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Butterfly Solar Farm Battery Energy Storage System – Outline Battery Safety Management Plan

Issue 1 – September 2025

Prepared for:

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Executive Summary

This Outline Battery Safety Management Plan (OBSMP) has been prepared in relation to the Butterfly Solar Farm Battery Energy Storage System (BESS) and associated infrastructure. Butterfly Solar Farm will be located to the south of Wrexham, adjacent to the A483, and between Johnstown to the west and Bangor on Dee in the East. The installation is henceforth referred to in this report collectively as the Butterfly Solar Farm site. The Butterfly Solar Farm BESS units will most likely use Lithium Ferrous Phosphate (LFP) chemistry cells.

This OBSMP provides details of the safety management processes and procedures to be implemented to satisfy the prevailing safety requirements for the Butterfly Solar Farm site and BESS system specifically. The safety management approach to be adopted is intending to satisfy the ethos of ‘As Low As Reasonably Practicable’ (ALARP), as defined by:

- The Health and Safety Executive (HSE) ’Reducing Risk, Protecting People’ (R2P2) Guidance document [Ref 1]
- The National Fire Chiefs Council (NFCC) Guidance for BESS installations and the associated Factory Mutual (FM) Global Datasheet 5-33 [Ref 2].
- The Department for Energy Security and Net Zero (DESNZ) Health and Safety Guidance for Electrical Energy Storage Systems [Ref 3].

Whilst the make and model of the BESS units to be employed at the site has yet to be determined, the selection of the BESS units will require that the design, development, and manufacture by the Original Equipment Manufacturer (OEM), demonstrates that high standards, in respect of safety and operational sustainability, can be evidenced. This will be achieved through adherence to internationally acknowledged codes of practice for Lithium-Ion BESS.

Abbreviations

ALARP	As Low As Reasonably Practicable
ARC	Abbott Risk Consulting Ltd
BESS	Battery Energy Storage System
BMS	Battery Management System
CO	Carbon Monoxide
DESNZ	Department for Energy Security and Net Zero
ECU	Environmental Conditioning Unit
ERP	Emergency Response Plan
FDSS	Fire Detection and Suppression System
fph	failures per hour
FRS	Fire and Rescue Service
H_2	Hydrogen
HF	Hydrogen Fluoride
HL	Hazard Log
HSAWA	Health and Safety at Work Act
HSE	Health and Safety Executive
LFP	Lithium Ferrous Phosphate
NFCC	National Fire Chiefs Council
NMC	Nickel Manganese Cobalt
OBSMP	Outline Battery Safety Management Plan
OEM	Original Equipment Manufacturer
R2P2	Reducing Risk, Protecting People
SF	Solar Farm
TR	Thermal Runaway
UK	United Kingdom
US	United States

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). The OBSMP has been prepared on behalf of RWE Renewables UK Solar and Storage Limited in relation to the BESS facility that will be located to the south of Wrexham, adjacent to the A483, and between Johnstown to the west and Bangor on Dee in the East, Figures 5-1, 5-2 and 5-3 refer. The BESS installations are in 3 parcels, henceforth referred to in this OBSMP as the Western Site, Central Site and Eastern Site, each site is accessed at various points and the BESS units are accessible through an internal network of roads.

This OBSMP has been developed to outline the potential risks presented by the BESS and its operation / maintenance. This OBSMP provides a robust safety strategy, supported by evidence to support full commissioning. The final design and equipment detail is yet to be fully defined and is based on the intended site layout plan and associated details currently available and provided by RWE at this juncture. This plan will be updated, as applicable, when additional information becomes available.

2.0 Background

ARC have conducted the Hazard Identification of the Butterfly Solar Farm site. This analysis has provided the necessary foundation for the identification of hazards and the development of a preliminary Hazard Log (HL) [Ref. 5], which contains:

1. Consolidated list of hazards and hazard descriptions.
2. Associated causes of the hazards with linkage to the relevant hazard(s).
3. Design controls implemented to ameliorate / mitigate the causes.
4. Identification of the potential outcomes or consequences from the hazards.
5. Identification and linkage to mitigating factors that could ameliorate the severity or frequency of occurrence of the outcomes (consequences).
6. Identification of any mitigation that will further ameliorate the probability of hazard or consequence frequencies and be contained in the Emergency Response Plan (ERP).

3.0 Aim

The overall safety aim is that the levels of risk of accident, death or injury to personnel or other parties, and risks to the environment due to the construction, operation and decommissioning are to be broadly acceptable or tolerable and ALARP, in accordance with the HSE R2P2 [Ref. 1]. For the OBSMP specifically, the document presents an initial appraisal of the safety risks including:

- An overview of the main characteristics and the associated design guidelines and legislative and compliance requirements.
- The identification of safety risks.
- The identification of inherent safety features and additional safety recommendations (e.g. emergency response planning) to be secured through the OBSMP at the detailed design stage and ensured by planning condition).

- Determination of the identified safety risks and their significance.

4.0 Scope

The scope of the OBSMP for the Butterfly Solar Farm site and capability covers the physical and functional aspects of the equipment. The safety management covers design, validation, and operation. It also includes any remote monitoring and control, maintenance, storage / transportation, and calibration.

4.1 Site Access

Primary access to the sites is shown, with the associated What3Words locations, in Figures 5-1, 5-2 and 5-3. Table 4-1 provides additional details[1].

Access	What3Words	Comment
Access to Western Site	///regaining.every.jeeps	Off B5426 to the west of Black Brook
Primary access to Central Site	///bloomers.materials.shunts	Off B5426
Secondary access to Central Site	///arrow.readjust.rationing	Unnamed road heading north off B5426
Tertiary access to Central Site	///begun.wasps.hobbyists	Unnamed road heading north off B5426
Access to Eastern Site	///machine.outcasts.bluntly	Off Kiln Lane (B5130)

Table 4-1 Access Points

The primary access tracks to the BESS units at all sites is a minimum of 4.0m in width, which loops around the site providing access to all BESS compounds. The primary access track is constructed using a crushed / compacted stone and capable of withstanding 20 tonne payloads.

A laminated site layout will form part of the Emergency Response Plan, contained in the ‘GERDA’ style emergency services box at the entrance to the individual sites. An illustration of the individual BESS unit compounds, located at various points in each of the sites, is at Figure 4-1.

[1] Theses access locations are currently only indicative and will be confirmed as the project progresses.

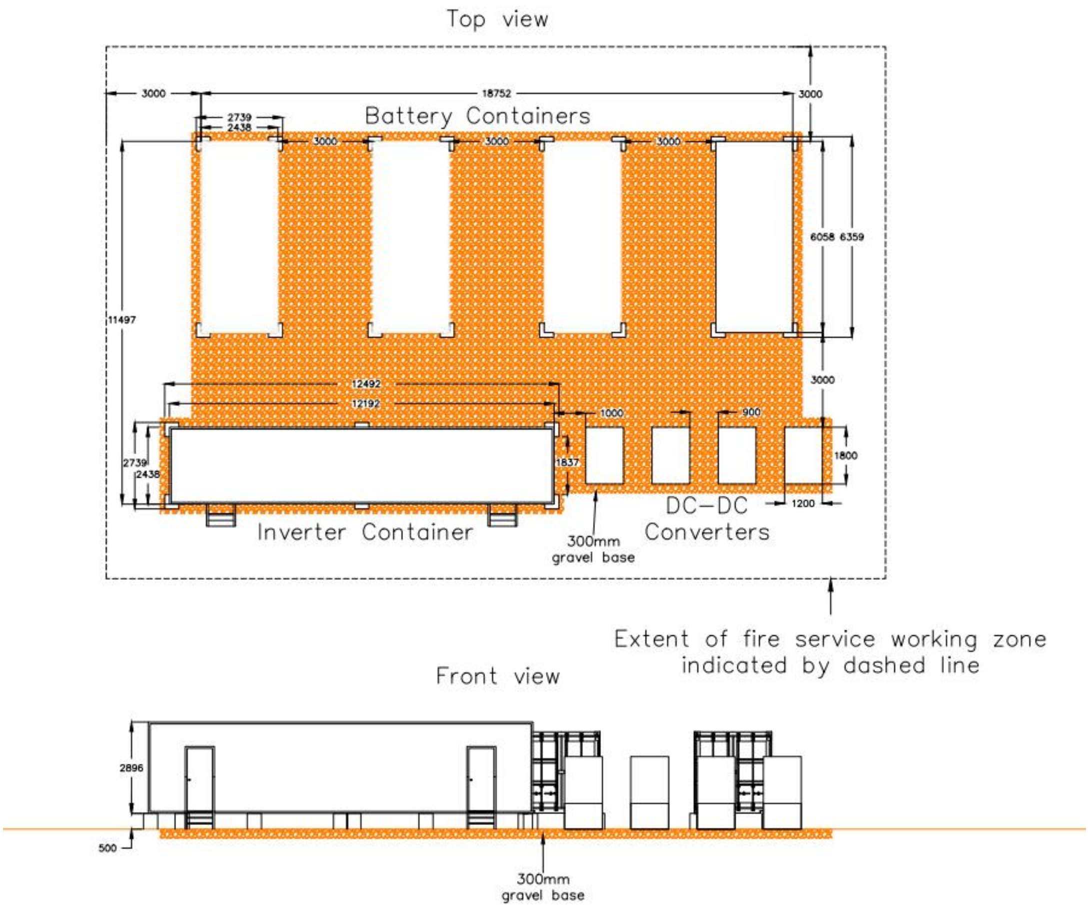


Figure 4-1 Butterfly Solar Farm BESS facility layout (single compound comprising 4 BESS units shown)

4.2 Frequently Asked Questions

Appendix A of this OBSMP contains frequently asked questions and is provided for assurance and a greater awareness of BESS and Lithium-Ion technologies in general.

5.0 Safety Requirements

5.1 High Level Safety Objective

The primary safety objective is to comply with applicable legal requirements and relevant good practice for large / grid scale BESS. Compliance with these requirements will be used as part of the safety evidence, to demonstrate that '***the risk posed to individuals, the environment and property has been reduced to a level that is ALARP'.*** The HL [Ref 5 and Appendix B] documents and records the management of the accident sequences, and the control measures employed for the associated risk..

5.2 Legislation and Compliance Requirements

Legislative compliance, specifically safety, will be demonstrated by compliance with the United Kingdom (UK) Health and Safety at Work Act (HSAWA) 1974 and the appropriate underlying legislation that is enacted through the HSAWA. The following legislation and industry guidance has been determined as applicable to this installation:

1. Legislation (England and Wales):
    a. Health and Safety at Work etc. Act 1974 – UKSI 1974/0037.
    b. Control of Noise at Work Regulations 2005 – UKSI 2005/1643.
    c. Control of Substances Hazardous to Health Regulations 2002 – UKSI 2002/2677.
    d. Control of Vibration at Work Regulations 2005 – UKSI2005/1093.
    e. Electrical Equipment (Safety) Regulations SI 1994/3260.
    f. Electro-magnetic Compatibility Regulations SI 2006/3418.
    g. Fire Safety (Employees' Capabilities) (England) Regulations SI 2010/471.
    h. Fire Safety Order 2023.
    i. Fire Safety Act 2021.
    j. Lifting Operations and Lifting Equipment Regulations 1998 – UKSI1998/2307.
    k. Management of Health and Safety at Work Regulations 1999 – UKSI1999/3242.
    l. Manual Handling Operations Regulations 1992 – UKSI1992/2793.
    m. Personal Protective Equipment Regulations 2002 – UKSI2002/1144.
    n. Provision and Use of Work Equipment Regulations 1998 – UKSI1998/2306.
    o. Reporting of Injuries, Diseases and Dangerous Occurrences Regulations SI2013/1471.
    p. Supply of Machinery (Safety) Regulations 2008 – UKSI2008/1597.
    q. Workplace (Health, Safety and Welfare) Regulations 1992 – UKSI1992/3004.
    r. Registration, Evaluation, Authorisation & Restriction of Chemicals Regulations – 1907/2006.
    s. Restriction of Hazardous Substances Directive – 2011/65/EU.
    t. Dangerous Substances and Explosive Substances Regulations 2002 - SI 2002/2776.
    u. Construction (Design and Management) Regulations - SI 2015/51.
    v. Health and Safety - Safety Signs and Signals Regulations 1996.
    w. Waste Batteries and Accumulators Regulations 2009.
2. Industry Guidance and Best Practice Documents:
    a. Underwriters Laboratory (UL)1973 – Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power, and Light Electric Rail Applications [Ref. 6].
    b. UL9540A – BESS Test Methods [Ref. 7].
    c. UN38.3 – Standard Requirements for Lithium-Ion Battery Production [Ref. 8].
    d. FM Global Property Loss Datasheet 5-33 – Lithium-Ion BESS [Ref. 4].
    e. NFCC Grid Scale BESS planning – Guidance for FRS [Ref. 2].

f. National Fire Protection Association (NFPA) 885 – Standard for the Installation of Stationary Energy Storage Systems [Ref. 9].

g. Department for Energy Security and Net Zero – Health and Safety Guidance for Electrical Energy Storage Systems [Ref. 3].

5.3 NFCC Recommendations

The NFCC Report Grid Scale Battery Energy Storage System Planning – Guidance for FRS [Ref 2] details the FRS recommendations for BESS installations. These have been distilled at Table 5-2 cognisant of the site layout at Figures 5-1, 5-2 and 5-3. At the time of the planning submission there was no specific UK regulation regarding fire safety of BESS facilities, however the DESNZ has produced the Health and Safety Guidance for Electrical Energy Storage Systems [Ref 3] report. For the BESS units, the NFPA 855 [Ref9] code is the internationally recognised most relevant document and this will be considered in the procurement of the BESS units and ancillary equipment.

5.4 FRS Consultation

The site location falls within the jurisdiction of the North Wales FRS. Consultation with the FRS will form an element of the initial planning process.

Figure 5-1 Butterfly Solar Farm Eastern Site Access Points (What3Words)

Figure 5-2 Butterfly Solar Farm Central Site Access Points (What3Words)

Figure 5-3 Butterfly Solar Farm Western Site Access Points (What3Words)

Ser	NFCC Recommendation	Status	Comment
1	Access - Minimum of two separate access points to the site	**Compliant**	The points of access to the various sites are detailed in Figures 5-1, 5-2, 5-3 and at Section 4.1. The distance from the point of access to the nearest BESS installation at each site is such that obscuration of this point of access through smoke is highly unlikely. The network of internal roads allows FRS Appliances to park and address any fire at multiple points.
2	Roads/hard standing capable of accommodating fire service vehicles in all weather conditions. As such there should be no extremes of grade	**Compliant**	The proposed access road serving the sites will be a crushed stone surface and is a minimum of 4.0m in width. There is no extreme of gradient at the site. Access roads have been subject to vehicle tracking and are considered suitable for FRS vehicles. Swept Path Analysis has been conducted, using RB32 data, and the roads at the site are required to withstand site construction vehicle traffic of more than 20 tonne gross vehicle weight. All roads will be maintained throughout the life of the site.
3	A perimeter road or roads with passing places suitable for fire service vehicles	**Compliant**	The BESS compound access road is a minimum of 4.0m wide hard surface running through the site allowing access to all BESS units. At intervals along all site access tracks there are ‘hammerhead’ junctions that allow for vehicles to pass or turn around.
4	Road networks on sites must enable unobstructed access to all areas of the facility	**Compliant**	The access roads are routed through the various sites, enabling access to the BESS compounds and associated infrastructure.
5	Turning circles, passing places etc. size to be advised by FRS depending on fleet	**Complaint**	Liaison and consultation with the FRS will establish if these arrangements are satisfactory. The access road upon entry to the site has a holding / assembly point for FRS appliances and other emergency vehicles.
6	Distance from BESS units to occupied buildings & site boundaries. Initial min distance of 25m	**Compliant**	There are no occupied buildings within 25m of any of the BESS units at any of the sites.
7	Access between BESS unit – minimum of 6.0m suggested. If reducing distances, a clear, evidence-based case for the reduction should be shown	**Compliant**	The suggested 6m separation is based on a 2017 Issue of the FM Global Loss and Prevention Datasheet 5- 33 [Ref. 6] (footnote 9 in the NFCC Guidance refers). This datasheet was revised in July 2023 and now details the following: *“For containerised LIB-ESS comprised of LFP cells, provide aisle separation of at least 5 ft (1.5 m) on sides that contain access panels, doors, or deflagration vents”.* This separation of 1.5m for LFP BESS is further articulated and supported in the Department of Energy Security and Net Zero document Health and Safety for Electrical Energy Storage Systems [Ref. 9]. The BESS units for the Development will be LFP and the distance between BESS unit is 3.0m distance, with the

Ser	NFCC Recommendation	Status	Comment
			units being orientated such that no vents are opposite each other, providing compliance against the updated FM Global Specification.
8	Site Conditions – areas within 10m of BESS units should be cleared of combustible vegetation	**Compliant**	Although on a greenfield site the BESS and other installations will be positioned on concrete plinths and the land between impermeable and laid out to a gravel covering. All areas within 10m of the BESS can be cleared of vegetation.
9	Water Supplies	**Compliant with caveat**	The water supply requirements set out in the NFCC Planning Guidance when applied to a de-centralised DC-coupled battery arrangement are not proportionate.
10	Signage	**Compliant**	Signage will be positioned at the entrance to each site, including a site-specific layout plan and the contact details of key personnel. Signage indicating the access routes to the secondary points of access will be included at the primary point of access.
11	Environmental Impacts	**Compliant**	No comments have been received from the Environment Agency to date.
12	Emergency Plans	**Compliant**	An ERP will be developed for the site in conjunction with the FRS.
13	System design, construction, testing and decommissioning	**Compliant**	Not a requirement at this juncture, details will be contained in the Detailed Battery Safety Management Plan (DBSMP) post consent. Compliant at this juncture in the planning process.
14	Deflagration Prevention and venting	**Compliant**	Deflagration venting is possibly most effective when fitted to the roof of the BESS units, as such deflecting blast upwards and away from FRS personnel. Compliant at this juncture in the planning process.

Table 5-2 - NFCC Recommendations Cross-Referenced to the Butterfly Solar Farm Site

6.0 Implemented Safety Strategy

6.1 Introduction

A safety strategy is required to support the design, development, and installation, providing the necessary assurance that the safety of the Butterfly Solar Farm site is at an acceptable level for its role in its intended operating environment. The safety strategy employed provides a logically stated and convincingly demonstrated reason that all safety requirements can be met. The overarching safety claim has the following elements:

1. A Technical Risk Element:
    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) Element:
    a. This part seeks to demonstrate that the processes used to design, implement, and verify the product is 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.
    b. The development of the HL [Ref 5] 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.

6.2 Safety Criteria

The consequence for each potential occurrence involving the BESS shall be categorised according to classification which accounts for both frequency of occurrence and severity of outcome (risk) as defined in the following:

1. The consequence definitions are defined in Table 6-1.
2. The frequency definitions and bands used are detailed in Table 6-2.
3. The Risk Class Matrix is shown in Table 6-3.
4. The Risk Class definitions are given in Table 6-4.

The safety criteria used in this document have been amended and adapted from those defined within the US Department of Defence Mil-Spec 882E [Ref. 10] and the Ministry of Defence UK Defence Standard 00-56 [Ref. 11], using safety target and limit benchmarks from the HSE R2P2 [Ref. 1]. This assessment criteria will be used to ascertain the residual risk posed by prospective suppliers BESS.

Table 6-1 – Consequence Definitions

Risk Category	BESS Description			
	Asset	Capability	Environmental	Human
Catastrophic	Complete loss of BESS and surrounding 3rd party assets	Capability lost	Irreversible and significant environmental impact	Fatality or permanent life changing disability
Critical	Complete loss of BESS	Capability seriously affected	Reversible but significant environmental impact (long-term)	Permanent partial disability, injuries, or occupational illness
Marginal	Partial loss of BESS Not repairable – components retrievable	Capability less seriously affected	Reversible moderate (decontamination possible) environmental impact	Less serious personal injury, illness – A&E / GP assistance required
Negligible	Minor BESS damage – repairable	Capability impaired but possible	Minimal (self-recoverable) environmental impact	Negligible injury or illness. Treatable without recourse to A&E / GP

Table 6-2 – Frequency Definitions

Accident Frequency	Occurrence Rate		Qualitative Definition
	Percentage Probability Range Per Annum	Frequency Per Annum (8760 hrs.) (fph)	
Frequent	10% < P	1.0E-03 or greater	Likely to occur often (repeatedly) in the 40-year operating period.
Probable	1% < P ≤ 10%	1.0E-04 to 1.0E-05	Will occur several times in the Lifetime
Occasional	0.1% < P ≤ 1%	1.0E-05 to 1.0E-06	Likely to occur sometime in the Lifetime
Remote	0.01% < P ≤ 0.1%	1.0E-06 to 1.0E-07	Unlikely, but possible to occur in the Lifetime
Improbable	P ≤ 0.01%	1.0E-07 or less	So unlikely, it can be assumed occurrence may not be experienced in the Lifetime
Eliminated	Incredible (physically impossible) of occurrence within the life of an item. This category is to be used when potential hazards are identified and later eliminated. (Nominally the occurrence rate has been assessed as <1.0E-08)		

Table 6-3 – Risk Class Matrix

	Severity			
	Catastrophic	Critical	Marginal	Negligible
Frequency	1	2	3	4
Frequent	A	A	A	B
Probable	A	A	B	C
Occasional	A	B	C	D
Remote	B	C	D	D
Improbable	C	D	D	D
Eliminated	E	E	E	E

Table 6-4 – Risk Class Definitions

Risk Class	Risk Class Definition
(A) *Intolerable*	Intolerable: Risks must be reduced.
(B) *Undesirable*	Undesirable: Risks should be reduced. ALARP must be demonstrated.
(C) *Limited Tolerable*	Limited Tolerable: Risks can be reduced. ALARP must be demonstrated.
(D) *Tolerable*	Tolerable: No action required. ALARP must be demonstrated.
(E) *No Risk*	No action required.

6.3 Modular Safety Assurance

The construct of the safety assurance in the design of a BESS unit is vested in a ground up approach from cell to battery to rack to fully built BESS, comprising:

1. UN38.3 Testing [Ref 8] - UN38.3 is the United Nations standard that lithium batteries must meet if they are certified as safe to transport. Whilst lithium batteries have safeguards built-in to withstand the environmental and physical hazards they may encounter during transportation, UN38.3 acts as a 'rubber stamp' and shows that batteries are safe to move from one location to another.

2. UL1973 (the Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power, and Light Electric Rail Applications) [Ref 6]. This is the safety standard for energy storage systems. It specifies detailed requirements that manufacturers of BESS must meet to qualify for safety certification. UL1973 certification ensures that the BESS system is safe and reliable for use in real-world conditions. Compliance with UL1973 is necessary to ensure the safety, reliability, and proper functioning of the battery components of a BESS system.

3. UL9540A (BESS Test Method) [Ref 7] is the Standard for Safety Test Method for Evaluating Thermal Runaway (TR) Fire Propagation in Battery Energy Storage Systems. There are four stages in the UL9540A test method:
    a. Cell Level Test: Assessing whether a cell can exhibit TR. It also checks its characteristics and flammability.
    b. Module (Battery) Level Test: The objective is to determine if TR propagates with the module. In addition, it establishes the heat release and gas composition.
    c. Rack Level Test: Assessment of the whole unit to establish initially how quickly fire spreads and secondly for the heat and gas release rates and relationship with other emerging hazards.
    d. Installation Level Test: For completeness installation testing is conducted. This is an optional test, but the objective is to determine how effective the product fire protection is.

6.4 Certification

The BESS units to be procured will be designed to meet relevant industry standards and legal requirements which contain specific safety requirements, Section 5.2 refers.

7.0 Safety Management

7.1 Hazardous Material

Any hazardous materials held and stored at the BESS facility will be fully justified and will be detailed in the Butterfly Solar Farm ERP, detailing the location, description, precautions to be adopted and quantity.

7.2 Emergency Response Plan

As part of the initial development, an ERP will be developed, in conjunction with the FRS, that outlines how the operator will respond to incident and accident scenarios at the site. This includes the interfaces with external first responder organisations. The ERP is iterative in approach and has been developed in parallel with technical safety requirements. This ensures that the site design and ERP are properly integrated, and that appropriate information can be provided to first responders to include in their planning activities.

7.3 BESS Hazard Log

The BESS HL [Ref. 5 and Appendix B] is managed in the form of an excel spreadsheet and is currently generic, detailing the risks most commonly present in a BESS utilising LFP technology. The benefit of using a HL tool is that it provides an auditable record of all decisions made for the assessment of risk for the BESS Project which will be managed through life on a central repository.

7.4 Safety Management Structure

The BESS 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 BESS. At this juncture the minimum requirement is for a formal top-down management structure that has the authority and responsibility to ensure safety management is at the forefront of products, procedures, and services.

7.5 Overarching Policy

All BESS development activities shall consider safety and environment as an integrated part of the BESS 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.

7.6 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. Further details will be captured within the OBSMP to be secured by planning conditions.

7.7 Staff Competence

The BESS 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.

8.0 Conclusions and Recommendations

8.1 Results

The HL [Ref. 5 and Appendix B] is the tool used to monitor and manage hazards, causes and controls associated with this site. The HL is used to tabulate the level of residual risk posed by the installation. The Site Safety Audit will determine that the control measures identified are present.

8.2 Conclusions

It is concluded that, as far as reasonably practicable and for the Butterfly Solar Farm site, that currently foreseeable hazards associated with the equipment have been identified, and these are contained in the HL [Ref. 5 and Appendix B]. These hazards are actively managed and added to as necessary and will be reported on at each Safety Working Group (SWG).

This OBSMP has been developed using existing knowledge of renewable and BESS capability and leans heavily on the subject matter expertise that ARC has in this technological domain. Installation of the BESS in accordance with OEM instructions followed by a period of qualification and testing will provide the supporting evidence. This will also allow for the consolidation of control evidence and enhanced development of mitigation to further reduce the level of risk posed.

8.3 Recommendations

It is recommended that the safety management, as defined in this OBSMP, is adhered to throughout the site life to ensure that safety management is developed as the programme progresses and remains valid through the life of the site.

Given the current understanding of the site layout, systems to be employed, and control measures to be implemented it has been determined that the residual risk to the public is Class D, Appendix B refers. The Class C hazards all relate to maintainer hazards and represent the worst-case scenario. Periodic review of the HL [Ref. 5] will identify further opportunities to improve these hazards.

Adherence to the recommendations and safety principles through detailed design, installation and operation will be demonstrated through the Operational Safety Audit Report to be approved prior to commercial operation of the site.

Given the above discourse and output of the Site Safety Audit, it will be possible to declare ALARP, cognisant of continued implementation of the proposed framework for safety management presented in this OBSMP. This OBSMP will be updated as and when additional information becomes available.

9.0 References

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

2. NFCC Grid Scale BESS Planning – Guidance for FRS dated Nov 2022.

3. Department for Energy Security and Net Zero – Health and Safety Guidance for Electrical Energy Storage Systems. Health and Safety Guidance for Grid Scale Electrical Energy Storage Systems (publishing.service.gov.uk)

4. Factory Mutual Property Loss Prevention Datasheet 5-33 dated Jan 2024 (Interim Revision).

5. Butterfly Solar Farm BESS Hazard Log - ARC-1302-011-R2, Draft A, May 2025.

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

7. UL9540A – BESS Test Methods.

8. UN38.3 Standard Requirements for Lithium Battery Production - 4th Revision.

9. NFPA 855 Standard for the Installation of Stationary Energy Storage Systems dated Aug 2023.

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

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

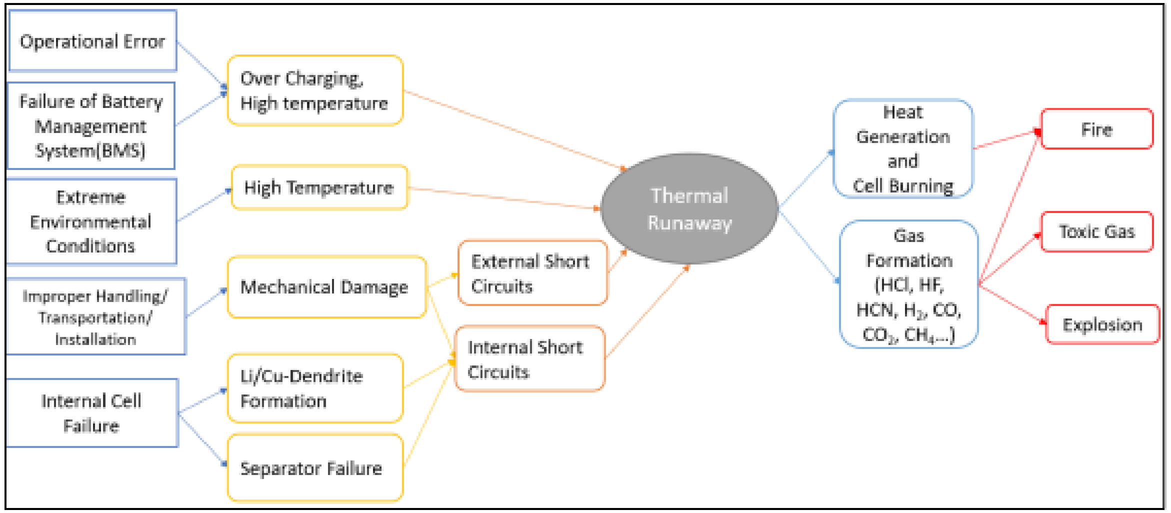
Appendix A – BESS Frequently Asked Questions

Ser	Question	Answer
1	How does a BESS work?	A BESS employs 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. The primary use for BESS is to store electrical energy generated by energy suppliers during period of low demand and releasing in periods of high demand, thus balancing out changes in supply and demand on the National Grid.
2	How safe is a BESS?	The Department for Energy Security and Net Zero promulgates on a regular basis the Renewable Energy Planning Database (REPD). From the quarterly extract (dated Apr 2025) the data has been filtered for BESS installations in the UK and the following salient points are deduced[2]: 1. As of Apr 2025, there are approx. 132 operational BESS sites listed in the REPD[3], 8 having been decommissioned, 96 are under construction and a further 834 have planning consent and are awaiting construction. 2. The current operational BESS provides the UK with an estimated 2.6GWelec storage and those awaiting construction will provide an additional 5.4GWelec of storage. 3. Since 2006 UK BESS installations have accumulated an estimated 700 years of operation, this equates to 240,000 days of operation. 4. There have currently been only two reported BESS fires in the UK that have required FRS attendance, these occurred at Carnegie Road, Liverpool in Sept 2020 and East Tilbury in Feb 2025, the cause of the latter is yet to be declared. Given the estimated 6 million hours of operation, extrapolates out to approx. 3.3E-07 (0.00000014) failures per hour (fph) for BESS in the UK. 5. To date, there have been no recorded fatalities, third-party injuries, or environmental damage resulting from BESS incidents in the UK. Reflecting on the HSE R2P2 guidance, an individual risk of death of 1.0E-05 per year (or 1 in 100,000 annually) is considered broadly acceptable for workers. Based on this framework, the risk

[2] The REPD tracks the progress of energy projects, including BESSs, through the planning system. Until 2021, the REPD only recorded projects with a capacity over 1 MW). Since 2021, it also includes projects with a capacity over 150 kilowatts (kW). Therefore, BESSs that were going through the planning system before 2021 may not have been captured in the REPD – Source: Commons Library Research Briefing, 19 April 2024 – BESS.

[3] This is a conservative figure as the REPD did not account for project under 1MW until 2021.

Ser	Question	Answer
		associated with BESS operation is assessed to be within the broadly acceptable range and compliant with the HSE ALARP principles.
3	Lithium-Ion is sensitive to temperature variations – how is this controlled?	The batteries are housed in an ISO 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 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 BESS 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 usually an issue for a BESS 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 of dendrites (electrolytic crystals) which puncture the membrane isolating the anode and cathode – this can, but not always, result in a short-circuit and TR. 3. Over-temperature in the cell because of: . Over-charging (which is controlled by 2 separate BMS – battery and rack). . High ambient temperature – controlled by the ECU. The illustration below provides an outline of the possible causes of TR.

Ser	Question	Answer
		
5	How can TR be controlled?	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. Since the early inception of BESS safeguards in the design have developed and are now details in UL1973 and BESS are assessed against UL9540A. 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 Heating, Ventilation and Air Conditioning unit (the ECU). 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 (the cells used in BESS, like other batteries do not perform well in

Ser	Question	Answer
		low temperature conditions). It should be noted that most BESS only operate at between 80-90% of capacity provide an engineering margin that mitigates the probability of over-charging the cells.
6	How is a BESS fire controlled and suppressed?	If the TR is not controlled and spreads, known as Thermal Runaway Propagation, the fire detection and suppression system (FDSS) will activate. There are currently two types of FDSS that are used in BESS; 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. Aerosol systems generally require a more complex and intricate delivery system to reach all areas of the container. 4. Gaseous systems require a sealed environment in which to operate. As such if the container is opened and oxygen reintroduced it can lead to the fire reigniting, as such they require the ECU to close prior to activation (to prevent the ECU from pushing out the extinguishing medium). 5. Various FDSS aerosols (also known as aqueous) and gaseous systems are available, and they use a variety of aerosol solutions. Under consideration for this site is the use of an aerosol aqueous solution containing potassium carbonate (K_2CO_3) – this inhibits the fire by isolating at a molecular level with the chemical chain reactions forming the flame front. This aerosol is non-harmful to the environment and presents no health and safety concerns to first responders.

Ser	Question	Answer
7	Can water be used to extinguish a Lithium-Ion fire?	The use of water to extinguish a BESS fire has some drawbacks and disadvantages over bespoke FDSS aerosol mediums, these being: 1. Due to the design of the BESS 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. 2. 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 BESS. 3. 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. 4. The application of water on a BESS fire increases the generation of gases such as carbon monoxide (CO), hydrogen (H_2) and hydrogen fluoride (HF). Applying water causes incomplete combustion of organic substances inside the battery resulting in production of CO rather than CO_2; when water is applied, H_2 is released that, without combustion, can react with phosphorus pentafluoride, if present in free form, to produce gaseous HF.
8	What are the environmental consequences of a BESS fire?	In the event of a BESS fire several chemicals in gaseous form can be released and the composition and concentration of the plume (also referred to as the vapour cloud). In the event of a BESS fire amongst the general gases released are CO, HF, oxygen and hydrogen. The BESS fire at Carnegie Road, Liverpool – Sept 2020 was monitored, and the resultant composition of the plume was 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 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 BESS and on testing was found to be a low alkaline level, as opposed to acidic. Further to this the recent fire at Moss Landing California (Feb 2025), was monitored at 1 second intervals for toxic substances in the smoke plume. It was established that the composition of the plume emanating from the fire was within US Air Pollution limits. California Air Quality limits for HF are stricter than those in the UK.

Ser	Question	Answer
9	How is the BESS site secured?	The BESS Site is secured through fences / walls and monitored remotely via security cameras. Warning signs along the fence indicates the presence of electrical storage facilities within the site.
10	How is the serviceability of the BESS assured?	The Health and Usage data for each BESS is remoted to a centralised 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 multiple times in the 40-year life of the site.

Appendix B – Butterfly Solar Farm Hazard Log

Hazard ID	Hazard Description	Cause ID	Causes Summary	Control ID	Control Measures	Cause Prob	Hazard Prob	Worst-Case Severity	Classification
Haz_BESS_001	Uncontrolled release of chemical energy - TR	Cse_BESS_001	Internal failure of cell	Ctrl_BESS_001	The cell has been selected and configured such that the loading of the cell does not cause excessive stress. The design of the BESS will be compliant to UL1973, and the BESS has been qualified to UL9540A	Improbable	Improbable	Marginal	D
				Ctrl_BESS_002	The cell will have been tested at the expected stress levels to show no signs of premature venting/failure or excessive voltage drop or temperature rise in accordance with the requirements of UL9540A				
				Ctrl_BESS_003	The battery design spaces cells as far apart as possible to reduce direct heating effect from one cell to another, in accordance with UL1973				
				Ctrl_BESS_004	The cells are certified by an approved 3rd party to meet UN38.3 transport test requirements and IEC62619 Safety Requirements				
		Cse_BESS_003	Over Temperature	Ctrl_BESS_005	The BMS senses the individual battery temperature will isolate the Charge (CHG) and discharge (DSG) of the totality of BESS.	Improbable			
				Ctrl_BESS_006	The BESS is remotely monitored and managed. Allowing the BESS to be electrically isolated from the supply (removing the charge will remove any external stimulus to the batteries).				
		Cse_BESS_004	OC - Excessive Charge Current	Ctrl_BESS_007	BMS Charge Control - The BMS can differentiate recoverable and irrecoverable balance issues, if a single battery was so heavily depleted that it was beyond the specification, the system (as a whole) would be permanently disabled to block all	Improbable			

Hazard ID	Hazard Description	Cause ID	Causes Summary	Control ID	Control Measures	Cause Prob	Hazard Prob	Worst-Case Severity	Classification
					further risks.				
				Ctrl_BESS_020	Fail safe: BMS is backed up by an Over Current Protection Fuse				
		Cse_BESS_005	OC - Excessive Discharge (Surge)	Ctrl_BESS_007	BMS Charge Control - The BMS can differentiate recoverable and irrecoverable balance issues, if a single battery was so heavily depleted that it was beyond the specification, the system (as a whole) would be permanently disabled to block all further risks.	Improbable			
				Ctrl_BESS_020	Fail safe: BMS is backed up by an Over Current Protection Fuse				
				Ctrl_BESS_001	Demand on cell stacks is lower than the maximum capability of the cells - Depth of Discharge within bounds and controlled via BMS				
		Cse_BESS_006	Over-Voltage (OV) - Continuous Charge	Ctrl_BESS_001	Demand on cell stacks is lower than the maximum capability of the cells - Depth of Discharge within bounds and controlled via BMS	Improbable			
				Ctrl_BESS_007	BMS Charge Control - The BMS can differentiate recoverable and irrecoverable balance issues, if a single battery was so heavily depleted that it was beyond the specification, the system (as a whole) would be permanently disabled to block all further risks.				
		Cse_BESS_007	Low Temperature Charging	Ctrtl_BESS_021	The BESS is a temperature-controlled environment and as such unlikely to be subject to temperatures below the operating capability of the Li-Ion Cells. In the event of ECU failure (or failure to maintain the temperature parameters, the BESS will inhibit	Improbable			

Hazard ID	Hazard Description	Cause ID	Causes Summary	Control ID	Control Measures	Cause Prob	Hazard Prob	Worst-Case Severity	Classification
					charging)				
				Ctrl_BESS_001	Demand on cell stacks is lower than the maximum capability of the cells - Depth of Discharge within bounds and controlled via BMS				
		Cse_BESS_008	Under-Voltage (UV) - Continuous Discharge	Ctrl_BESS_001	Demand on cell stacks is lower than the maximum capability of the cells - Depth of Discharge within bounds and controlled via BMS	Improbable			
				Ctrl_BESS_007	BMS Charge Control - The BMS can differentiate recoverable and irrecoverable balance issues, if a single battery was so heavily depleted that it was beyond the specification, the system (as a whole) would be permanently disabled to prevent further discharge.				
Haz_BESS_002A	Contact with exposed electrical components - HV-3P	Cse_BESS_009	Exposure to electrical sources (e.g., contacts, wiring etc.)	Ctrl_BESS_008	Access to the sites is controlled and the access secured. The site is remotely monitored 24/7 with security cameras.	Improbable	Improbable	Critical	D
				Ctrl_BESS_009	Access to the invertors is controlled and the access secured when in operation.	Improbable			
		Cse_BESS_010	Effect of high current pulses (Electro Magnetic (EM)) introduce a conductive path	Ctrl_BESS_010	3P cables are routed in separate cable tray and kept distant from other cables to reduce propensity for current induction	Improbable			
		Cse_BESS_011	Internal short to casing provides conductive path	Ctrl_BESS_011	Inverters will be fully earthed to ground	Improbable			
Haz_BESS_002B	Contact with exposed electrical components - HV-DC	Cse_BESS_009	Exposure to electrical sources (e.g., contacts, wiring etc.)	Ctrl_BESS_008	Access to the sites is controlled and the access secured. The site is remotely monitored 24/7 with security cameras.	Improbable	Improbable	Critical	D

Hazard ID	Hazard Description	Cause ID	Causes Summary	Control ID	Control Measures	Cause Prob	Hazard Prob	Worst-Case Severity	Classification
				Ctrl_BESS_009	Access to the BESS is controlled and the access secured when in operation.				
		Cse_BESS_010	Effect of high current pulses (EM) introduce a conductive path	Ctrl_BESS_010	BESS sourced will be Electromagnetic Compatibility (EMC) certified to IEC 61000-6-2 and IEC 61000-6-4	Improbable			
		Cse_BESS_011	Internal short to casing provides conductive path	Ctrl_BESS_011	All infrastructure is fully earthed to ground and monitored. All infrastructure is subject to periodic inspection	Improbable			
Haz_BESS_002C	Contact with exposed electrical components - LV-DC	Cse_BESS_009	Exposure to electrical sources (e.g. contacts, wiring etc.)	Ctrl_BESS_008	Access to the sites is controlled and the access secured. The site is remotely monitored 24/7 with security cameras	Improbable	Improbable	Critical	D
				Ctrl_BESS_009	Access to the BESS is controlled and the access secured when in operation.				
		Cse_BESS_011	Internal short to casing provides conductive path	Ctrl_BESS_011	BESS units are fully earthed to ground and monitored by the BESS BMS	Improbable			
Haz_BESS_003	Failure of EMC/EMI protection impacts on system functionality	Cse_BESS_012	BESS not EM compatible with environment in which it is located	Ctrl_BESS_012	BESS is located remotely and EMC compatible with all associated site infrastructure	Improbable	Improbable	Marginal	D
Haz_BESS_004	Operator / maintainer exposure to Hazardous substances	Cse_BESS_013	Operator/Maintainer accesses internal components of the BESS	Ctrl_BESS_013	All hazardous substance listed in the OEM documentation. All maintainers provided with the appropriate PPE. A list of hazardous substances held on site is detailed in the ERP	Occasional	Occasional	Marginal	C
Haz_BESS_005	Ingress of water	Cse_BESS_014	Water Ingress into the BESS internals to the degree that it effects thaffectsionality of BESS	Ctrl_BESS_014	BESS is housed in a container and a minimum of IP44 compliant and elevated on concrete plinths	Remote	Remote	Marginal	D
				Ctrl_BESS_015	The BESS design is such that the batteries are off the floor and held in shelving				

Hazard ID	Hazard Description	Cause ID	Causes Summary	Control ID	Control Measures	Cause Prob	Hazard Prob	Worst-Case Severity	Classification
Haz_BESS_006	Maintainers are required to access the internals of BESS	Cse_BESS_013	Operator/Maintainer accesses internal components of the BESS	Ctrl_BESS_017	A Safe System of Work (SSOW) is to be developed, and a BESS maintenance course is provided to maintainers. All maintainers will require to be qualified and current prior to work on the BESS	Improbable	Improbable	Critical	D
Haz_BESS_007	Maintainers are require to lift, move, or carry heavy BESS components (in confined spaces)	Cse_BESS_015	Maintainer required to access and remove/refit heavy BESS components	Ctrl_BESS_017	A SSOW is to be developed, and a BESS maintenance course is provided to maintainers. All maintainers will require to be qualified and current prior to working on the BESS	Occasional	Occasional	Marginal	C
				Ctrl_BESS_018	MHE to be provided for the movement of components more than 25kg				
Haz_BESS_008	Gases vented during BESS operation (off-nominal) accumulate within enclosure	Cse_BESS_013	Cells stressed through failure of BMS to monitor status correctly	Ctril_BESS_016	BESS are fitted with off-gas sensors that activate ECU on detection of off-gas from cells and concurrently notify the 24/7 Remote Monitoring Facility for additional action	Improbable	Improbable	Critical	D
			Operator/Maintainer accesses internal components of the BESS	Ctrl_BESS_017	A SSOW is to be developed, and a BESS maintenance course is provided to maintainers. All maintainers will require to be qualified and current prior to working on the BESS	Improbable			
Haz_BESS_009	Operation / maintenance of the BESS exposes the user to sharp edges and hard surfaces	Cse_BESS_013	Operator/Maintainer accesses internal components of the BESS	Ctrl_BESS_017	A SSOW is to be developed, and a BESS maintenance course is provided to maintainers. All maintainers will require to be qualified and current prior to working on the BESS	Occasional	Occasional	Marginal	C
				Ctrl_BESS_019	All sharp edges to be radiused or covered to ameliorate				
Haz_BESS_010	Operator / Maintainer exposure to biological growth in the BESS	Cse_BESS_013	Operator/Maintainer accesses internal components of the BESS (after a prolonged period of use)	Ctrl_BESS_017	A SSOW is to be developed, and a BESS maintenance course is provided to maintainers. All maintainers will require to be qualified and current prior to working on the BESS	Improbable	Improbable	Negligible	D