Abbott Risk Consulting Limited

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Outline Battery Safety Management Plan - Land North of Bronwylfa Road

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Prepared for:

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Executive Summary

This Outline Battery Safety Management Plan (OBSMP) has been prepared for Innova Renewables Developments to support the proposed development of an Energy Storage System (ESS) at Land north of Bronwylfa Road, Rhostyllen, Wrexham. The aim of the OBSMP, at this planning phase of the programme, is to define the proposed safety strategy, requirements, and processes necessary to meet derived safety objectives and to set a level of safety performance that the installation is to be measured against. These standards are derived from three main sources:

1. Planning Practice Guidance (PPG) for Renewable and Low Carbon Energies.

2. Fire and Rescue requirements detailed in the National Fire Chiefs Council (NFCC) Report Grid Scale Battery Energy Storage System Planning – Guidance for FRS.

3. FM Global Loss and Prevention Datasheet 5-33 (as cited in the NFCC Report).

It also provides the basis for the safety management processes and procedures required to satisfy the identified safety requirements for an ESS system capability.

The preliminary risk identification and analysis, based on like for like energy storage systems of this type, namely Lithium Ferrous Phosphate (LFP) Battery chemistry, has determined the likely causes and risk associated with ESS technology of this type and enabled the initial identification of potential control measures that when implemented will reduce the level of risk posed to an acceptable level.

As far as reasonably practicable, and for this planning stage of this ESS installation, the currently foreseeable risks associated with the technology proposed have been identified. These will form the initial safety foundation going forwards and be actively managed as the project and installation matures. At this juncture of the programme the selection of the specific manufacture of ESS to be positioned at the site has yet to be decided.

The design, development, and manufacture of the ESS requires the development and maintenance of high standards in respect of safety and operational sustainability. It will be the responsibility of all personnel involved in the future development of the proposed undertaking to strive to reduce the potential for accidents to the lowest practicable level by being a ‘risk aware’ and promoting a supportive safety and environmental culture at all stages of the development. This OBSMP is the starting point from which the project will progress and demonstrates a commitment to safety from the outset of the project and throughout.

Abbreviations

ALARP	As Low As Reasonably Practicable
ARC	Abbott Risk Consulting Ltd
ESS	Energy Storage System
BMS	Battery Management System
BoM	Bill of Materials
CID	Current Interrupt Device
DBSMP	Detailed Battery Safety Management Plan
EM	Electro-Magnetic
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
FDSS	Fire Detection and Suppression System
HSAWA	Health and Safety at Work Act
HSE	Health and Safety Executive
HV	High Voltage
IEC	International Electrotechnical Commission
NFCC	National Fire Chiefs Council
NFPA	National Fire Prevention Association
OBSMP	Outline Battery Safety Management Plan
OC	Over Current
OV	Over Voltage
PPG	Planning Practice Guidance
PTC	Positive Thermal Coefficient
REACH	Registration, Evaluation, Authorisation & Restriction of Chemicals Regulations
RFQ	Request for Quotation
RoHS	Restriction of Hazardous Substances Directive
S&E	Safety and Environmental
SIL	Safety Integrity Level
SME	Subject Matter Expert
SMS	Safety Management System
SQEP	Suitably Qualified and Experienced Person
SRD	System Requirements Document
SWG	Safety Working Group
UK	United Kingdom
UL	Underwriters Laboratory
US	United States
UV	Under-Voltage

Contents

1.0 Introduction

This OBSMP has been developed by Abbott Risk Consulting Ltd (ARC) in the role of the Safety Subject Matter Expert (SME) and aims to identify the safety requirements (and any additional derived safety requirements) such that the proposed Energy Storage System (ESS) development can be assessed against a common benchmark, criteria set and safety targets.

This OBSMP has been developed at this early planning stage to identify and assess the potential risks associated with the ESS design, installation, and operating capability, and to provide a robust safety argument, supported by evidence, prior to full commissioning. It is proposed that the safety programme will develop following three phases reflecting the maturity of the programme:

1. **OBSMP (Planning)** – this report. The OBSMP informs on how safety management is to be conducted by:

    a. Outlining the processes, procedures and means by which the ESS safety management is to be conducted, implemented, and assessed, such that the ESS design and development, initial construction, and operation safety performance can be conducted with an acceptable level of residual risk.

    b. Providing the criteria and targets against which the installation will be assessed.

    c. Providing the initial compliance status against key requirements contained in the PPG (and referenced guidance).

    d. Identifying the common risks associated with ESS installations of this type.

2. **Detailed Battery Safety Management Plan (DBSMP) (Installation and Implementation)** – The DBSMP builds upon the OBSMP and reflects the maturity of the project and availability of detailed information and evidence to support safety claims, the DBSMP. The DBSMP will:

    a. Assess the level of residual risk posed by the ESS design to individuals (both those directly involved in the operation and 3rd parties), the immediate environment, the asset (ESS), interfacing / interdependent assets and property / equipment that could be affected by the operation of the ESS (noise, radiated emissions etc.).

    b. Contain the Emergency Response and Contingency Plans.

    c. Reference out to supporting evidence.

    d. Detail any recommendations for improvement.

3. **Site Safety Audit (Operation)** – The Site Safety Audit validates the ESS installation against the safety requirements and identified control measures in the DBSMP. It also validates that the safety processes and procedures required to ensure that the risk posed by the design remains within the bounds established have been implemented i.e., training, provision of Personal Protective Equipment, calibration, scheduled maintenance etc.

2.0 Background

ARC have conducted an initial risk identification of the ESS capability as a conceptual model, ex-committee. This analysis has provided the necessary foundation for the identification of potential hazards and the development of a formalised Hazard Log, ARC-1206-001-R2 [Ref. 1], which contains:

1. A consolidated list of hazards and hazard descriptions;
2. Associated potential causes driving the hazards with linkage to the relevant hazard(s);
3. Design controls in place that reduce the causes;
4. Identification of the potential outcomes or consequence from the hazards;
5. Identification and linkage to mitigating factors that could reduce the severity or frequency of occurrence of the outcomes (consequences); and
6. Identification of additional design controls and mitigating factors that will further reduce the frequency of hazard or consequence frequencies.

3.0 OBSMP Purpose and Boundaries

3.1 Aim

The aim of this report is to outline the safety management approach that will be adopted. Furthermore, the overall ESS safety aim is that the levels of risk of accident, death or injury to personnel or other parties, and to the environment due to ESS activities are to be broadly acceptable or tolerable and As Low As Reasonably Practicable (ALARP), in accordance with the Health and Safety Executive (HSE) Reducing Risk, Protecting People [Ref. 2].

3.2 Scope

The scope of this report for the proposed ESS development and capability covers the physical and functional aspects of the equipment, Figure 3-1 illustrates the preliminary layout for the ESS installation. The ESS safety management will cover design, validation, siting, operation, removal from site (post use), recycling and disposal. It will also include any remote monitoring and control, maintenance, storage / transportation, and calibration requirements.

Figure 3-1 **Site Layout**

3.3 Frequently Asked Questions

Appendix A to this OBSMP contains the frequently asked questions (FAQs) by planning authorities, local area fire brigades and residents for ESS installations and sites. It is provided for assurance and a greater awareness of ESS and Lithium-Ion technologies in general.

Whilst the FAQs are not exhaustive it is included to address any commonly held understanding regarding ESS technologies, the way they function, ESS safety management and contingency planning.

4.0 Safety Requirements

4.1 High Level Safety Objective

The primary safety objective for the ESS is achieve a safe design for both operators/maintainers and the public through demonstrable compliance with applicable legal requirements and relevant emerging good practice for large / grid scale battery energy storage systems. These will be distilled into safety requirements that will be included in the requests for quotations (RFQs) and be flowed down to prospective suppliers.

Compliance with these safety requirements (by the potential suppliers) will be used as part of the safety argument, to demonstrate that '***The risk posed to individuals, the environment and property from the ESS programme of work has been reduced to a level that is Broadly Acceptable or Tolerable and ALARP'***. These derived safety requirements will be fundamental to the ESS development and will be used to ensure that all direct and indirect safety requirements for ESS are met and the supplier(s) is safety compliant.

4.2 ESS Safety Guidance

Safety Guidance for the ESS installation will be demonstrated by alignment with prevailing industry guidance, both national and globally. The following industry guidance / best practice has been determined as applicable to this ESS installation:

1. PPG Renewables and Low Carbon Energy, which refers out to;
    a. National Fire Chiefs Council (NFCC) Grid Scale Battery Energy Storage System planning – Guidance for FRS.
    b. FM Global Property Loss Datasheet 5-33 – Lithium-Ion ESS.
2. National Fire Protection Association (NFPA) – Energy Storage Systems and Solar Safety, which refers out to:
    a. Underwriters Laboratory (UL)1973 – Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail Applications.
    b. UL9540A – ESS Test Methods.
    c. UN38.3 – Standard Requirements for Lithium-Ion Battery Production.
3. International Electrotechnical Commission (IEC) 61508 - Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems (E/E/PE, or E/E/PES).

4.3 Legislation and Compliance Requirements

Legislative compliance, specifically safety, for the ESS will be demonstrated by compliance with the UK Health and Safety at Work Act (HSAWA) 1974 and the appropriate underlying legislation that is enacted through the HSAWA. The following current legislation has been determined as applicable to the ESS development:

1. Health and Safety at Work etc. Act 1974 – UKSI1974/0037.
2. Control of Noise at Work Regulations 2005 – UKSI 2005/1643.
3. Control of Substances Hazardous to Health Regulations 2002 – UKSI 2002/2677.

4. Control of Vibration at Work Regulations 2005 – UKSI2005/1093.
5. Electrical Equipment (Safety) Regulations SI 1994/3260.
6. Electro-magnetic Compatibility Regulations SI 2006/3418.
7. Lifting Operations and Lifting Equipment Regulations 1998 – UKSI1998/2307.
8. Management of Health and Safety at Work Regulations 1999 – UKSI1999/3242.
9. Manual Handling Operations Regulations 1992 – UKSI1992/2793.
10. Personal Protective Equipment Regulations 2002 – UKSI2002/1144.
11. Provision and Use of Work Equipment Regulations 1998 – UKSI1998/2306.
12. Reporting of Injuries, Diseases and Dangerous Occurrences Regulations SI2013/1471.
13. Supply of Machinery (Safety) Regulations 2008 – UKSI2008/1597.
14. Workplace (Health, Safety and Welfare) Regulations 1992 – UKSI1992/3004.
15. Registration, Evaluation, Authorisation & Restriction of Chemicals Regulations (REACH) – 1907/2006.
16. Restriction of Hazardous Substances Directive (RoHS) – 2011/65/EU.
17. Dangerous Substances and Explosive Substances Regulations 2002 - SI 2002/2776.
18. Construction (Design and Management) Regulations - SI 2015/51.

5.0 Safety Strategy

5.1 Introduction

A safety argument is required to support the design, development, installation, and use of the ESS, arguing that the safety of the ESS is at an acceptable level for its role in its intended operating environment. A safety argument is defined as “a logically stated and convincingly demonstrated reason why safety requirements are met”. The ESS safety argument will have the following elements:

1. A Technical Risk Argument:
    a. An element that provides the argument that articulates the technical aspects of the design which serve to control the identified hazards, through the application of design control measures.
    b. It will identify system hazards and the causes that can contribute to these hazards.
    c. It will specify the risk analysis conducted and risk reduction requirements implemented.
    d. It will provide the evidence to support any risk reduction claimed.
2. A Confidence (Assurance) Argument:
    a. This part will focus on arguing that the processes used to design, implement, and verify the product are appropriate to its contribution to overall system risk – this being specific to the development of software and provide the requisite audit trail to validate any claimed safety integrity level (SIL) in accordance with IEC61508.

b. The development of the Hazard Log and identification of imbedded physical attributes that support risk reduction.

c. The cross-referencing of these physical attributes (and any supporting qualification data / certification) to the relevant cause(s), providing the evidence of validity of the control measure claimed.

5.2 Safety Integrity Level Requirements

The SIL requirements for the ESS will be driven by the functionality implemented in the successful design solution. As a minimum it is anticipated that the ESS supplier and operator will provide a layered protection approach from cell to container to remote monitoring. The envisaged safety control measures and design features under consideration, and those that will be flowed to the prospective suppliers, include:

1. Appropriate battery chemistry selection - balancing energy density requirements against available volume and operating parameters. LFP cell chemistry has been selected for this installation as it provides the correct balance between safety and capability.

2. Cell level control – consideration of the use of battery technology incorporating Current Interrupt Devices (CID) and Positive Thermal Coefficient (PTC) protection, enabling the cell to disconnect from the battery in the event of cell failure.

3. Implementation in the design of an approved Battery Management System (BMS) and a layered protection system in accordance with UL1973 [Ref. 4] guidelines.

4. Safety certification and qualification to UL9540A [Ref. 6] or equivalent.

5. The ability for 24/7 Remote Monitoring and Control and automated shut-down.

6. Off-gas detection to allow for preventative interaction.

7. Lithium-Ion bespoke fire detection and suppression systems (FDSS) fitted to containers.

8. Site Security and Monitoring.

9. At a site and installation level:

    a. The segregation of containers in accordance with the national and international guidance detailed in this report.

    b. The landscaping of land adjacent to and between ESS containers and maintenance of vegetation to provide a natural firebreak.

    c. The provision of suitable and sufficient access / passing points for emergency services.

    d. Communication with local emergency services and the provision of site maps, detailing ESS locations, access points and water sources.

5.3 NFCC Requirements

The NFCC Report Grid Scale Battery Energy Storage System Planning – Guidance for FRS [Ref. 7] details the FRS requirements anticipated at ESS installations. These have been distilled at Table 5-1 cognisant of the preliminary site layout at Figure 3-1.

Ser	Requirement	Site Status	Options / Comments
1	Access - Minimum of 2 separate access points to the site	**Compliant**	The site can be accessed via the B5097 from both east and west. The site has a primary access gate at the West of the site, to accommodate the prevailing Westerly wind direction. There is an additional secondary access to the east of the site, also accessible from the B5097, closer to the A483.
2	Roads/hard standing capable of accommodating fire service vehicles in all weather conditions. As such there should be no extremes of grade	**Compliant**	Immediate site access road is suitable for HGV traffic – asphalt in construction. All site service roads are suitable for HGVs, given the need to locate the ISO containers and other installations using transporters of a similar size and weight to that used by the FRS. Site-wide – OS Map indicates no significant gradient on the access to the site or at the site.
3	A perimeter road or roads with passing places suitable for fire service vehicles	**Compliant**	The site access road loops around the site allowing for passage of fire service vehicles in rotation around the site.
4	Road networks on sites must enable unobstructed access to all areas of the facility	**Compliant**	The site access road loops around the site allowing for unobstructed access to all areas of the site.
5	Turning circles, passing places etc. size to be advised by FRS depending on fleet	**Compliant**	The site access road loops around the site allowing for passage of fire service vehicles in rotation around the site. FRS to be consulted to validate suitability for the fleet
6	Distance from ESS units to occupied buildings & site boundaries. Initial min distance of 25m	**Compliant**	Site containing ESS is 25m distant from occupied buildings (less site buildings)

Ser	Requirement	Site Status	Options / Comments
7	Access between ESS unit – minimum of 6 metres suggested. If reducing distances, a clear, evidence based, case for the reduction should be shown.	**Compliant with caveat**	The suggested 6m separation is based on a 2017 Issue of the FM Global Loss and Prevention Datasheet 5-33 (footnote 9 in the NFCC Guidance refers). This datasheet was revised in July 2023 and now details the following: *For containerized LIB-ESS comprised of lithium iron phosphate (LFP) cells, provide aisle separation of at least 5 ft (1.5 m) on sides that contain access panels, doors, or deflagration vents.* Following this revision to the Datasheet, the BESS containers on site, which utilize a LFP chemistry are compliant with the minimum distances and conformance to ASTM E119 1-hour fire rating will be confirmed on the down select of the BESS units to be procured. The distance between ESS Container pairs is 4.0m for sides that contain access panels or doors.
8	Site Conditions – areas within 10m of ESS Units should be cleared of combustible vegetation	**Compliant**	The ESS units will sit on concrete slabs or supporting feet. Internal access tracks will comprise crushed stone and the access road for the abnormal load will be asphalt. Within fence line and between ESS containers units the surface is laid over to gravel.
9	Water Supplies	**Compliant**	The site has 5 water storage containers for FRS use. In addition, there is a Water Main with a Fire Hydrant near the railway bridge to the west of the site, approx. 100m from the primary site entrance.
10	Signage	**Compliant**	Signage to be positioned at the entrance to the site. Signage to be confirmed through design process and will be detailed in the Emergency Response Plan.
11	Emergency Plans	**Compliant**	Future iteration of the OBSMP to DBSMP will roll up the Emergency Response Plan outlining who and how FRS will be alerted, facility description, number of operatives, detailed site plan etc.
12	Environmental Impacts	**Compliant**	An attenuation basin is included on the eastern part of the main site for sustainable drainage. The application will be supported by a Flood Risk Statement and Sustainable Drainage Systems report.

Ser	Requirement	Site Status	Options / Comments
13	System design, construction, testing and decommissioning	**Compliant with caveat**	Several of the elements under this aspect of the NFCC Guidance are contained in this plan, however details of the construction, testing and decommissioning will only be available in later stages of the programme and be contained in the DBSMP.
14	Deflagration Prevention and venting	**Compliant with caveat**	Elements of this requirement are contained in this plan, but the actual technique to be adopted will not be apparent up to the point the decision is made as to what ESS is being used. Deflagration venting is possibly most effective when fitted to the roof of the ESS Units, as such deflecting blast upwards and away from FRS personnel

Table 5-1 – NFCC FRS Requirements Status

6.0 Safety Management Strategy and Activities

6.1 Introduction

The proposed ESS will be designed to meet relevant industry standards and legal requirements which contain specific safety requirements, section 4.3 refers.

6.2 Safety Criteria

The consequence for each potential hazard shall be categorised according to classification which accounts for both frequency of occurrence and severity of outcome (risk). This will be developed as the project matures and used to measure the implementation of additional control measures as and when merited.

6.3 ESS Safety Working Group

An ESS Safety Working Group (SWG) is proposed post planning acceptance, which will be the forum for the review and continued validity of key elements which support the safety argument. The ESS SWG will comprise Suitably Qualified and Experienced Person (SQEP) stakeholders who are drawn from various stakeholder communities because of their relevant knowledge and experience.

The ESS SWG will be responsible for the oversight of ESS safety management and supporting safety artefacts to ensure that they are reviewed and updated. One of the key tasks is the production of the Hazard Log for the equipment and the management of this through life utilising Hazard Identification and Hazard Analysis techniques. The ESS SWG is also the forum for capturing equipment safety issues that require addressing, terms of reference for the SWG will be captured in the DBSMP.

The overall principal tasks, duties, and responsibilities of the ESS SWG are defined in Section 0. The ESS SWG frequency being dependent on the activities required for the prevailing stage of the project.

6.4 Hazardous Material

Any hazardous materials used in the ESS development will need to be fully justified and captured in the ESS Hazardous Materials Register, a sub-set of the Bill of Materials (BoM). The register is used to highlight the hazardous materials contained within ESS and provides justification as to why they cannot be eliminated and to highlight exact quantities of hazardous materials that are present to satisfy legislative requirements. The ESS Hazardous Materials Register will be made available to the local emergency services.

6.5 Safety Disposal Considerations

Disposal activities will be considered at the ESS concept stage and will be included within the ESS safety management process. As the programme matures the hazard log will be expanded to cover each phase of product development and installation.

6.6 Forward Plans

This is the initial OBSMP for ESS and as such the identification of potential hazards, causes and controls is limited to the concept stage, i.e., the ESS concept design and the initial proof of design artefact. Therefore, several controls have been identified are also conceptual and subject to technological assessment, as such no ALARP statements can yet be formulated.

All the control measures identified thus far are founded on good practice and based on previous knowledge of ESS systems in use and other associated products using Lithium-Ion energy storage technology. These mitigations may in some instances require further development and ratification as the programme progresses. Upon successful implementation, and with suitable evidence available to validate effectiveness, reassessment can be conducted with the aim to consider the reduced the level of risk.

6.7 Emergency Plans

As part of the initial development of the ESS, Emergency Plans will be developed that will outline how the operator will respond to incident and accident scenarios at site. This will include the interfaces with external first responder organisations.

The Emergency Response Plans will be developed in an iterative manner in parallel to technical safety requirements. This will ensure that the ESS design and Emergency Plans are properly integrated (e.g., that the ESS layout ensures access for first responders) and that appropriate information can be provided to first responders (e.g., the type and meaning of external indication on containers) to include in their planning activities.

The Emergency Response Plan will be formed through two distinct elements, both of which will be promulgated to the FRS on commissioning of the ESS Site, these being:

1. The Risk Management Plan, a distillation of the OBSMP and DBSMP which will include:

    a. The hazards and risks at and to the facility and their proposed management.

    b. Any safety issues for the FRS responding to emergencies at the facility.

    c. Safe access to and within the facility for emergency vehicles and responders, including to key site infrastructure and fire protection systems.

    d. The adequacy of proposed fire detection and suppression systems (i.e., bespoke FDSS fitted to ESS containers, off-gas detection systems, enclosure fire rating etc.)

    e. Any natural or built infrastructure and on-site processes that may impact or delay effective emergency response.

2. The Emergency Response Plan will be developed and include:

    a. How the FRS will be alerted.

b. The site layout including infrastructure details, operations, number of personnel, and operating hours.

c. A site plan depicting key infrastructure in overview: site access points and internal roads.

d. Details of emergency resources, including fire detection and suppression systems and equipment; gas detection; emergency eyewash and shower facilities; spill containment systems and equipment; emergency warning systems; communication systems; personal protective equipment; first aid.

e. Up-to-date contact details for facility personnel, and any relevant off-site personnel that could provide technical support during an emergency.

f. A list of any dangerous goods stored on site.

g. Site evacuation procedures.

h. Emergency procedures for all credible hazards and risks, including building, infrastructure and vehicle fire and vegetation / flora fire.

6.8 ESS Hazard Log

The preliminary ESS Hazard Log (Ref. 1) is currently managed in the form of an excel spreadsheet and is provided as an example of the risks most commonly present in an energy storage system utilising Lithium-Ion technology. The benefit of using this Hazard Log tool is that it provides an auditable record of all decisions made for the assessment of risk for the ESS Project which can be managed through life on a central repository. ESS Safety Management Team

6.9 Safety Management System

The Safety Management System (SMS) provides a system of management that ensures that all safety related aspects are managed in accordance with applicable industry standards and United Kingdom (UK) legislation. Within the safety context, the ESS SMS ensures that the risks associated with the ESS capability will be managed such that they are ALARP and broadly acceptable or tolerable and will remain so throughout the lifetime of the equipment.

Some of these safety requirements and consequential decisions will need to be balanced against the practicability of implementation for the ESS and an affordability balance against the risk reduction afforded. Likewise, when a hazard occurrence has been reduced to a level whereby it is considered eliminated, further risk reduction will only be implemented because of indirect risk reduction measures implemented for other hazards or causes. The SMS will, through the application, further facilitate the strong safety culture for the ESS development, including and encompassing sub-contractors and suppliers and the wider stakeholder community who interface with the ESS capability.

6.10 Safety Management Structure

The ESS safety management structure has yet to be fully defined and will be subject to the safety management strategies and procedures that are in place with the successful supplier and installer of the ESS. The minimum requirement is a formal top-down management structure that has the authority and responsibility to ensure safety management and environmental risk is at the forefront of products, procedures, and services. This will need to be expanded as the project develops.

6.11 Overarching Policy

All ESS development activities shall consider safety and environment as an integrated part of the ESS life cycle and shall be assessed from a safety viewpoint. This safety-focused approach shall span all programme phases. This encourages and develops a safety and environmental culture that spans all levels of the organisation and encompasses all aspects of its working practices. It views safety as a holistic quantity that is owned by the organisation rather than something to be passed by function. This safety culture is supported by training to develop and maintain expertise and awareness for good practice, knowledge of emerging standards and in the understanding of legislation.

6.12 Management Plan

This OBSMP incorporates the management activities relevant to safety. This includes the planning for Quality, Engineering Development and Configuration Management. These are important disciplines that underpin arguments for safety and environment. This OBSMP will be periodically revisited and revised to accommodate any changes or enhancements to the programme.

6.13 Staff Competence

The ESS safety and environmental management programme shall ensure that all personnel who have any responsibility for a safety or environmental activity are competent to discharge those responsibilities or are adequately supervised/approved by someone with appropriate competencies.

6.14 Overview

The implementation of safety management and safety activities will be given the highest priority during the ESS programme. It is recognised that the management of safety is an integral part of the safety assurance process, and the observance of the requirements specified in this report will be mandatory for all involved with the ESS Project.

7.0 Conclusions and Recommendations

7.1 Conclusions

It is concluded that, as far as reasonably practicable and for this planning stage of the ESS project, that currently foreseeable hazards associated with the equipment have been identified, and these will be flowed, through the mechanism of the System Requirements Document (SRD), to prospective suppliers. These hazards will be actively managed throughout the life of the installation and added to as necessary as the ESS Project develops and will be reported on at each SWG.

This OBSMP has been developed using existing knowledge of the ESS capability and leans heavily on the subject matter expertise that ARC have in this technological domain.

Further development of the ESS design will provide more detailed information that will enhance future safety analysis and management, where further understanding of the hazards and development of mitigations can be undertaken to reduce the potential level of risk posed by ESS.

7.2 Recommendations

It is recommended that the ESS safety management and criteria (for assessment and analysis) as defined in this OBSMP, is adhered to throughout the ESS project lifecycle to ensure that safety management is developed as the programme progresses and remains valid through the life of the ESS capability.

It is recommended that to reduce the level of residual risk to meet the **LOW** 'tolerable' region that all the identified control measures are assessed as the design matures to elicit; applicability, feasibility and the potential amelioration afforded. At this juncture of the programme, it is not possible to declare ALARP, however successful implementation of the proposed framework for safety management presented in this OBSMP will provide the necessary arguments and supporting evidence to make such a claim.

8.0 References

1. ESS Hazard Log - ARC-1206-001-R2, Draft A, Nov 2023.

2. Reducing Risk, Protecting People (HSE Publications) - https://www.hse.gov.uk/risk/theory/r2p2.pdf.

3. MIL-STD-882E, Department of Defence Standard Practice: Safety Systems Dated May 2012.

4. Defence Standard 00-56, Ministry of Defence: Safety Management Requirements for Defence Systems July 2012.

5. UL1973 – Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail Applications.

6. UL9540A – ESS Test Methods.

7. NFCC Grid Scale Battery Energy Storage System Planning – Guidance for FRS dated Nov 2022.

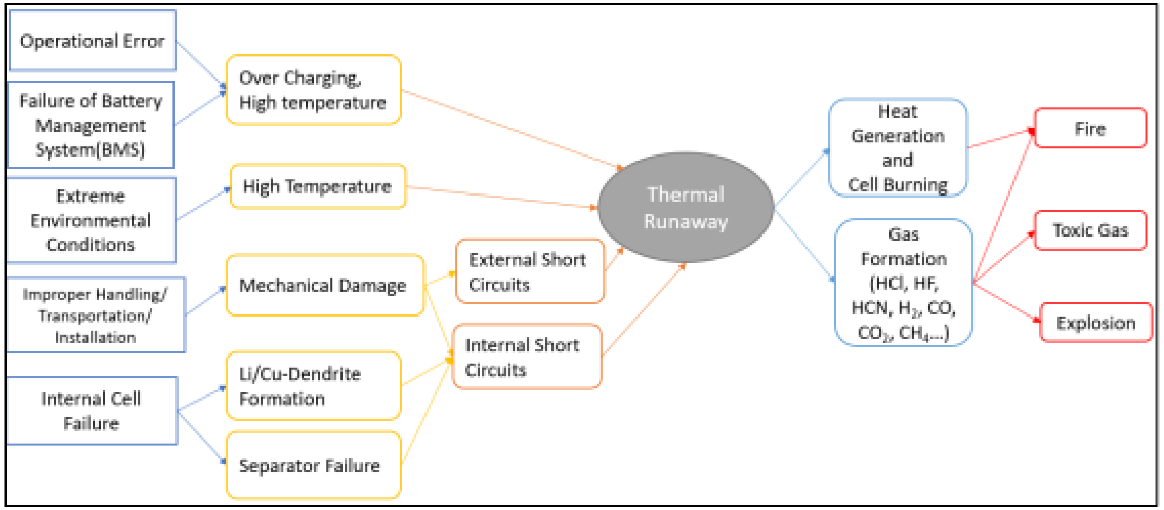
Appendix A - FAQs

Ser	Question	Answer
1	How does an ESS work?	A ESS employs Lithium-Ion technology to temporarily store electrical energy, very much in the same manner as a mobile phone or laptop battery, but on a much bigger scale. The energy can be stored and released when demand on the National Grid is high and assists in balancing out variations in demand. ESS can be connected to a PV Solar Farm and store energy throughout the day for release in the evening and in this mode of operation is a green renewable energy. An alternative use for ESS is to store electrical energy generated by energy suppliers during period of low demand and releasing in periods of high demand, thus balancing out variation on the National Grid. This mode of operation allows energy suppliers to operate their power station in a more economical manner and assists in reducing the carbon-footprint of the power suppliers. Two different primary Lithium-Ion battery chemistries (the elements that form the energy storage parts of the batteries) are used in ESSs, these being: ○ **Lithium iron phosphate (LFP)** - LFP batteries are possibly the best types of batteries for ESSs. They provide cleaner energy since LFPs use iron, which is a relatively green resource compared to cobalt and nickel. Iron is also cheaper and more available than many other resources, helping reduce costs. The overall production cost is lower as well. LFP batteries have a lower power density, but this characteristic is less important for energy storage systems than it is for Electric Vehicles (EVs), as ESS can occupy larger spaces without concern. LFP batteries are also safer because thermal runaways are less likely, and they have a higher life cycle (between 2,000 and 5,000 cycles) than most other Li-ion battery technologies. ○ **Lithium Nickel Manganese Cobalt (NMC)** - NMC batteries feature both strong energy and power density, and they are relatively safe compared to other types of lithium-ion batteries when it comes to thermal runaways. However, they offer a significantly lower number of life cycles compared to LFP batteries, generally between 1,000 and 2,000 cycles. NMC batteries also require cobalt and nickel, which are more expensive and harmful to the environment. There is also significant concern about shortages in these minerals, which can significantly impact both cost and availability.

Ser	Question	Answer
2	How safe is a ESS?	The Department for Energy Security and Net Zero (DESNZ), promulgates on a regular basis the Renewable Energy Planning Database. From the quarterly extract (dated July 2023 and published 8 August 2023) the data has been filtered for ESS installations in the UK and the following salient points are deduced: 1. As of July 2023, there are 93 ESS sites in operation across the UK. 2. The total energy capable of being stored is estimated at 1580MW (1.58GW). 3. Since 2006 ESS have operated for approximately 4.8 million hours (data details 4,729,560 hours) which is equivalent to 540 years of operation. 4. There has currently been only one reported UK ESS fire that required FRS attendance, this occurred at Carnegie Road, Liverpool in Sept 2020. 5. This equates to 2.11E-07 (0.000000211) failures per hour (fph) for ESS fires in the UK. Noting that to date no ESS incident has led to a personal injury. ESS are designed to industry specific guidelines and subject to UK legislation.
3	Lithium-Ion is sensitive to temperature variations – how is this controlled?	The Lithium-Ion batteries are housing in an ISO type container which is fitted with an Environmental Control Unit (ECU). The ECU maintains the temperature and humidity within the container, allowing the Lithium-Ion batteries to operate within the optimum temperature range. The temperature of individual Lithium-Ion cells in each battery is monitored by the battery management system (BMS) and is reported back to the Container level BMS which adjusts the internal temperature in response. Should the ECU develop a fault the container will isolate charge and discharge to the batteries until the fault has been rectified. All faults in the ESS are remotely fed to a centralised Control Room.
4	What is Thermal Runaway?	Thermal Runaway (TR) is the term used to describe an internal short-circuit in one of the battery cells that can lead to cell over-pressure and the venting of combustible gases. Should this gas ignite then the cell will increase in over-pressure and the resulting fire will be self-sustaining until all the material in the cell is expended. Short-circuits in cells are generally a result of: 1. Cell penetration by a foreign object (not usual an issue for a ESS as the batteries are housed in sturdy containers). 2. Impurities in the electrolyte (deposited during the manufacturing process), which over time can lead to the formation if dendrites (electrolytic crystals) which puncture the membrane isolating the anode and cathode – this can, but not

<table>
<tr><th>Ser</th><th>Question</th><th>Answer</th></tr>
<tr><td></td><td></td><td>always result in a short-circuit and TR. Dendrite formation was a common problem in early Nickel Manganese Cobalt (NMC) battery chemistries but is not prevalent in Lithium Ferrous Phosphate (LFP) battery chemistries.
3. Over-temperature in the cell because of:
a. Over-charging (which is controlled by 2 separate BMS – battery and rack).
b. High ambient temperature – controlled by the ECU.

The illustration below provides an outline of the possible causes of TR.


</td></tr>
<tr><td>5</td><td>How can Thermal Runaway be controlled?</td><td>TR is not always inevitable, and the nature of the cell design is such that early warning signs of a stressed cell can be detected by the BMS. Initial signs of cell degradation are an increase in the time it takes the cells to reach full charge (maximum voltage) and a decrease in the time it takes to discharge. These indicators are picked up by the BMS and if persistent the BMS will isolate (prevent charge and discharge) to the battery and inform the centralised Control Room. In turn an engineer will be dispatched to remove the battery and replace it with a serviceable item.</td></tr>
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Ser	Question	Answer
		If these indicators are not present, and the cell enters early stages of short-circuit the over-pressure in the cell will result in the venting of off-gas which is detected by the off-gas detectors built into the container. This will result in the container disabling the charge and discharge (the act of charging and discharging the batteries generates heat, which is what we want to avoid) and setting the ECU to maximum volume setting. This has a twofold effect, it clears the container of combustible gas and cools the internals, taking the energy out of the cells (Lithium-Ion like other batteries do not perform well in low temperature conditions).
6	How is a ESS fire controlled and suppressed?	If the TR is not controlled and spreads, known as Thermal Runaway Propagation (TRP) the fire detection and suppression system (FDSS) will activate. There are currently two types of FDSS that are used in ESS; gaseous systems and aerosol systems. Each system has advantages and disadvantages: 1. Aerosol systems are better in terms of extinguishing the fire and benefit against gaseous systems, which generally supress the fire by reducing the level of oxygen in the container. 2. Gaseous systems are instantaneous in operation, the gas being kept under pressure in bottles. Aerosol, by the nature of the deployment as a fine mist, take a little longer to reach all areas of the container. 3. Aersol system generally require a more complex and intricate delivery system to reach all areas of the container. 4. Gaseous system requires a sealed environment in which to operate. As such if the container is opened and oxygen reintroduced it can lead to the fire reigniting. 5. Various FDSS aerosols (also known as aqueous) and gaseous systems are available, and they use a variety of aerosol solutions.

Ser	Question	Answer
7	Can water be used to extinguish a Lithium-Ion fire?	The use of water to extinguish a ESS fire has some drawbacks and disadvantages over bespoke FDSS aerosol mediums, these being: 1. The high conductivity of water may cause short circuiting of cells presenting collateral damage risk and increase the spread of the fire internal in the ESS. 2. A high volume of water is required to cool the cells below the critical temperature to prevent TR propagation, this results in a high volume of fire water run-off and a potential environmental impact. 3. The application of water on a ESS fire increases the generation of gases such as CO, H2 and HF. Applying water causes incomplete combustion of organic substances inside the battery resulting in production of CO rather than CO2; when water is applied, H2 is released that, without combustion, can react with phosphorus pentafluoride, if present in free form, to produce gaseous HF. 4. Due to the design of the batteries and racks (in which they are contained), the inability of water to cool the cell interiors may result in re-ignition of a fire once the water application is halted.
8	What are the environmental consequences of an ESS fire?	In the event of an ESS fire several chemicals in gaseous form can be released and the composition and concentration of the plume (also refer to as the vapour cloud) is dependent on the Lithium-Ion chemistry in use, the design and components of the ESS and the magnitude of the fire. Amongst the general gases released are Carbon Monoxide (CO), Hydrogen Fluoride (HF), Oxygen and Hydrogen. The only UK ESS fire (Carnegie Road, Liverpool – Sept 2020) was monitored and the resultant composition of the plume determined as being negligible in toxic gas concentration. Should the resulting fire be treated with water in the presence of HF the result can be the formation of a HF acid which can be detrimental to the environment, especially the aquatic habitat. To prevent this, it is possible to contain the fire run-off water but often best, if feasible, to let the fire run its course and burn-out. It is worth noting that the fire run-off water at Carnegie is considered to have been neutralised by the lime-based gravel covering used at the base of the ESS and on testing was found to be a low alkaline level, as opposed to acidic.
9	How is the ESS site secured?	ESS Site are secured through fences / walls (some sites will have 3-4m high acoustic walls to attenuate and reduce ECU noise) and sites monitored remotely via CCTV. Warning signs along the fence indicate the presence of electrical storage facilities within the site.

Ser	Question	Answer
10	How is the serviceability of the ESS assured?	The Health and Usage data for each ESS is remoted to a centralise Control Room and the serviceability of each battery determined on an hour-to-hour basis. Given that the batteries have a finite number of cycles over a given period it is envisaged that the batteries will be renewed 5 to 6 times in the 40-year life of the site.