joseph Holt
Senior Consultant

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	Can the document be distributed internally within DNV after a specific date? No Yes
☒ Open ☐ DNV Restricted	-- --
☐ DNV Confidential ☐ DNV Secret	☐ ☐

Additional authorised personnel for distribution within DNV:

Keywords BESS, KFX, Plume

Rev. no.	Date	Reason for issue	Prepared by	Verified by	Approved by
A	2025-04-22	Draft issue	C. Davis	D. Yalcin, J. Holt	J. Singh
0	2025-04-25	Formal Issue	C. Davis	D. Yalcin, J. Holt	J. Singh

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Compliance review

DNV's compliance with ethical and industry standards in the separation of DNV's roles is subject to periodic external reviews.

Table of Contents

EXECUTIVE SUMMARY

This report has been commissioned by Statkraft UK LTD ('Statkraft') to accompany a full detailed planning application for the development of a Greener Grid Park in East Claydon, UK. The development will comprise energy storage and grid balancing equipment and associated infrastructure including access, drainage, landscaping and other incidental works.

This report contains the Plume Dispersion Study prepared by DNV for the East Claydon Greener Grid Park. DNV has extensive experience globally assessing the hazards posed by various BESS including accident investigation [Ref. /10/], 2D and 3D consequence modelling and full-scale testing at DNV's facilities in the UK, USA, and Europe.

The evaluation is a consequence-based study utilising Computational Fluid Dynamics (CFD) to assess the potential impact of a battery failure event. It examines the effects on visibility (impairment), toxicity, and heat flux in the surrounding area during a fire. The analysis has evaluated the credible worst-case scenario in terms of consequence for a fire event, where safety systems and barriers to prevent escalation were assumed to have failed, and a reasonable worst-case (full BESS enclosure) fire was modelled. The results are presented in terms of recognised hazardous exposure thresholds. The hazardous threshold is known as Immediately Dangerous to Life and Heath (IDLH) [Ref. /6/].

Four scenarios were modelled that varied the wind speed and direction for the BESS fire. The main findings from the simulations were:

- There is no impact to the Site Entry Junction to the east of the nearest BESS Unit or to the residential buildings to the South-West of the Site for any toxic gas, visibility impairment, or thermal effects, for any wind conditions modelled.
- The 5 m/s wind speed results in the longest impairment distances, the higher wind speed of 10 m/s disperses the flame, shortening its length and diluting the plume.
- The concentrations measured of toxic gases show that the hazards posed by a battery unit fire are confined to the immediate surrounds of the battery unit and within the BESS compound fence line, Hydrogen Fluoride (HF) remains within 3 m and Carbon Monoxide (CO) within 5 m.
- The maximum impairment distance for Site Junction Entrance (located 54 m away from the nearest BESS enclosure) is discussed below:
    - 20 mph stopping distance – 4.7 m impairment distance
    - 40 mph stopping distance – 10.7 m impairment distance
- Heat flux of greater than 12 kW/m^2 is localised to the immediate surroundings of the incident BESS unit for all scenarios.

To add confidence to the results of the study, conservative assumptions have been used due to the uncertainty in the analysis. For example, peak fire loads have been modelled, whereas in reality, the peak fire intensity would only last for 1–2 hours. This would typically be followed by 6–8 hours of lower intensity burning, and then over a day of smouldering. The aim of the analysis was to demonstrate the consequences of the reasonable worst case Battery Unit fire. With this conservatism, no impairment was observed at the site entry junction (54 m from the nearest battery unit) or the nearby residential buildings to the south-west of the site (300 m from the nearest battery unit).

From the study, it can be concluded that there is no impact due to toxic gas, visibility impairment, or heat flux on any sensitive receptor in the proximity of the site due to a reasonable worst-case (full BESS) fire. The effects of the fire are confined to close proximity of BESS enclosures, within the bounds of the security fence. Emergency responders would only require breathing apparatus if located within the immediate area of the BESS enclosure that is on fire due to potential for toxic gas concentrations exceeding IDLH levels at these distances. The residential areas and road targets are sufficiently far away from the BESS as to not be impaired by any of the simulated fires in terms of heat flux, visibility or toxicity.

GLOSSARY OF TERMS

Term	Description
BESS	Battery Energy Storage System
CFD	Computational Fluid Dynamics
CO	Carbon Monoxide
HF	Hydrogen Fluoride
HVAC	Heating, Ventilation and Air Conditioning
IDLH	Immediately Dangerous to Life or Health
KFX	Kameleon FireEx
NFPA	National Fire Protection Association

DEFINITIONS

Term	Description
Battery Cell	The basic functional unit of a battery unit contains an assembly of electrodes, electrol separators, and terminals in a container. It is a source of electrical energy by conversion of chemical energy.
Battery Cluster	Battery units are designed to be installed and connected in rows (often referre clusters).
Battery Module	A battery module is comprised of many cells and can be equipped with venting fans a communication connections for remote monitoring and switch off in response to abnorr cell behaviour that indicates a potential fault.
Battery Unit	The main functional unit of a battery energy storage system. The battery unit ca multiple racks of battery modules and may include a Battery Management System (BI controller. The battery unit is housed in a rigid metal enclosure which provides protection from weather, animal and mechanical damage.
BESS	Battery Energy Storage System, describes all equipment, hardware and software that makes up a working system.
BESS Site	The Battery Clusters are installed and connected to transformers and other equipmer form a BESS Site.

1 INTRODUCTION

1.1 Proposed Development

On behalf of Statkraft UK LTD (‘Statkraft’), a full detailed planning has been submitted for the development of a Greener Grid Park, comprising a Battery Energy Storage System (BESS), synchronous compensators, associated infrastructure, landscaping, and access in East Claydon UK. The Greener Grid Park is located on Land North of East Claydon Road, RG24 7AL within the local authority of Buckinghamshire Council.

The proposed layout is presented in Figure 1-1 below.

Figure 1-1: East Claydon Greener Grid Park – Site Layout Plan

1.2 Document Scope

This document presents the Plume Dispersion Study prepared by DNV for the East Claydon Greener Grid Park. The Plume Dispersion Study is a consequence-based study using Computational Fluid Dynamics (CFD) to evaluate potential impact for a battery failure event and assess the impact of smoke and toxic gas on the neighbouring area in the event of a battery fire. The analysis evaluates the reasonable worst-case scenario in terms of consequence for a fire event.

2 CFD Model

The 3D CFD modelled software Kameleon FireEx (KFX) has been used for the fire simulations [Ref. /1/]. KFX is capable of calculating heavy and light gas dispersion and hydrocarbon fires in connection with practical fire safety studies. It can handle liquid pool fires as well as gas jet and fires, in enclosures and in open air. It has been tested against experimental data ranging from small-scale laboratory flames to large-scale jet and pool fires. KFX can be used for most safety related analysis related to gas dispersion and fire.

2.1 Site Layout Model

Satellite imagery of the proposed development area with the site plan superimposed is shown in Figure 2-1 (Including distances to targets) [Ref. /11/].

Figure 2-2 shows the site in detail. The two highlighted detailed BESS (Purple) have been used for simulations, due to their location being closest to the targets. The geometry model of the site is configured according to this site layout. Terrain is not considered in the modelling, which is conservative as the effective distance between BESS and target is reduced.

Figure 2-1: East Claydon Greener Grid Park Site Model with Target Distances

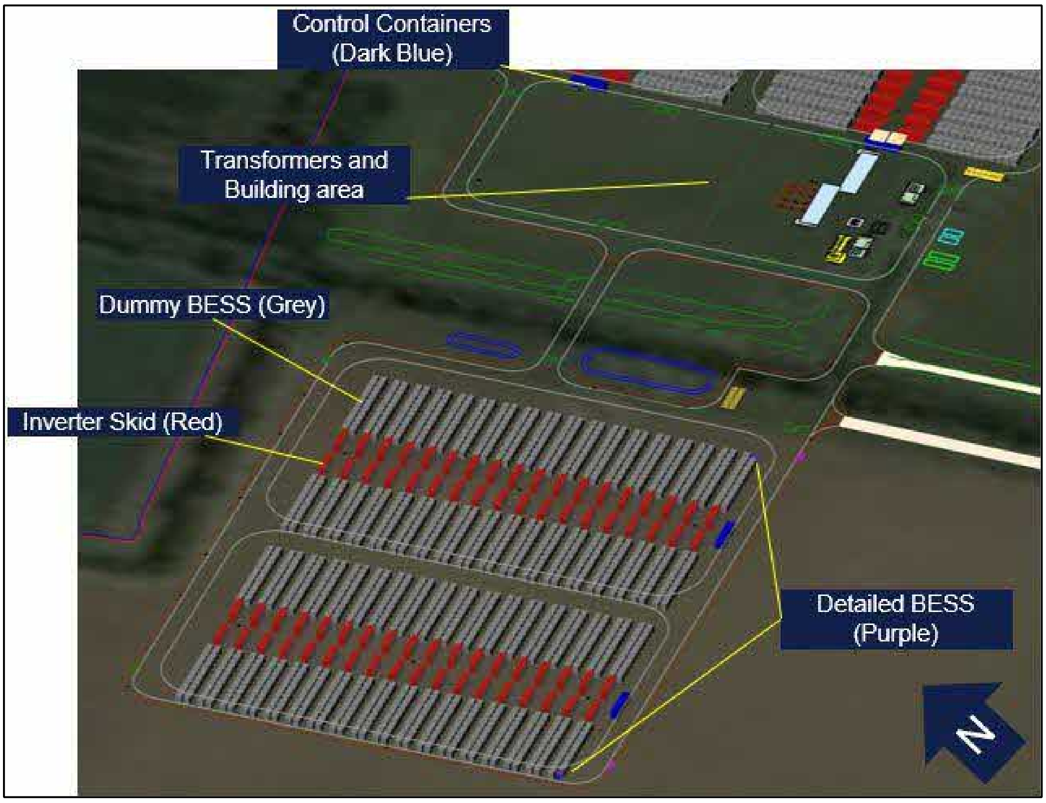

Figure 2-2: East Claydon Greener Grid Park Detailed Site Model

2.2 BESS Geometry

The BESS geometry and site were built in the 3D modelling software Rhinoceros [Ref. /2/]. Figure 2-3 shows the 3D geometrical representation of the BESS Unit (detailed BESS geometry was not available for the site, therefore a representative BESS Unit was built based on the site specifications). The top figure shows the outside of the BESS Unit, the bottom figure shows the BESS Unit with front walls removed. The BESS contains 2 Racks in a 1 × 2 arrangement and each rack measures 0.9 m × 1.05 m × 2.1 m. Each Battery Unit measures 2.45 m × 2.15 m × 2.6 m. Each Battery Unit has 2 deflagration panels, each located above a rack, measuring 0.65 m x 1.85 m. Each Battery Unit also has a forward-facing door with a built-in window panel, measuring 1.35 m × 1.7 m. The deflagration panels are assumed to be fully opened (100% open), as the overpressure generated by the explosion preceding the fire would exceed the panels opening pressure. The door window panel is assumed to be 20% open, a conservative assumption which accounts for the effects of any damage caused by the initial explosion overpressure on the door.

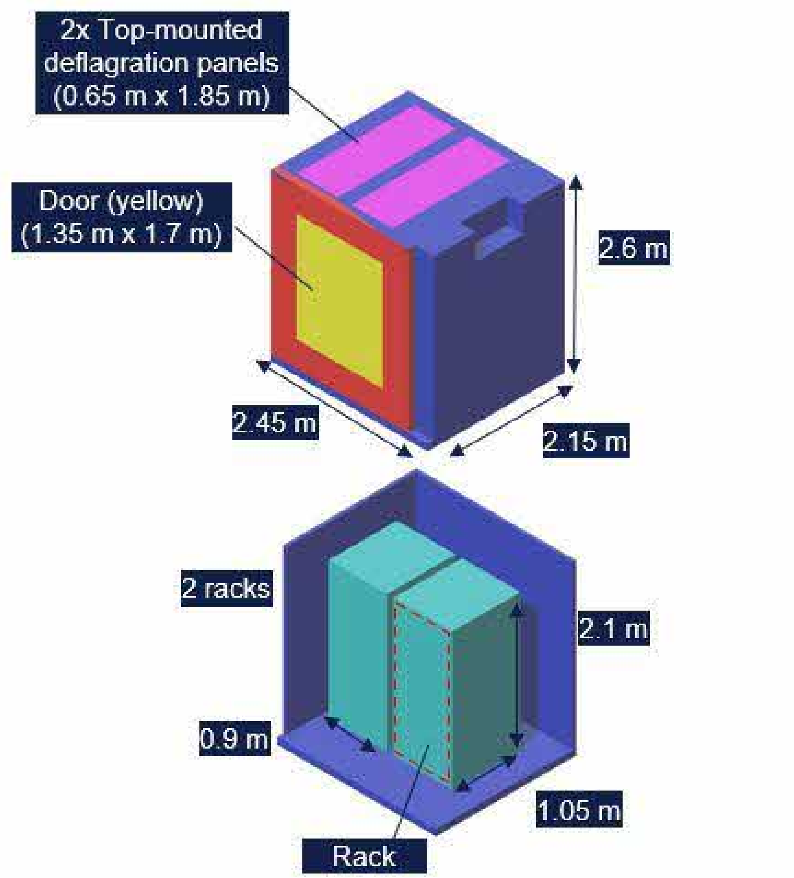

Figure 2-3: 3D Model (Top – BESS from outside; Bottom – Front walls removed)

2.3 Input and Assumptions

A battery failure event is caused by a fault in a battery cell which can lead to thermal runaway in the cell. During thermal runaway, off-gas is produced and released from the cell. Off-gas is a flammable mixture of gases consisting mainly of hydrogen, some hydrocarbons, carbon dioxide and other gases (including hydrogen fluoride) at lower percentages. During the release, it is possible for a cascading failure of multiple cells in a module, or the entire BESS. The initial fuel source of the fire is the off-gas released by the cells. After some time, the other combustible items in the BESS are consumed in the fire, these are mainly plastic items.

The following safety systems and CFD input data have been acknowledged for the basis of the study assumptions. Test data was not available for the site due to the BESS product not being selected at that project stage. Instead, the assumptions are based on aggregated test data from BESS of similar size and capacity to the BESS proposed for the development.

Propagation between cells:

No module level test report was available. Previous UL 9540A module level test reports have indicated it is possible to have cell to cell propagation within a module.

Assumption: It is assumed that all cells within a module can fail. This is a conservative assumption assuming an escalation of any cell failure.

Propagation between modules:

No unit level test report was available. Previous UL 9540A unit level test reports have indicated module to module propagation is unlikely, however full-scale fire tests have shown this was possible.

Assumption: It is assumed that in the event of thermal runaway in the Battery Unit that module-to-module propagation will occur, and that all modules of the Battery Unit could be engaged in the fire. This is a conservative assumption assuming an escalation between modules.

Propagation between Battery Units:

Full-scale fire tests show that Battery Unit to Battery Unit propagation is unlikely with appropriate spacing.

Assumption: It is assumed that in the event of a fire in a battery unit it does not propagate to the neighbouring Battery Units, limiting the failure to the Battery Unit of origin. This assumption will be supported by large scale fire testing, such as expected for all new BESS.

Ventilation system:

The Battery Unit would have a HVAC system for cooling the internal components.

Assumption: The HVAC will be shut down in the event of a fire. This aligns with industry best practices to prevent the ingestion of hot gases, which could exacerbate the fire.

Gas composition and properties:

Gas composition was derived from previous UL 9540A test data.

Assumption: The combustion of plastic items in the Battery Unit has also been considered with additional propane added to the off-gas composition. Propane has similar yields of CO and CO_2 to polypropylene plastic which is typical for battery casings [Ref. /3/]. The gas composition accounting for the plastics can be seen in Table 2-1.

Table 2-1: Gas Composition Data

Gas		Adjusted for Plastic (%)
Hydrogen	H_2	41
Carbon Dioxide	CO_2	23
Carbon Monoxide	CO	8
Propane	C_3H_8	17
Ethane	C_2H_6	1
Ethylene	C_2H_4	4
Methane	CH_4	6

Note: Hydrogen Fluoride is assumed to be present in off-gas with a concentration of 1000 ppm. See below for further detail.

Off-gas release rate (mass/time):

Off-gas release rate was averaged from previous test data where cells are assumed to fail in a module and then propagate to adjacent cells and adjacent modules.

<u>Assumption</u>: The peak release rate is 0.134 kg/s (134 g/s) for a BESS Unit and is aggregated from data for previous BESS of similar size and capacity to the BESS proposed for the site.

Toxic gas content in battery unit fire:

Toxic gases are produced in a battery fire, the most dangerous of which is hydrogen fluoride. While other toxic gases are produced, depending on the battery chemistry, hydrogen fluoride is the most abundant and has the lowest threshold, meaning it is the most restrictive.

<u>Assumption</u>: Based on DNV's experience and testing [Ref. /4/], around 0.1% of the combustion product is hydrogen fluoride. This equates to around 1000 ppm at source. It is therefore assumed that there is 0.1% of hydrogen fluoride in the combustion product.

2.4 Simulations

The inputs and assumptions made in the previous section are conservative and define a reasonable worst-case fire. This fire was modelled with varying wind speeds and directions to obtain the maximum impact due to the smoke plume at the different targets of interest.

A total of four scenarios have been identified to model the BESS fires as shown in Table 2-2. Two scenarios target the Site Entry Junction to the East of the site, and the other two scenarios target the closest residence to the South-West. A wind speed of 5 m/s (18 km/h) was used as this is the annual average for the closest weather station (the meteorological data considered is 4 km from the site) [Ref. /5/], and 8.5 m/s (36 km/h) was used as a conservatively higher wind speed. This wind speed represents the 90th percentile wind conditions averaged over a year. Lower and higher wind speeds are chosen to cover the range of conditions, where lower wind speeds may not sufficiently dilute the plumes, but higher wind speeds may have more potential to elongate and bend the plumes.

The Site Junction Entrance is 54 m East from the nearest BESS. Wind blowing from the West (W) represents the worst-case scenario for this target as the smoke plume will be blown towards it. Wind blowing from the West accounts for 11% of the average annual wind probability. The closest residence is 300 m South-West from the nearest BESS. Wind blowing from the North-East (NE) represents the worst-case scenario for this target and accounts for 9% of the average annual wind probability. The predominant wind direction at the site is from the from the South and accounts for 21% of the average annual wind probability.

Table 2-2: Simulation Scenarios

Simulation ID	Fire Size	Target	Wind Direction (from)	Wind Speed (m/s)
101	Battery Unit	Site Junction	W	5
102			W	8.5
103		Residence South-West of Site	NE	5
104			NE	8.5

2.5 Impairment Thresholds

The following thresholds are defined for impairment to people and are based on industry best practise [Ref. /6/, /7/, /8/, and /9/]. The simulation results will be compared to the below criteria to determine the severity of th consequences on the identified targets.

Note that, for the purposes of this report, impairment refers to the severe degradation or loss of physical or cognitive function resulting from exposure to smoke, toxic gases, or heat. This may include disorientation, reduced mobility, unconsciousness, or distress, which can significantly hinder a person's ability to escape and may pose a direct risk to life. The maximum impairment distance refers to the boundary within which this may occur.

2.5.1 Safe Exposure Limits

Exposure to hazardous substances can lead to adverse health effects. This is dependent on the concentration of the gas and the exposure time. One measure for exposure limits to toxic gases is the Immediately Dangerous to Life or Health (IDLH) values [Ref. /6/]. This was developed to enable the safe escape of workers if their breathing apparatus failed in a contaminated environment in 30 minutes, to provide maximum worker safety.

In this study, the IDLH values are used to indicate that there is an immediate danger to health without a breathing apparatus. The following hazardous substances and their IDLH limits are provided below.

Hydrogen Fluoride (HF):

IDLH level is 30 ppm.

Carbon monoxide (CO):

IDLH level is 1,200 ppm.

2.5.2 Visibility Impairment

Reduced visibility due to smoke produced in a fire can prevent the safe escape of personnel. A visibility of 10 m is typically considered acceptable for personnel to escape from a fire.

Reduced visibility is also a hazard for vehicles driving on nearby roads that would have reduced visibility if the smoke plume obstructed the road. This is potentially dangerous as they would have a reduced effective stopping distance. Of particular importance is the impact of low visibility on any emergency vehicles attempting to enter the site. The stopping distances at 40 mph and 20 mph are 36 m and 12 m, respectively [Ref. /9/]. Any reduction on these visibilities would be considered as impaired. As such, 36 m and 12 m have been set as impairment of the roads for this study, with 12 m being the threshold of interest and results for 36 m being provided as a conservative comparison.

2.5.3 Heat Flux

The heat flux (thermal radiation) plots will be shown for the thresholds below:

2 kW/m^2 Minimum to cause pain after 60 s.

12 kW/m^2 Piloted ignition of wood [Ref. /7/] Reference for extreme pain within 20 s. Fatal if no escape (70% lethality outdoors) is 12.5kW/m^2, this will conservatively be lowered to 12 kW/m^2. This is the threshold of interest.

25 kW/m^2 Unprotected steel will reach thermal stress temperatures than can cause failure.

35 kW/m^2 Immediate fatality (100% lethality). Reference for structural time to failure of steel plate in 20 minutes is 37.5 kW/m^2 [Ref. /8/], this will conservatively be lowered to 35 kW/m^2 for this study.

250 kW/m^2 Reference for structural time to failure in 5-10 minutes.

3 RESULTS

The results evaluate the potential impact of a Battery Unit failure and assess the impact of thermal effects and smoke on the neighboring area in the event of a fire.

Contour plots for all simulations are presented in Appendix A for visibility impairment, toxicity and heat flux. The following observations are made from the results:

- There is no impact to the site junction (to the West of the nearest BESS unit) or the residence (to the South-West of the site) for any toxic gas, visibility impairment or heat flux for any wind conditions modelled.
- By inference, other nearby residential buildings would not be impacted by a battery fire, as they are located at greater distances (>300 m) from the BESS site than either target explicitly modelled.
- The wind speed of 5 m/s produces the largest distance to impairment compared to the higher wind speed of 8.5 m/s. This is due to the flame being dispersed by the higher wind speeds, which reduces the flame length and dilutes the smoke plume. The lower wind speed by contrast is less turbulent, disrupting the flame less and the smoke plume travels for a greater distance.
- The concentrations measured of toxic gases show that the hazards posed by a battery unit fire are confined to the immediate surrounds of the battery unit, HF remaining within 3 m and CO within 5 m. This is due to the relatively high concentrations of smoke required to reach the IDLH thresholds.
- The maximum impairment distance for Site Junction (located 54 m away) is discussed below:
  - 20 mph stopping distance – 4.7 m impairment distance
  - 40 mph stopping distance – 10.7 m impairment distance
- Heat flux of greater than 12 kW/m^2 is localised to the BESS unit for all scenarios.
- For the targets identified in the study to be impacted by a battery fire, a significant number of Battery Units would need to simultaneously fail. However, the full-scale fire test showed that battery unit to battery unit escalation is unlikely when the separation distance is in line with industry best practices (NFPA 855).

To add confidence to the results of the study, conservative assumptions have been used due to the uncertainty in the analysis. For example, peak fire loads have been modelled, whereas in reality, the peak fire intensity would only last for 1–2 hours. This would typically be followed by 6–8 hours of lower intensity burning, and then over a day of smouldering. The aim of the analysis was to demonstrate the consequences of the reasonable worst case Battery Unit fire. With this conservatism, no impairment was observed of the nearest road target (Site Junction, 54 m from the nearest battery unit) or the nearest residence (South-West of the site, 300 m from the nearest battery unit).

4 CONCLUSIONS

This document contains the Plume Dispersion Study for Statkraft's proposed Greener Grid Park Extension, in East Claydon, UK. From the study, it can be concluded that there is no impact due to toxic gas, visibility impairment or heat flux on any target in the proximity of the site due to a reasonable worst-case (full BESS) fire. The effects of the fire are restricted to the proximity of the BESS. Emergency responders would only require breathing apparatus if located within the immediate area of the BESS that is on fire due to toxic gases potentially exceeding IDLH values at these distances. The residential areas and road targets are sufficiently far away from the BESS as to not be impaired by any of the simulated fires in terms of heat flux, visibility or toxicity.

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APPENDIX A
CFD Plots

Figure A 1 to Figure A 16 show the contour plots for hydrogen fluoride, carbon monoxide, visibility distance, and heat flux for all simulations with targets and wind directions labelled.

Figure A 1: Case 101 – Hydrogen Fluoride Plot with Wind from W at 5 m/s

Figure A 2: Case 102 – Hydrogen Fluoride Plot with Wind from W at 8.5 m/s

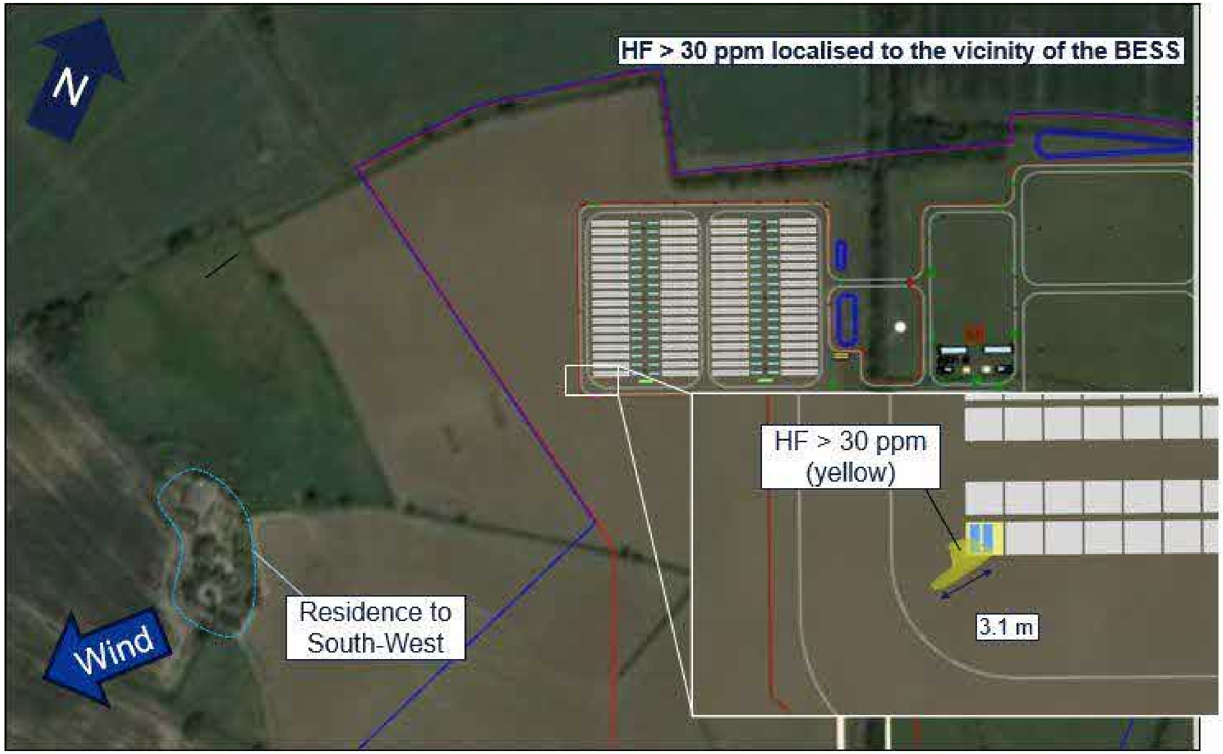

Figure A 3: Case 103 – Hydrogen Fluoride Plot with Wind from NE at 5 m/s

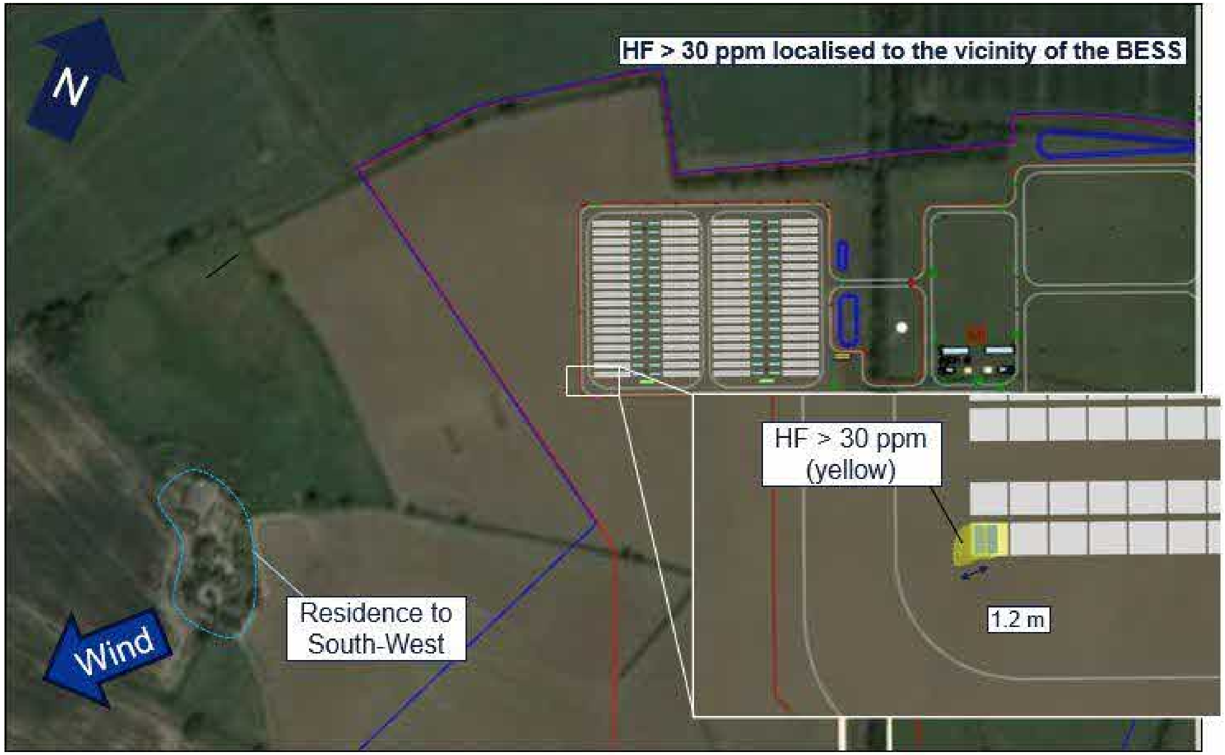

Figure A 4: Case 104 – Hydrogen Fluoride Plot with Wind from NE at 8.5 m/s

Figure A 5: Case 101 – Carbon Monoxide Plot with Wind from W at 5 m/s

Figure A 6: Case 102 – Carbon Monoxide Plot with Wind from W at 8.5 m/s

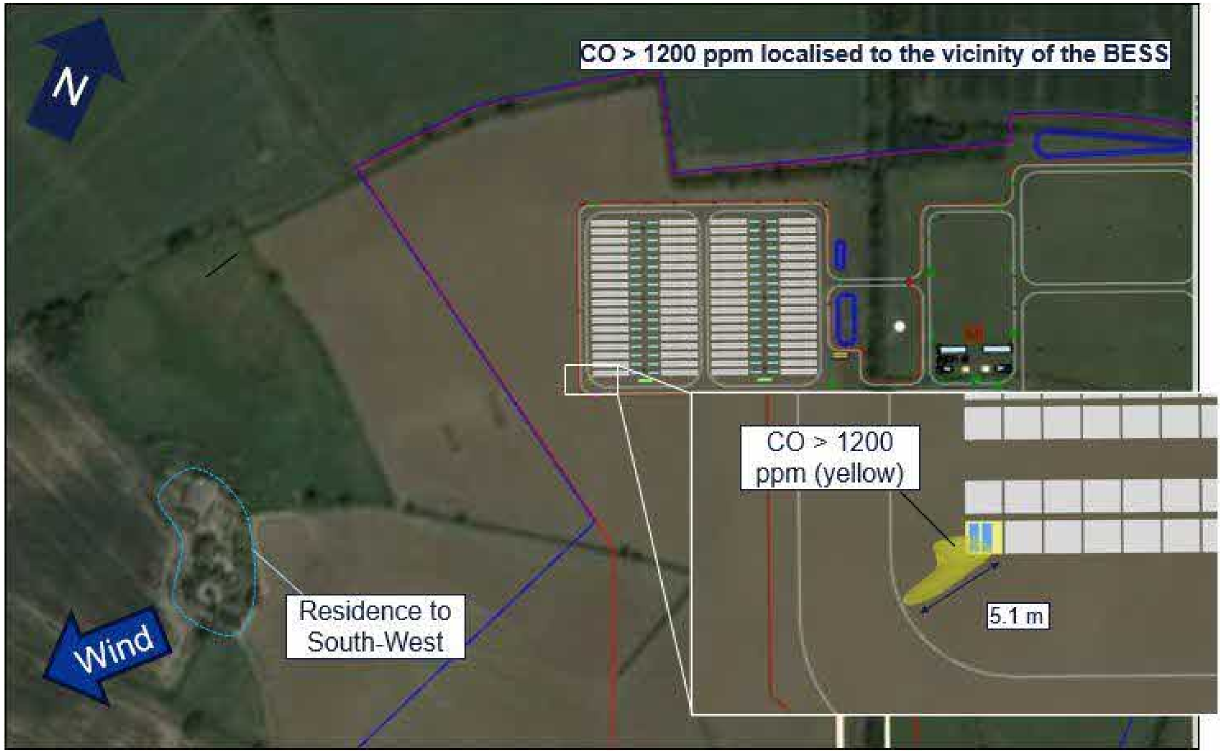

Figure A 7: Case 103 – Carbon Monoxide Plot with Wind from NE at 5 m/s

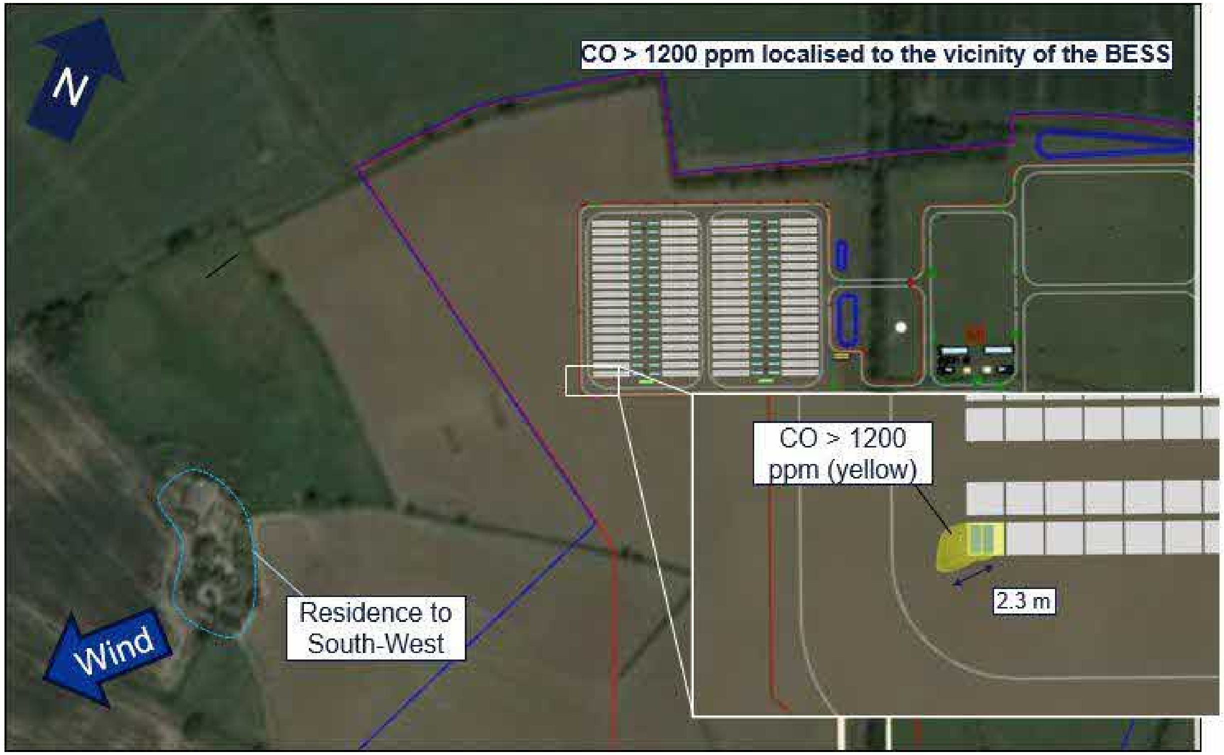

Figure A 8: Case 104 – Carbon Monoxide Plot with Wind from NE at 8.5 m/s

Figure A 9: Case 101 – Heat Flux Plot with Wind from W at 5 m/s

Figure A 10: Case 102 – Heat Flux Plot with Wind from W at 8.5 m/s

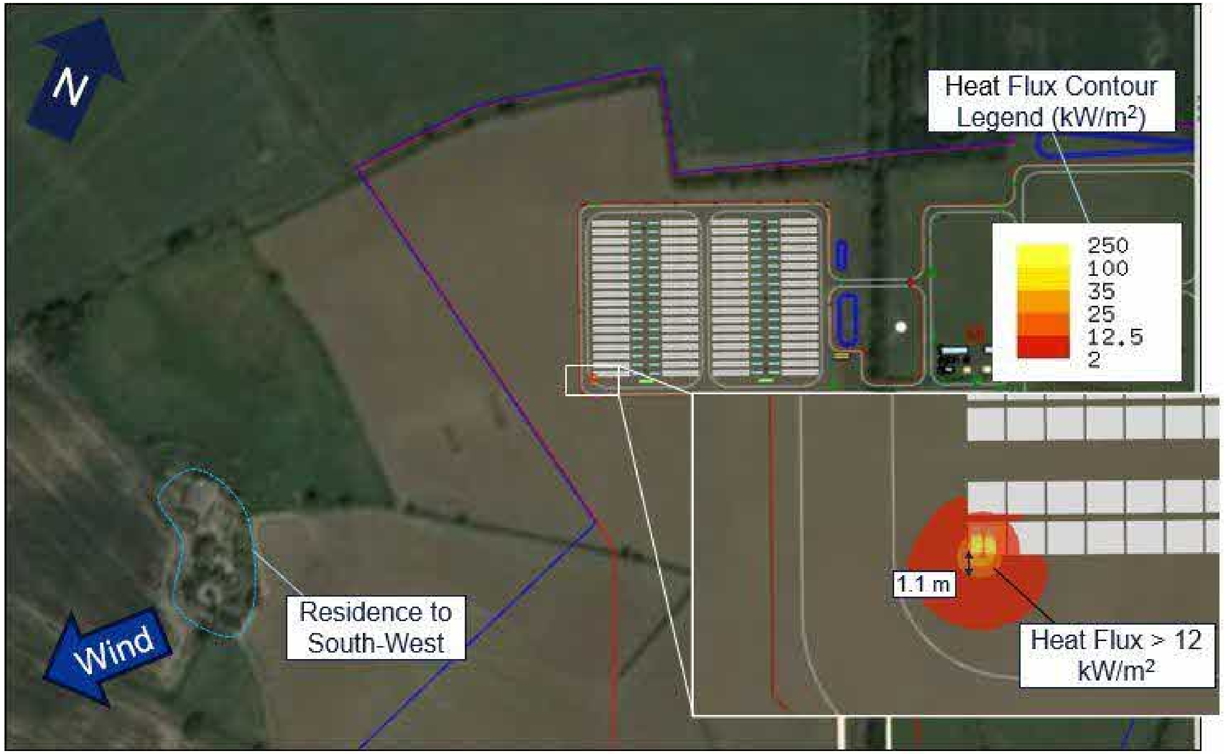

Figure A 11: Case 103 – Heat Flux Plot with Wind from NE at 5 m/s

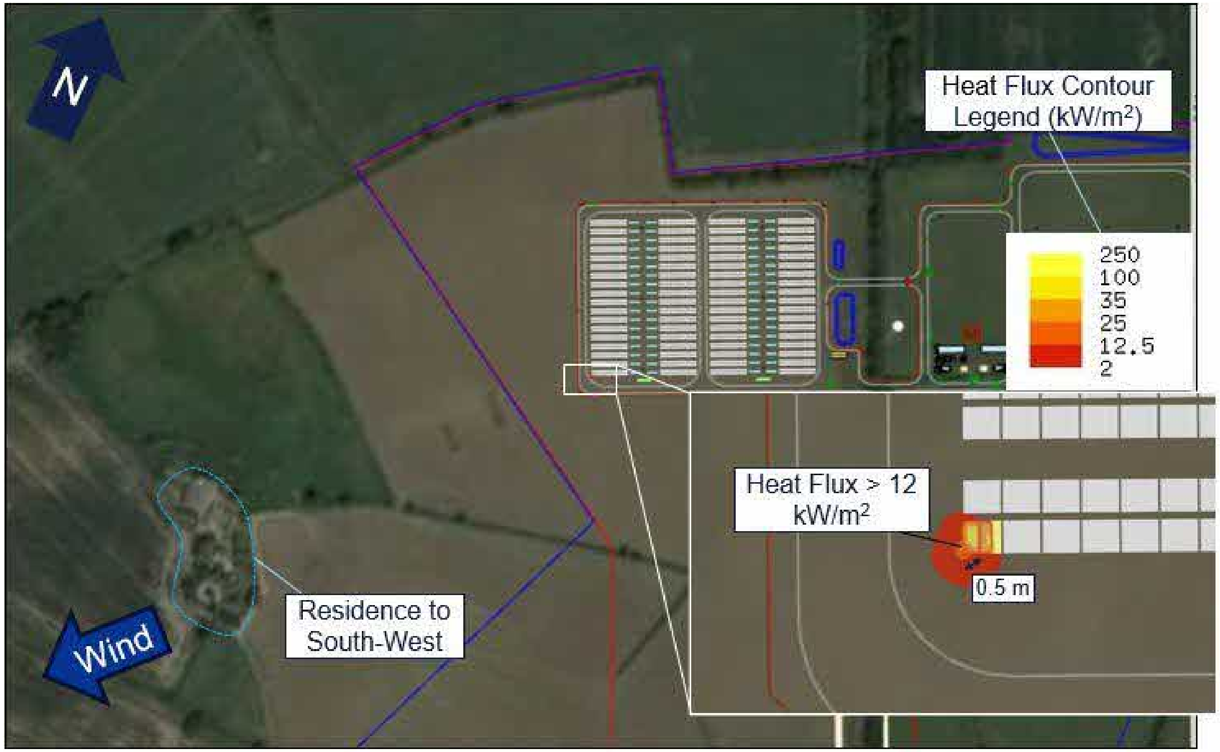

Figure A 12: Case 104 – Heat Flux Plot with Wind from NE at 8.5 m/s

Figure A 13: Case 101 – Visibility Plot with Wind from W at 5 m/s

Figure A 14: Case 102 – Visibility Plot with Wind from W at 8.5 m/s

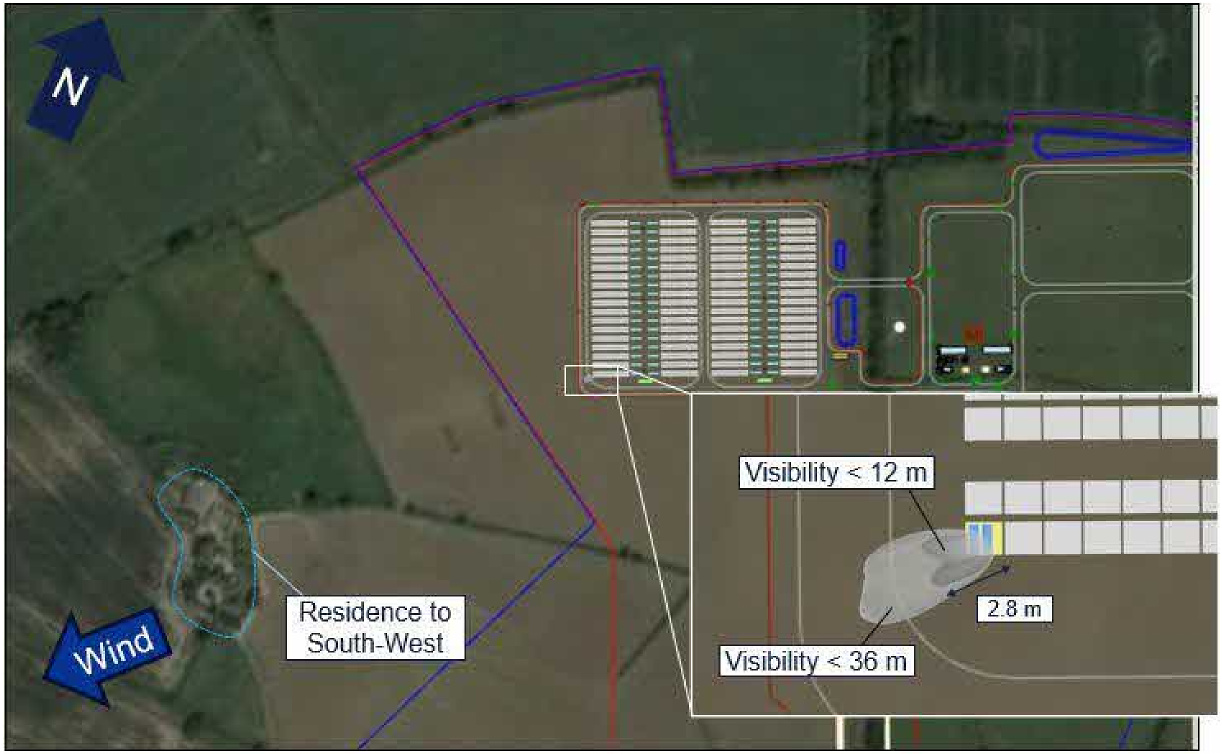

Figure A 15: Case 103 – Visibility Plot with Wind from NE at 5 m/s

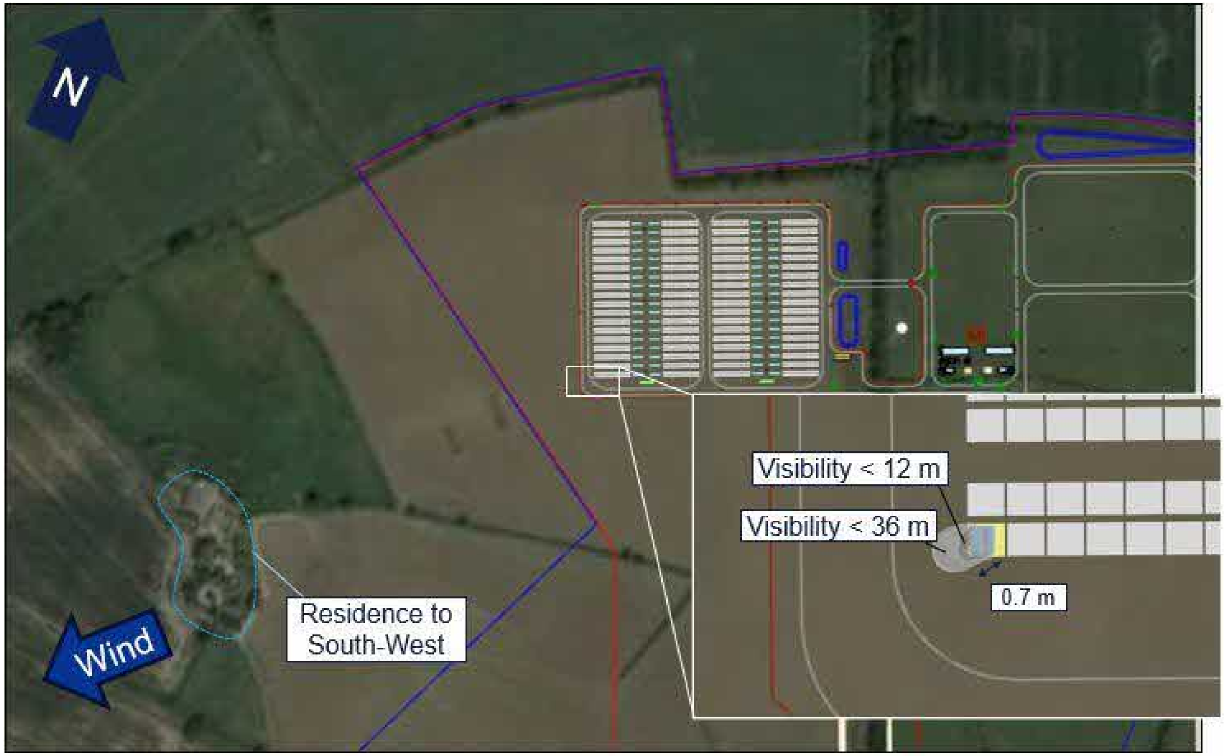

Figure A 16: Case 104 – Visibility Plot with Wind from NE at 8.5 m/s

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Driven by its purpose, to safeguard life, property, and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today and is a trusted voice for many of the world's most successful and forward-thinking companies.

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