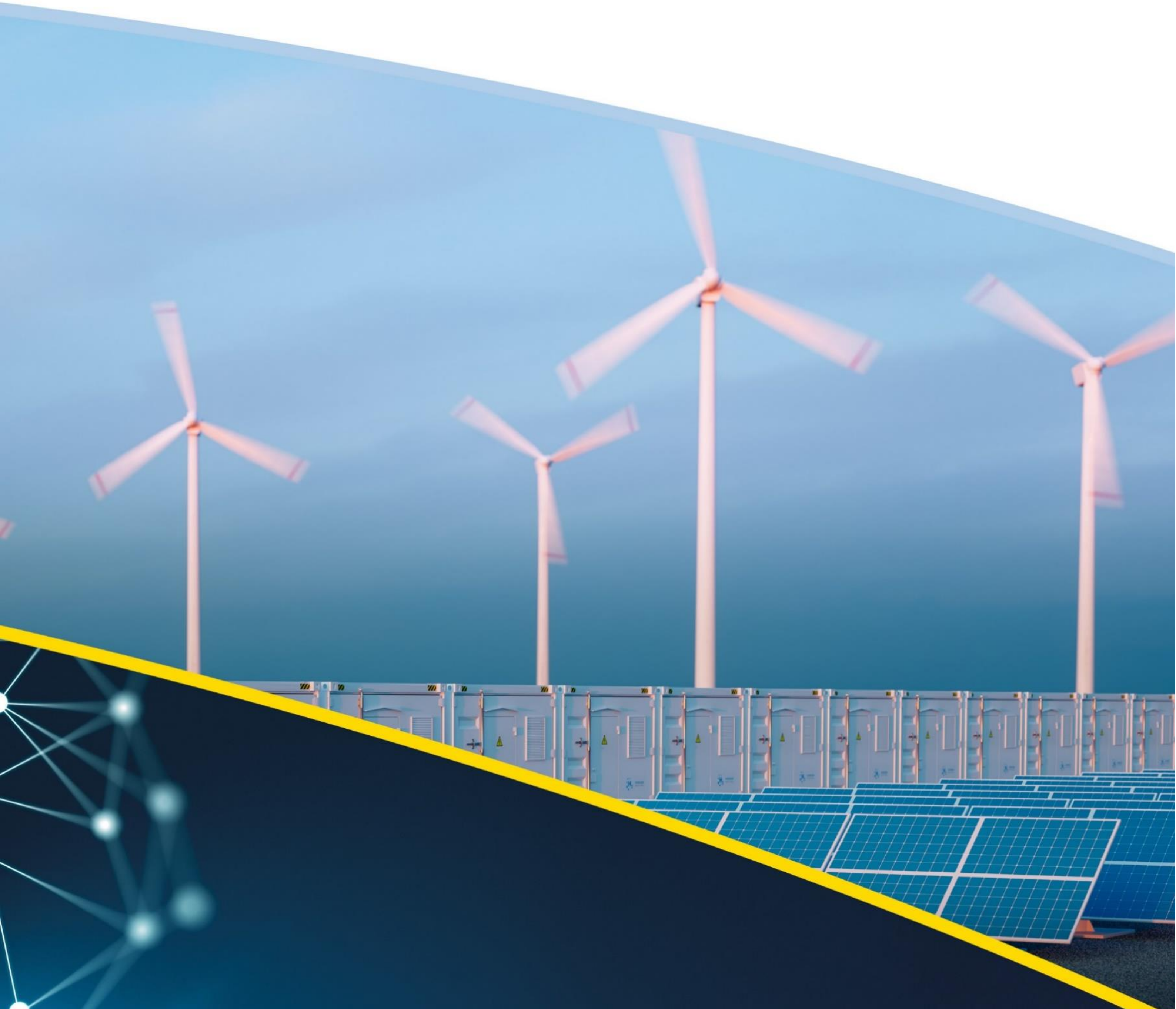

Health and Safety Guidance for Grid Scale Electrical Energy Storage Systems

March 2024

Prepared for: Department for Energy Security and Net Zero

fnc.co.uk

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Smart: Energy Storage & Flexibility Innovation

Health and Safety Guidance for Grid Scale Electrical Energy Storage Systems

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Executive Summary

The volume of grid-scale electrical energy storage systems (EESS) connecting to our electricity system is growing rapidly. These EESSs provide a key role in the decarbonisation of the electricity system by providing enhanced grid flexibility, providing ancillary services (e.g. frequency response), maximising the usable output from intermittent low carbon generation by deferring or avoiding the need for costly network upgrades and new generation capacity, and by contributing to energy security.

It is essential that EESS are developed in line with appropriate health and safety (H&S) standards and that regulations are adhered to across the industry. The complexity of the landscape, with a plethora of standards (some with overlapping requirements), can be a barrier to this. Therefore, the Department for Energy Security & Net Zero (DESNZ) have commissioned Frazer-Nash Consultancy to create a non-exhaustive, good practice guidance document.

By highlighting existing legislation, regulations, standards and other industry guidance, this document should act as guidance to EESS project developers, help navigate the H&S landscape and ensure relevant aspects of H&S are integrated into their process(es). This document focusses on ‘grid-scale’ battery applications, which for the purposes of this report are systems rated at 1MW and greater. The document is applicable to any organisation who trade in a lifecycle stage of grid-scale battery system, from design to decommissioning, as well as situations such as battery co-location with other technologies. This guidance is also primarily targeted at variants of lithium-ion batteries, which are currently the dominant energy storage solution in the market. However, the nature of the guidance is such that elements will be applicable to other battery technologies or grid scale storage systems.

Glossary

Term	Definition
BESS	Battery Energy Storage System(s)
BSI	British Standards Institution – www.bsigroup.com
CENELEC	European Committee for Electrotechnical Standardization. Responsible for European standardisation in electrical engineering. Along with two other organisations it forms the European system for technical standardisation. Standards harmonised by these agencies are regularly adopted in many countries outside Europe.
COMAH	Control of Major Accident Hazards Regulations
DESNZ	Department for Energy Security & Net Zero – one of the four branches which formerly were collectively named Department for Business, Energy and Industrial Strategy (BEIS).
DOD	Depth of Discharge
(E)ESS	(Electrical) Energy Storage System(s)
EN	European Norm. A standard developed by a European Standardisation Body that provides the basis for evaluation of equipment.
ENA	Energy Networks Association
EIA	Environmental Impact Assessment
Grid connected	Any power generation equipment which is connected directly to the public electrical supply with the purpose of providing distributed generation.
HF	Hydrofluoric Acid. A by-product of a Li-ion battery fire. Corrosive and acutely toxic.
HSE	Health and Safety Executive. Britain's national regulator for workplace health and safety.
IEC	International Electrotechnical Commission. An international standardisation body.
IEEE	Institute of Electrical and Electronics Engineers
IET	Institute of Engineering and Technology. UK based Professional Body. Develops Codes of Practice and Guidance documents and maintains the UK Wiring Regulations.
ISO	International Organisation for Standardisation
LEL	Lower Explosive Limit is the lowest concentration of vapour in air at which the vapour/air mixture is flammable
Li-ion	A broad range of rechargeable cell chemistries based on lithium-ion technology.
LPA	Local Planning Authority
MAH	Major Accident Hazard
MW	Megawatt
MWh	Megawatt-hour
NAMOS	Dangerous Substances (Notification and Marking of Sites) Regulations 1990
NFCC	National Fire Chiefs Council (based in the UK)
NFPA	The National Fire Protection Association (a U.S.-based international organization who develop codes and supporting material on topics such as fire prevention and electrical safety)
O&M	Operation and Maintenance. A lifecycle stage, relevant to ESS, when equipment upkeep is undertaken.
Ofgem	The Office of Gas and Electricity Markets
PV	Photo-voltaic(s). The term used to describe the energy generating mechanism that converts light into electrical energy.
PPE	Personal Protective Equipment

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Term	Definition
RACI	Responsible, Accountable, Consulted and Informed. A colour-coded matrix used to easily illustrate which stakeholders have which role in relation to each stage of the EESS system lifecycle.
SOC	State Of Charge
TC	Technical Committee
UPS	Uninterruptable Power Supply

Contents

1 Introduction

1.1 Document context

As the industry for battery energy storage systems (BESS) has grown, a broad range of H&S related standards have been developed. There are national and international standards, those adopted by the British Standards Institution (BSI) or published by International Electrotechnical Commission (IEC), CENELEC, ISO, etc. Furthermore, organisations such as UL and NFPA (both US based) have led the development of design, testing and installation requirements. Some commercial (e.g., dnvgl-rp-0043 part of GRIDSTOR) and not for profit organisations also produce standards or codes of practice, often in advance of a national or international standard[1].

The complexity of the landscape, with a plethora of standards (some with overlapping requirements), can be a barrier to the development of BESS in line with appropriate regulations and health and safety (H&S) standards. This highlights the need for robust, clear guidelines for grid-scale battery systems so that all stakeholders can understand good-practice and are implementing the correct health & safety measures throughout the BESS lifecycle.

Detailed guidance has been developed for domestic and small-scale commercial systems [1], [2], [3]. Furthermore, planning guidance for grid-scale battery systems has been published by government [4], and fire safety considerations published by the National Fire Chiefs Council [5].

This report builds on these other documents to provide specific guidance for grid-scale systems across their development and operational life. Frazer-Nash are the primary authors of this report, with DESNZ and the industry led storage health and safety governance group (SHS governance group) providing key insights into the necessary content.

1.2 Scope

This guidance document is primarily tailored to ‘grid scale’ battery storage systems and focusses on topics related to health and safety. There is no specific definition of ‘Grid Scale Storage’ however for the purposes of this guidance document, this is assumed to be systems with an installed capacity of 1MW or greater. The guidance covers both stand-alone open-air sites, and storage co-located with large scale generation or demand, although it is noted that co-located storage introduces design complexity and variability which cannot be fully reflected in a general guidance document.

This guidance is also primarily targeted at variants of lithium-ion batteries, which are currently the most economically viable energy storage solution for large-scale systems in the market. However, the nature of the guidance is such that elements will be applicable to other battery technologies or grid scale storage systems.

This document is applicable to any organisation or individual who trade(s) in a lifecycle stage of grid-scale battery storage, from design to decommissioning[2]. It has been structured such that readers can review key considerations for each lifecycle at an outline level across the following sections, with a detailed review of

[1] For example, IEEE or IET documents are often treated as de facto standards and considered requirements by insurance companies.
[2] Defined further in section 2.

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applicable technical standards provided in the document annexes. The guidance is not intended to be exhaustive, but it should act as a checklist, to simplify navigation of the complex standards landscape.

The document focuses on the health and safety aspects of grid scale battery system development, drawing on both national and international standards and guidance documents to highlight current good practice. It is however not a guide on battery project development, and it does not cover the standard planning and consenting process for battery system developments. Furthermore, it does not comment on any ongoing regulatory changes such as those related to Brexit or the establishment of a UKCA marking regime.
It should be emphasised that what is presented within this document is not a prescriptive checklist of activities and it is the responsibility of the overall duty holder (typically the owner and operator employer of the asset) to apply guidance to their specific project, comply with the relevant laws and take into account relevant standards.

1.3 Report Structure

This guidance document is intended to inform those involved in all stages of grid-scale battery storage system lifecycle of the relevant H&S standards that should be adhered to. The document structure is as follows:

Section 2: Grid Scale Storage Project Context and Lifecycle
This section provides a high-level overview of the lifecycle of an energy storage project, the stakeholders involved at each lifecycle stage and methods to the responsibilities each of its stakeholders may have.

Section 3: Design & Planning
This section provides an overview of considerations during the design, manufacture and certification of equipment, site appraisal and performance estimation. This section also describes the framework for risk assessment and reduction and considerations for emergency response arrangements at the planning stage.

Section 4: Transportation
This section provides guidance on health & safety during the physical movement of equipment and assets between locations.

Section 5: Installation and Commissioning
This section describes considerations for the physical installation of assets at their intended location and connection to their respective interfaces, as well as inspection, testing and training for operators and handover of the system from installer to operator, and for the post-handover tuning/bedding-in period.

Section 6: Operation & Maintenance
This section provides guidance on the safe usage, inspection, testing and upkeep of the BESS. This section also describes the Plan-Do-Check-Act concept for continual improvement.

Section 7: Decommissioning & End-of-Life
This section describes health & safety aspects during the preparation for and execution of permanent shutdown activities, including disconnection of the system and its components, their removal from the site, restoration of the land to an agreed standard, and recycling or disposal in accordance with regulations.

Section 8: References

Annex A: Standards Checklist

This section comprises of a checklist of standards, categorised to help stakeholders navigate the H&S landscape and ensure relevant aspects of H&S are integrated into their process(es). The checklist contains standards based on their relevance to each stage of the system lifecycle as well as which identified stakeholder(s) is the most likely to be responsible for the standard's implementation.

Annex B: Principal Hazards
This section presents a short overview of the principal hazards associated with battery storage and the initiating events which can cause these hazards.

Please note there are no normative references in this document. Users can refer to the documents listed in the Bibliography for further information on grid-scale H&S guidelines and other relevant standards/regulations/legislation originating in the UK or overseas (with an application to UK grid-scale H&S).

2 Grid Scale Storage Project Context and Lifecycle

2.1 System Lifecycle Stages & Stakeholders

The guidance within this document is structured around the key lifecycle stages during which H&S risks should be identified and mitigated. The system lifecycle stages for grid-scale storage systems are defined below.

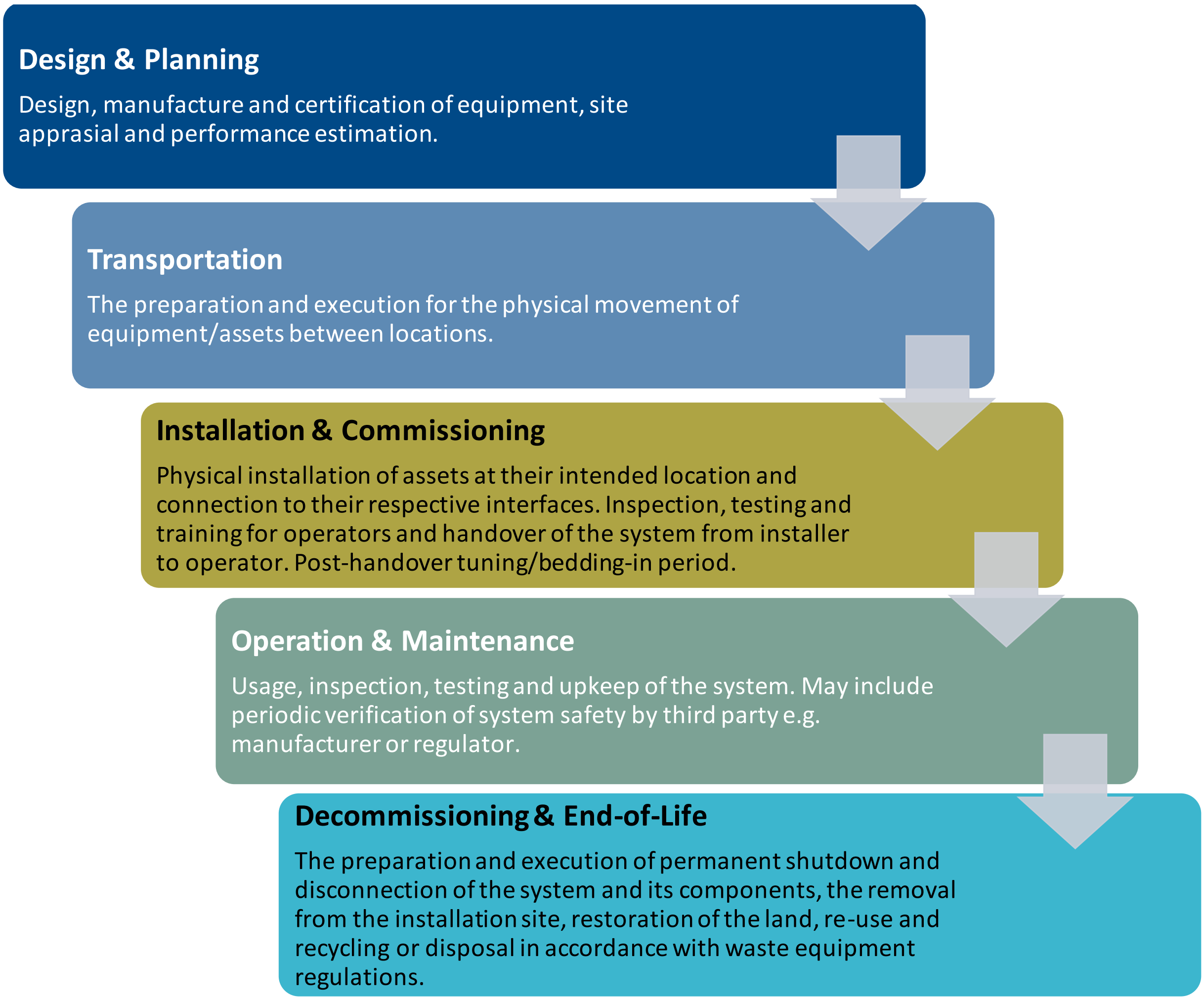

Figure 1: System lifecycles applied within this guidance document

2.2 Determining System Context, Stakeholders and Responsibilities

Different stakeholders involved across the lifecycle of the battery storage system have various roles in managing H&S risks. ISO 45001 provides a high-level framework to assess the overall system context, stakeholders, roles and responsibilities, and legal and technical requirements which with the system should comply.

2.2.1 System context

The aim of understanding the context of a system (whether that is an organisation, single stakeholder, product or full grid-scale storage system) is to review and assess what it does, where it is in the marketplace and, with respect to H&S, who could be harmed or affected by its activities. Determination of issues that could affect the system can be undertaken in a number of structured approaches such as Strengths, Weaknesses, Opportunities, Threats (SWOT) or Political, Economic, Sociological, Technological, Legal and Environmental (PESTLE) analysis [6]. The context of the system should be defined in two parts:

- **Stakeholders:** Identify the internal and external stakeholders to the system, including their requirements and expectations.
- **Scope:** Identify the internal and external factors that influence the system including planned or performed activities.

2.2.2 Determining Scope

Once the context of the system is understood, the boundaries and applicability of the H&S standards referenced within this document can be determined, which will establish the scope of its management system. The scope should not be used to exclude activities, products or services that have or can impact the system's H&S performance, or to evade its legal and other requirements. The H&S standards applicable shall include those which refer to the activities, products and services within the stakeholder's control or influence that can impact the system's H&S performance.

The stakeholder(s) will need to consider the external and internal issues which may affect the system as well as workers and other parties, the requirements of the system as they relate to their context and industry as well as the planned or performed work-related activities. The scope boundary will need defined in terms of who is included. For example, a whole organisation, only specific functions of an organisation or one or more functions across an organisation.

2.3 Stakeholders and responsibilities

There are several stakeholder groups which have different levels of responsibility for, and interest in, following guidance and best-practice relating to the five system lifecycle stages. The RACI Matrix below shows an illustrative relationship between the stakeholder groups and the system lifecycle stages. This matrix illustrates the identification of which stakeholders are responsible for each lifecycle stage, which are accountable, and which need to be consulted or informed.

This Responsible, Accountable, Consulted, and Informed (RACI) Matrix applies to the scenario where at each system lifecycle stage the product/assets are bought/procured by each stakeholders group as it progresses from design to decommissioning. Here, the Designer is responsible for the Design & Planning stage, the Installer for the Transportation and Installation & Commissioning stages and the Operator for the Operation & Maintenance stage.

		Illustrative Stakeholders							
		Designer	Installer	Operator	Asset Owner	New Investor / Developer	Regulator	Assessor / Insurer	Fire Service
System Lifecycle Stage	Design and Planning	R	C	I	C	C	C	I	C
	Transportation	I	R	I	C	I	I	C	I
	Installation & Commissioning	R	C	A	A	C	A	A	I
	Operation & Maintenance	I	C	R	A	I	A	A	I
	Decommissioning & End-of-Life	C	I	A	R	I	C	A	I

Figure 2: Example RACI matrix for a battery system development

The role of each of these stakeholders and the relationships between them can change depending on the application. Therefore, RACI matrices are application specific, and the relationships between stakeholders and lifecycle stages will need to be defined for each application. The primary responsibility for this allocation of responsibility sits with the asset owner.

2.4 Construction (Design and Management) Regulations 2015

The Construction (Design and Management) Regulations 2015 (CDM 2015) apply to the whole construction process on all construction projects and detail what each dutyholder must or should do to comply with the law to ensure projects are carried out in a way that secures health and safety. The HSE have published guidance on CDM 2015 to support understanding of legal requirements [7], and key points are summarised below. CDM 2015 primarily applies to the Design and Planning (section 3) and Installation and Commissioning (section 5) sections of this report.

CDM defines various CDM dutyholders including Clients (organisations or individuals for whom a construction project is carried out), Designers, Contractors and Workers, and identifies their main duties within a construction project. For example, Regulations 4 and 5 set out the client's duty to make suitable arrangements for managing a project and maintaining and reviewing these arrangements throughout, so the project is carried out in a way that manages the health and safety risks. These duties include:

- Appointing other dutyholders.
- Allocating sufficient time and resources to the project.
- Providing relevant information to other dutyholders.
- Ensuring the principal designer and principal contractor carry out their duties.

For grid-scale battery projects, the asset owner is likely to be the Client, and as such have ultimate responsibility for manages the health and safety risks.

Designers and Principal Designers (where there is more than one designer) are usually appointed by the client to take control of the pre-construction phase, and will have a key role in planning, managing, monitoring and coordinating health and safety in the pre-construction phase. Designers should eliminate foreseeable health and safety risks and, where that is not possible, take steps to reduce or control those risks. Designers should make sure the client is aware of the client duties under CDM 2015 before starting any design work.

Contractors and Principal Contractors (where there is more than one contractor) is appointed by the client to control the construction phase of any project, and will have an important role in managing health and safety risks during the construction phase so they must have the skills, knowledge and experience to carry out this work. They will also be responsible for developing construction plans, ensuring workers understand health and safety arrangements and have ongoing arrangements in place for managing health and safety throughout the construction phase.

3 Design & Planning

In addition to the core site and system design, the Design & Planning stage covers a range of elements which must be considered early in the project lifecycle. This is due to their potential to impose changes on the design, such as additional risk mitigations, which would be difficult or costly to make after procurement or building work has begun. The sections below outline key areas to consider, and Annex A - provides an overview of relevant technical standards.

Related guidance for the Design & Planning stage include planning and practice guidance from the Department for Levelling Up, Housing and communities [4] and guidance on Grid Sale Battery Energy Storage System fire safety planning by the National Fire Chiefs Council (NFCC) [5]. CDM 2015 (introduced in section 2.4) applies to this phase and details the duties of clients (e.g. asset owners) and system designers.

3.1 Risk Management

3.1.1 BESS Risk Assessment

Effective assessment of potential risks is central to management of health and safety at the outset of a project.

When considering the BESS context, hazards should be considered for all stages of the system lifecycle which are applicable to the organisation (either directly or indirectly). All system components should be designed, manufactured, and tested in accordance with relevant safety standards. The integration of BESS components should also be considered when performing a risk assessment, in particular any incompatibilities between components which may present a risk to H&S. The assessment should consider the total energy stored in the BESS and the population which may be affected by particular hazards.

As introduced in Annex A, IEC 62933-5-2:2020, the international standard for electrochemical-based EES system safety requirements, is a standard which describes safety aspects for grid-connected electrochemical energy storage systems. IEC 62933-5-2 provides an assessment framework for the reduction of the risk associated with BESS as manufactured and intended to be installed [8].

Further detailed information on designer's considerations for risk assessments are presented in the Construction Industry Research and Information Association (CIRIA) guidance (C755 and C756). Planning applications and decisions should always be taken with a complete assessment of risks and impacts, both of the facility and the surrounding environment.

There should be a full consideration of risks including, but not limited to, accidental or intentional damage and natural phenomena and security. Note that risk assessments should be bidirectional – i.e., include both risks to the project and from the project. The planning process should assess the following risks and describe how the credible worst case has been mitigated.

Due to the potential hazards to the surroundings of any BESS, careful considerations must be made as to its location to determine the risks that the storage proposes. With lithium-based technologies, thermal runaway is a key failure mode which can lead to hazards to the nearby environment. Thermal runaway can be caused by a wide variety of internal and external factors, including physical damage, misuse, aging and fluctuating temperatures outside of the safe temperature range. Thermal runaway can lead to:

- Fire

- Explosion
- Release of toxic gases or water run-off

These hazards pose a serious risk to the immediate vicinity of any BESS, which places an emphasis on the consideration of site location, a few of which are explored in the following subsections. More detailed information on the hazards posed by chemical storage can be found in Annex B.

3.1.2 Risk Assessment & Reduction

Prior to completing any work or activity, the stakeholder(s) should determine and assess the risks and opportunities that are relevant to the intended outcomes of the management of H&S. The stakeholder(s) should maintain documented information on risks and opportunities as well as the processes and actions needed to determine and address its risks and opportunities to the extent necessary to have confidence they are conducted as planned.

Following a risk assessment and analysis framework is one method of doing this. One example is the framework defined in the BSI Standard for BESS BS EN 62933 Part 5-2 [8] for the assessment and reduction of risk associated with the BESS as manufactured, and as intended to be installed. This is a sequence follows this general process:

- Definition of the project,
- Identification of hazards,
- Estimation of risk,
- Evaluation of risk.

If the risk is deemed tolerable after these 4 steps, then it can be validated and documented. However, if it is deemed an intolerable risk then the stakeholder should proceed to risk reduction, and then the re-estimated and re-evaluation of the risk until it is deemed tolerable. Evidence and documentation of completion of the sequence should be kept, and eventually validated to complete the risk assessment. Risk management should be conducted through three main approaches [9]:

- Inherently safe design,
- Guards and protective devices and,
- Information for end users.

Annex B in this guidance provides further detail on the relevant hazards associated with various energy storage technologies which could lead to a H&S risk, potential risk analysis frameworks and considerations for site/project risk assessments. The following section also contains guidance on specific challenges related to lithium-ion technology.

3.2 Technology Selection

3.2.1 Battery system

3.2.1.1 Battery chemistry

There are a range of battery types available which suit different use cases, have a different maturity and which present different risks and safety profiles. Lithium-ion batteries make up the majority of the current

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grid-scale BESS global market share, due to their ideal characteristics of high energy density, high energy efficiency, and a long cycle life.

There are multiple variants of li-ion batteries, with Lithium Nickel Manganese Cobalt Oxide (NMC) and Lithium Iron Phosphate (LFP) the two main chemistries that dominate stationary li-ion energy storage projects. There are multiple trade-offs when selecting a battery cell types, including: power and energy density, availability, cost, and safety. From a safety perspective, it is noted that LFP batteries typically have better thermal stability (lowering the probability of thermal runaway) than NMC batteries [10]. Battery chemistries will influence vapour cloud formation in the event of a battery fire. This can impact recommendations for system layout and fire containment as described in section 3.4.1.

3.2.1.2 Battery system capabilities, architecture and control

Battery systems are developed in a modular fashion, where individual battery cells are combined to create modules, modules are combined within racks, and these can then be combined to make fully containerised battery systems (usually with in-built control, protection and safety functions). Grid scale applications consist of multiple containers, connected via multiple inverters, transformers and switchgear under a single point of connection to the electrical grid. The individual batteries are monitored and controller via Battery Management Systems (BMS) (often with hierarchical control from modules up to overall containers), with an overall Plant Controller coordinating full BESS system operation (including interfacing with individual BMSs and other control systems such as the Energy Management System (EMS)). An onsite and/or remote-control room will provide a Human Machine Interface (HMI) to enable operator control. Sites may also integrate a third-party control/control signals for service optimisers or Route to Market providers.
All aspects of this modular architecture can affect the capabilities and safety of the battery system. Specific safety considerations include:

- **Equipment certification** – having battery components tested under standards such as IEC 62619 and UL9540A[3] is a key step in ensuring the robustness of battery installations. However, project integrators should not fully rely on test compliance, and ensure that their own specific system configuration matches standard test conditions. Potential issues may include:
  - Insufficient segregation or partitioning between battery modules, where adjacent modules may drive an increase in temperature increase.
  - Ineffective management of off gases between racks within a container.
  - Insufficient separation between containers (see section 3.4.1 for more detail)
- **Use case** – The system is designed and operated to match its intended use case (s) (e.g. energy arbitrage, frequency response, stability support). Specific characteristics may include appropriate charge/discharge cycling capability and tolerance to rapid discharge and how asset health may degrade over time based on how the battery is used. The use case for the battery system may change over time (e.g. to provide new grid services) and as such you may want to specify equipment with operating margins to safely manage future use cases. Battery manufacturers will be able to advise on the capability of their specific systems.
- **Detection and monitoring** – available technologies to identify and warn of developing hazards, (such as thermal runaway, cell venting or leakage) include BMSs able to detect developing fault conditions, electrolyte vapour detection systems, combustible gas monitoring with the ability to control container ventilation systems, and external audible and visual warning devices. Specific devices to assist in

[3] Note that UL9540 was updated in July 2022 to include large-scale fire testing. UL9540A provides details of new test requirements to meet the revised UL9540 standard. Where UL9540 compliance is required, developers should check that testing is compliant with the new UL9540A.

monitoring cell and container conditions are commercially available and can be deployed in addition to existing BMSs. Site level monitoring should be provided via the control room. The safety implications of any remote monitoring and control systems failures (e.g. due to a communication network failure) should also be assessed. This should inform design aspects such as communication reliability, availability, redundancy and back up control arrangements.

- **Electrical configuration and interface** – batteries can rapidly discharge significant amounts of electrical energy and as such electrical protection should be used to manage these hazards. Hazards such as arc flash are discussed further in section 3.2.2.1.
- **Designing for location weather** – consideration should be given to how weather at the selected battery site may impact operating capabilities or asset degradation. Obvious examples include ambient temperature and how this might change over time (including the impacts of climate change and the possibility of extreme heatwaves). This could impact asset operation and cooling requirements. Other considerations include locations near the coast, where coastal 'salt air' can accelerate corrosion.

3.2.1.3 Lithium-ion specific standards

As a maturing technology there are standards addressing the full lifecycle of Li-ion battery developments, however these standards are also being constantly updated as technology progresses and risks are better understood.

Lithium-Ion specific standards include BS EN IEC 62458-6 covers the measures for protection for secondary batteries and battery installations and the measures for protection during both normal operation and under expected fault conditions. This standard applies to the installation, use, inspection, maintenance, and disposal of lithium batteries, which encompasses all lifecycle stages of the installation, and applies to all stakeholders in the use of this battery technology.

BS EN IEC 62619:2022 covers the safety requirements and tests for the safe operation for secondary lithium cells and batteries, for industrial applications, which includes stationary applications. Published under the IEC 62619 umbrella, BS EN IEC 63056:2020 is specific towards lithium cells and batteries for use in BESS and covers the requirements and tests for product safety. Both documents make a normative reference towards BS EN 62620:2015, which also covers the marking, tests, and requirements for lithium secondary cells.

3.2.2 Balance of plant

3.2.2.1 Electrical, control and communication equipment

Electrical and control systems associated with the battery system and interface to the power network have a substantial role in managing potential hazards. Electrical power distribution equipment (including inverters, distribution buses, cables, switchgear/ protection systems, transformers) all have their own failure modes which can lead to safety issues on any generation, network or storage site. These risks are better understood and regulated, through longstanding electrical industry guidance and codes, and top-level hazards are outlined in Annex B. Network operators, manufacturers and experienced electrical contractors will be able to offer guidance and clarify connection requirements.

Specific considerations associated with battery systems include:

- **Arc Flash** – battery systems present a potential source of arc flash energy[4]. The electrical characteristics of batteries is such that their energy is readily discharged. When coupled to suitable high voltage and

[4] AS/NZS 5139:2019 [38] defines arc flash as an "electrical explosion or discharge, which occurs between electrified conductors during a fault or short circuit condition". It further states that "Arc flash occurs when electrical current

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capacity levels they can supply high magnitude and high rate of change of fault current. This rapidly developing fault current can quickly contribute energy to a fault, risking an arc flash event. Whilst the arc flash risk is relatively well understood for AC systems, DC arc flash assessment is less standardised. Reference [11] introduces two methods through which arc flash risk can be assessed being on size and scale of the storage facility. Effective electrical protection is key to mitigating arc flash risk as well as appropriate PPE for operators and maintainers of equipment.

- **Changing use cases** – As noted in sections 3.2.1.2, the use case for the battery system may change over time (e.g. to provide new grid services) and as such you may want to specify equipment with operating margins to safely manage future use cases.
- **Repowering** - battery (and other generation) installations are often repowered, with battery modules being replaced and upgraded but certain electrical equipment being maintained[5]. Given the potential for substantial battery technology development over the ~10-year operating life of Li Ion modules, care must be taken that the capabilities of the electrical equipment and repowered battery remain matched.
- **Futureproofing and resilience** – Designs should be futureproofed where possible for the effects of climate change (e.g. extreme operating temperatures beyond historical norms).
- **Detection and monitoring** – as with the battery system itself (section 3.2.1.2), appropriate fault detection equipment should be employed for all related electrical plant and control systems.
- **Electrical interface and network communications** – As with other generation assets, appropriate communication and interface protection equipment should be in place to manage any safety issues on the network side (e.g. faults and islanding events). Due to electrical network constraints, battery systems may be subject to various active network management control schemes to manage capacity issues.
- **Backup supplies** – Uninterruptible Power Supplies (UPS) may be required for monitoring, communication and protection equipment. This should be suitably rated to maintain basic control, monitoring and protection functionality during events such as loss of grid supply such that the site can be maintained safely. UPS systems will also have their own failure modes which could introduce separate hazards.

3.2.2.2 Monitoring, Fire Detection and Suppression

The selection of appropriate equipment for hazard mitigation can have a significant impact on overall system risk. Key considerations, particularly related to fire and explosion risks, are:

- **Fire Detection and monitoring** – detection of developing hazards such as fire, thermal runaway, cell venting or leakage through battery management systems (as discussed above) or separate smoke detectors, heat sensor, off-gas detection etc.
- **Fire alerting** – fire detection system should be linked to on-site alarms sirens, control centres and the fire services for appropriate response.
- **Fire suppression** – this needs to be considered at both at a module and site level, and approaches will depend on how fire spread is mitigated (e.g. separation as discussed in section 3.4) and the firefighting strategy for the facility (discussed more in section 3.5). Options include water or aerosol-based systems,

passes through the air between electrified conductors when there is insufficient isolation or insulation to withstand the applied voltage."

[5] The asset life of electrical equipment (switchgear, transformers, power converters etc) can be significantly longer than battery modules offering the potential to reuse it within a repowered battery system.

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with the NFCC [5] highlighting that water-based systems are considered more effective than gaseous systems for fires involving battery cell modules.

- **Venting and exhaust systems** – to effectively mitigate explosion and deflagration hazards, BESS containers should be fitted with venting and explosion protection. The NFCC [5] recommend that exhaust systems should be specified to maintain an environment below 25% of Lower Explosive Limit (LEL) (in line with similar industry guidance such as that from NFPA) and discharge vented flames and materials to a safe location where it will not contribute to further fire propagation.
- **Security systems** – including CCTV, alarms, motion sensors, container door sensors to enable remote site monitoring and prevent unauthorised access.

As above, the safety implications of any remote monitoring and control systems failures (e.g. due to a communication network failure) should be assessed. This should inform design aspects such as communication reliability, availability, redundancy and back up control arrangements.

There is ongoing work within the industry to determine the most effective approaches for managing battery fires and as such guidance around this will likely change over time. To incorporate up to date good practice at the time of battery system development, it is important to seek advice from qualified persons. Engagement with the Fire and Rescue Service at this stage of development will also enable fire suppression systems to be aligned with a wider firefighting strategy.

3.3 Site Selection

There are multiple drivers for selection of a given location, including the availability of land, a grid connection and the need for grid services in that region of the electrical network. From a health and safety perspective, the location of sites must be studied carefully, evaluating the threats the BESS both proposes and are exposed to, and the acceptable levels of risk to the local environment.

Examples of possible site considerations are:

- Nearby commercial or residential premises,
- Local environment and ecosystem,
- Industrial sites,
- Other nearby batteries or power generation facilities.

The following sections give a brief overview of potential issues, although it is noted that where storage is near or co-located with other facilities it introduces design complexity and variability which cannot be fully reflected in a general guidance document.

3.3.1 Site Risk and Environmental Assessment

There should be a full consideration of site/project risks including, but not limited to, accidental or intentional damage and natural phenomena such as fire, weather (including snow and ice and access during severe weather), flooding, land subsidence, flora, and fauna (including birds and mammals), and security. Note that risk assessments should be bidirectional – i.e. include both risks to the facility and from the facility. The planning process should assess the following risks and describe how the credible worst case has been mitigated.

Depending on the size and location of a project there may be a requirement to undertake an Environmental Impact Assessment (EIA). An EIA aims to protect the environment by ensuring that a local planning authority when deciding whether to grant planning permission for a project, which is likely to have significant effects on the environment, does so with full knowledge of these likely effects. The EIA will identify any specific measures required to mitigate the impact on the environment [12].

Studies and risk assessments for the local ecosystems must be considered in site proposals, as the release of potentially harmful gases and chemicals could cause irreparable damage to the nearby environment. [13]

As the footprint required for a BESS is relatively small, the impacts are usually quite limited. It may be appropriate to do a noise assessment to mitigate any impacts to local residents or the environment. For example, installing acoustic fencing and tree planting, as is suggested by Aura Power who were granted planning permission in May 2022 for the Drax battery storage scheme by Selby District Council [14]. A noise assessment may be appropriate to undertake before and after any additions to the system, so the impact of one battery unit for example, can be quantified.

The American organisation the National Fire Protection Association (NFPA) produced a standard (NFPA 855) for the installation of stationary energy storage systems [15], which outlines standards for the design, construction, installation, commissioning, operation, maintenance and decommissioning of BESS, which includes standards for the location of BESS facilities. Within NFPA 855, ‘remote’ locations are classed as those located more than 100 ft or 30.5m away from “any buildings, lot lines, public ways, stored combustible and hazardous materials, high piled stock, and other exposure hazards”. Locations which do not comply with this are classed as ‘Locations near exposures’ and subject to constraints on size and separation and maximum stored energy.

Further guidance on appropriate distances between BESS containers and site boundaries or occupied buildings is also provided by the NFCC [5].

3.3.2 Location near industrial sites

Former industrial or brownfield sites can be attractive for battery storage given the reduced environment planning concerns (compared to greenfield sites) and the greater potential for nearby grid infrastructure. From a safety perspective, consideration should be given to the nature of surrounding sites and the potential for increased risk if hazards such as fire were to propagate from one site to the other (particularly where those sites also have an elevated fire risk).

3.3.3 Risks of co-location with renewable generation and other storage

Co-locating energy storage with energy generation is becoming increasingly common. Energy storage could be co-located with solar panels, wind turbines, hydroelectric generators, hydrogen production facilities or storage or different battery technologies. Where there is the potential for co-location, additional risk assessments need to be undertaken for the combination of technologies at a given site and the potential propagation of hazards.

Where multiple generation, storage or industrial facilities are located in close proximity (but not necessarily co-located in such a way as to pose a direct risk to one another), consideration should also be given to the local capacity to deal with multiple concurrent issues and the implications for emergency response.

3.4 Site Layout

The layout of a BESS site is key to its safety, both in mitigating the effects of fire and in ensuring access for staff and emergency services. Key considerations are outlined in the following sections.

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3.4.1 Equipment Location

The physical distance between equipment is the most significant factor in how fire can spread within a BESS site, so maintaining adequate separation is crucial to minimising its potential impacts. Containers housing battery cells, being the most likely source of a fire, must be separated from each other and from other equipment such as transformers, control equipment, office buildings, and from the site perimeter. These separating areas, in addition to being physically large enough to prevent fire spreading across them, should be kept clear of obstruction and regularly assessed for contamination, e.g. with plant growth or spilled substances which could assist in fire propagation.

Guidance on appropriate separation distance varies across existing guidance documents, and as with all standards these are subject to change over time. It is advised that the relevant competent duty holder take a precautionary approach based on available standards and always conduct their own fire risk assessment to understand site specific risks and demonstrate that appropriate mitigations for fire spread are in place.

Current standards include:

- NPFA 855 (which is perhaps the most commonly applied standard) requires a standard separation distance of a minimum of 10 ft (3048 mm), with the opportunity to reduce this to 3 ft (914 mm) where design mitigations have been taken such as large-scale fire testing (complying with UL 9540A or equivalent test standard), the use of non-combustible walls or containers with 2-hour fire resistance rating established in accordance with ASTM E119 or UL 263.
- In guidance updated in July 2023, FM Global [16] differentiate requirements for different battery chemistries. For outdoor containers made of non-combustible materials:
  - Where the BESS comprises of LFP cell type, separation of at least 5 ft (1.5 m) on sides that contain access panels, doors or deflagration vents is recommended.
  - Where the BESS comprises of NMC cell type, separation of at least 13 ft (4.0 m) on sides that contain access panels, doors, or deflagration vents is recommended. Where containers have at least a 1-hour rating in accordance with ASTM E119, aisle separation of at least 8 ft (2.4 m) is acceptable.

Guidance on appropriate separation distances between BESS containers is provided by the NFCC [5].

The location and routing of cables, pipes and other conduits should also be considered at this stage, for example whether cables should be buried in the ground or carried by overhead gantries.

3.4.2 Access Routes

Developers should consider how personnel will need to move in and around the BESS site during different phases of its lifecycle:

- **Installation & Commissioning** – consider how equipment is brought onto the site, such as whether access routes are wide enough and can bear the load of heavy goods and vehicles;
- **Operation & Maintenance** – consider how personnel will need to move around the site, what maintenance equipment will be needed and where, and whether any work in confined spaces or at height may be required;
- **Decommissioning & End-of-Life** – similarly to Installation & Commissioning, consider what access will be needed within and from the site to enable the disconnection and removal of equipment;
- **Emergency scenarios** – consider how emergency responders, such as the Fire and Rescue Service or paramedics, can obtain access to and move around the site in the event of a fire or other emergency.

This will likely necessitate at least two separate access routes onto the site in case one becomes obstructed or inaccessible.

Further guidance on site access requirements for response to emergency situations is provided by the NFCC [5].

3.4.3 Lighting & Signage

To support safe access to and navigation of the site, developers should consider the location and specification of lighting and signage. This may include signage around the external perimeter warning of high-voltage equipment, warning notices on containers housing hazardous substances, ground markings to demarcate restricted areas, and installation of emergency lighting systems to enable egress from the site in the event of a fire.

3.4.4 Security

Although not directly related to health and safety, good security practices can play a role in improving the safety of a BESS site. The site operator, in addition to being responsible for the safety of authorised personnel at the site, is also responsible under the Occupiers Liability Act 1984 for the safety of *unauthorised* persons who may gain access to the site through, for example, a broken fence. It is therefore important that perimeter fencing and other site security measures are substantial enough to deter potential trespassers and are maintained in a good state of repair.

The use of CCTV and motion/break glass sensors could also be considered where appropriate, as well as alarm systems connected to a monitoring and response service to enable rapid detection and attendance if a security incident occurs. In addition to helping protect the valuable assets installed on site, these measures can reduce the risk of harm to unauthorised persons and associated legal liability.

3.5 Emergency Planning

Emergency response arrangements and preparedness plans should be developed as early as possible in the system lifecycle and be considered at each stage. Services such as the local Fire and Rescue Service should be consulted primarily in the Design & Planning stage to understand emergency response requirements (e.g. the potential firefighting strategy) and inform the stakeholders (Asset Owners and Designers) of the H&S requirements for their application. This engagement is encouraged by government within BESS planning guidance [4].

Documented procedures for emergency access and plans to minimise fire risk will also contribute to the avoidance of incidents and damage to both the assets, the environment, and potential injury to workers and emergency response personnel. Having the Fire and Rescue Service, or similar, consulting on the project/design of a project will also ensure they are aware of potential hazards installed in their area which may include natural, human-error or technical fault events that can occur at any time.

An emergency response plan (ERP) should be produced detailing key actions and arrangements for foreseeable emergencies, including:

- Response to fire incidents, including the firefighting strategy for large scale fires.
- Management of potential chemical release (e.g. assessment of smoke plume impacts during fires, water and drainage management, including for contaminated run-off).
- Response to severe environmental hazards such as flooding and operating in high winds (including responding to emergencies in these conditions).

- Access/egress routes for staff, emergency responders and vehicles during emergencies including routes in and out of site, access to key equipment, out-of-hours response, site visibility particularly in dark conditions, sufficient turning circles secondary routes available if primary routes are blocked.
- Response to security incidents including cybersecurity attacks.

The ERP should also made available to the local Fire and Rescue Service for review. Once finalised the ERP should be stored in a clearly marked location on site, so that emergency responders are able to identify and access it quickly. Duty holders responsible for sites containing 25 tonnes or more of dangerous substances must notify fire and rescue services under the NAMOS Regulations 1990.

It is noted that the American Clean Power Association (ACP) have published a Draft Emergency Response Plan [17], with the intention that this be adapted by their members. This may serve as a useful reference when developing a site ERP.

4 Transportation

The preparation and transport of BESS equipment can pose various logistical challenges and safety risks and as such should be considered in the context of health and safety. Key areas of concern are highlighted in the following sections with relevant standards summarised in Annex B.2.

4.1 Safety in transport

During transportation there is potential that BESS components will not have the same level of protection as they would once installed, for example from fire monitoring and suppression systems. It may be necessary to implement additional protections to mitigate this risk, such as disconnecting or separating components, limiting their charge level, or installing additional sensors that remain active during transport.

It is noted that there may be the need to charge batteries to a certain state of charge (e.g. between 20-50%) to avoid excess discharge impacting battery health. This and balancing charge across batteries can help with early installation and commissioning. Standard IEC 62281 describes various cell tests, packaging and handling considerations to support safe transport.

UN Transport Regulations classifies lithium-based batteries as “Class 9 - miscellaneous dangerous substances and articles” (with various sub-classifications based on the battery type and how it is packaged). These regulations will apply to the transport of grid-scale BESS, and as such they should be treated as dangerous goods. Additional guidance on moving potentially dangerous goods and equipment is provided by the HSE [18] and Department for Transport [19].

4.2 Logistics

BESS developers should consider access requirements for equipment transportation, which may include heavy or oversized vehicles requiring wider or stronger access routes than will be needed during normal site operation. This should extend not just to the site itself, but to surrounding roads and routes from nearby trunk roads that equipment will be transported on. Where oversize loads (e.g. transformers) are being transported consider whether special signage or escort vehicles may be required. Depending on the site location, local roads may need to be temporarily closed to enable plant movements – this will likely require liaising with the local highways commission and/or police.

Where lifting equipment such as cranes or platforms are required for delivery or commissioning, their access and staging requirements should be accounted for in the site layout. This may include widening access routes or ensuring suitably clear and flat areas are available during construction.

5 Installation & Commissioning

The Installation & Commissioning stage covers the physical installation of assets at their intended location and connection to their respective interfaces, as well as inspection, testing and training for operations and handover of the system from installer to operator. Post handover tuning and bedding-in periods are also included at this stage. The sections below outline key areas to consider, and Annex A provides an overview of relevant technical standards.

5.1 Management & Governance

Project management and governance during the Installation & Commissioning stage can impact health and safety in a number of ways. Considerations include:

- CDM 2015 duties for clients, designers and contractors (as introduced within section 2.4).
- Construction site management and the party who takes ownership of hazards across the project. This will be influenced by the contracting approach, e.g. an Engineering, Procurement, Construction (EPC) full wrap versus an Engineering, Procurement, Construction Management (EPCM) approach (reference [20] helps explain the distinction between these approaches).
- Contractor selection – due diligence on potential contractors is key where those contractors will be relied upon to perform hazardous work or provide approvals/certifications of project progress.
- Named persons for legal purposes, e.g. owner, site manager, H&S officer.
- Staff training – it is important that health and safety principles are embedded in training plans and that training is delivered to all relevant staff, including contractors and temporary workers. This should cover general risks and processes for working on site, specific risks to the tasks they will be undertaking and points of contact for reporting or queries. Keeping accurate records of staff training is also important, as it allows the organisation to plan for refresher courses as needed and demonstrate to external parties that required training has been delivered.

5.2 Logistics during construction

During the Installation & Commissioning phase it is possible that safeguards planned for the final site configuration, such as fire detection and suppression systems, will not yet be in place. Developers should consider how hazards may arise or evolve during this stage, and whether temporary mitigations such as portable fire detection/firefighting equipment are required.

As highlighted in section 4.2, where lifting equipment such as cranes or platforms are required for delivery and construction, their access and staging requirements should be accounted for in the site layout. This may include widening access routes or ensuring suitably clear and flat areas are available during construction.

5.3 Commissioning

Commissioning consists of a series of steps to demonstrate, measure and record component and system performance. Commissioning processes include sets of tests, checklists, specifications, standards and procedures to validate performance and identify and correct problems before a system becomes operational.

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Sandia National Laboratories [21] present a helpful overview of the range of activities which could be expected to be undertaken during commissioning, many of which have implications for system safety. These include:

- Factory Acceptance Testing of equipment prior to delivery on site
- Operational Acceptance Testing of individual systems and system setpoints on site. This includes:
  - Testing of the BMS (hardware and software) to ensure correct management of battery state of charge and fail-safe functionality.
  - Testing the communication across the control hierarchy (i.e. BMS through to overall plant controllers and third party operators) to ensure correct data flows, control signals are acted upon, and alerts/alarms are activated.
  - Inverter control and protection functionality operates as required and is coordinated across the site (e.g. implements interface protection functions, such as described in G99, in agreement with network operator requirements).
- Functional or Site Acceptance Testing to test the capability of equipment at a whole system level to safely perform its intended functions across different operating cycles, and maintain grid code compliance. Witness testing is often conducted by the relevant network operator to ensure correct protection functionality.
- ‘Shakedown’ or robustness testing to ensure the system operates as expected under degrading operating conditions (e.g. loss of grid, cooling, communications). This includes shutting down, restarting or raising alarms as needed.

Commissioning testing should be conducted and signed off by qualified personnel in line with site safety rules. Effective record keeping of issues, resolutions and approvals will help ensure safety and operational issues are dealt with effectively.

Monitoring data gathered during the commissioning phase can be valuable in detecting issues with equipment or installation and as such there is benefit to recording and analysing this data from early in commissioning phase. The commissioning phase is also an opportunity to familiarise operating staff with the storage systems and finalise operational and safety plans.

6 Operation & Maintenance

6.1 Safe Operation

Safe operation will be supported by a range of operational and safe working practices. Plant should only be operated by skilled personnel and output should be maintained within operational limits[6]. Site access should be limited to authorised personnel, site safety rules (e.g. for electrical HV/LV safety) should be in place and policies and processes adopted to maintain site cybersecurity.

Bringing together the various safety plans, features and monitoring systems discussed across previous sections, safe operation will include continuous monitoring of equipment across the site (batteries, inverters, transformers etc) to detect abnormal operation or indications of emergent faults and monitoring of CCTV to ensure site security. Escalation plans should be in place to respond to potential hazards, including out of hours support.

6.2 Asset management

There should be asset management strategy in place which details appropriate equipment inspection, preventative and reactive maintenance requirements and the methods through which equipment defects are assessed. This may include multiple inspections or maintenance and testing intervals throughout the year to ensure all parts of the system are in working order and system settings (e.g. electrical protection) are correct. Equipment manufacturers should be able to provide guidance on maintenance requirements for specific equipment and may also provide servicing and service level agreements to support ongoing operation. There is also a range of resources available from network operators on electrical asset health assessment (e.g. [22]). As noted above, maintenance work should only be undertaken by skilled personnel and follow site safety rules.

6.3 System changes and unplanned modification

During the life of a BESS there may be the need to make unplanned changes to its design or operational arrangements. In these cases, many of the principles discussed earlier in the document around risk assessment around any redesign, installation, commissioning, operation and maintenance apply. Standard IEC 62933-5-3 addresses unplanned modifications and covers changes: in energy storage capacity; chemistries, design and manufacturer of the battery; subsystem component using non-OEM parts; to the mode of operation; of the installation site.

6.4 Ongoing improvement

The industry-wide understanding of risks assessment and reduction, emergency response arrangements and best H&S practices for all stages of the system lifecycle is constantly developing but lagging behind the pace of technology development. This makes it difficult to know the benchmark for H&S in the context of grid-scale storage systems, and how to continually improve and ensure compliance with relevant standards at all times.

Regular monitoring, review and auditing of system performance and operating procedures contributes to safe operation. This should be subject to governance and oversight by a responsible party (e.g. the employer or asset owner).

[6] These limits should also be communicated to any relevant third parties such as route to market providers.

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6.5 Emergency Response Planning

The emergency planning work undertaken at the Design & Planning stage should be subject to regular review to ensure it remains fit for purpose throughout the lifetime of the BESS site. This should include:

- Regular staff training, including evacuation drills, new starter briefings and refresher courses;
- Testing and recertification of safety equipment, such as alarms and fire suppression systems;
- Periodic review of emergency response plans, especially if site equipment or layout is modified or if the site's immediate neighbours or local access routes change;
- Regular engagement with local Fire and Rescue Service to ensure they remain aware of current hazards at the site – approaches to tackling these hazards may change over time.

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7 Decommissioning & End-of-Life

7.1 Decommissioning and Repowering

The decommissioning of a BESS site presents similar health and safety risks to its commissioning, due to changes in the site's operation and potential removal of safeguards. Considerations at this stage include:

- Disconnection from grid – the relevant TO/DNO should be consulted where work to remove grid connection equipment is planned, to avoid disruption to the wider network.
- Life extension/Repowering – it may be desirable to extend the working life of the site through refurbishment or replacement of some equipment, such as degraded battery cells. Developers should consider the rated lifetimes and condition of their equipment (e.g. the electrical distribution and protection equipment that may be reused) and seek expert advice on potential safety risks from the integrating new battery options.

New risks may also be introduced where storage equipment is repurposed, relocated or used in second life applications. Many of the principles described in earlier sections would apply for risk assessing these applications.

7.2 Equipment Disposal

The Waste Batteries and Accumulators Regulations 2009 require that "industrial batteries" – a definition that applies to BESS li-ion cells – must be sent for recycling by an approved operator. Distributors of industrial batteries are also obliged to take back waste cells free of charge when requested by the end user. BESS developers should consult with proposed battery suppliers at an early stage to establish their processes for take-back and recycling, and to ensure as far as possible that these schemes (or equivalents) will be available at the predicted end of site life.

Developers should also be aware of the Waste Electrical and Electronic Equipment Regulations 2013, which imposes broad obligations on recycling of electronic products. While the core equipment of a BESS site may not meet this definition, many items installed on site will – examples may include computers and display equipment, monitoring, control and communication instruments and lighting equipment.

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Annex A - Relevant Technical Standards

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A.1 Overview

This annex includes a range of standards considering the main battery design, their installation, auxiliary systems and hazards. It also contains a list of the standards laid out in TC 120, and other related international standards by UL, NFPA and FM Global, as these are particularly relevant to grid-scale energy storage and will be the most relevant standards once published. These standards are organised with reference to the development lifecycle where applicable.

Not all standards listed here will be relevant to every situation. Necessarily, this section cannot be exhaustive and further legislation or later amendments may apply. It is the responsibility of the relevant person(s) (designer, installer, maintainer, decommissioner, etc.) to determine the applicable legislation and adopt suitable standards where appropriate.

Internationally developed standards are often mirrored by the BSI in the UK and so become UK standards. They form the bulk of the technical standards related to energy storage. They are developed through relevant working groups in organisations such as the IEC, CENELEC, or ISO and present international consensus on what standards should apply. The UK has membership of these organisations and working groups enables the UK to influence what becomes an international standard. Where legislation has been adopted as a British Standard, it is listed in the UK-based BSI (rather than the EU based, IEC or ISO, etc.).

The 62933 series of normative documents (standards and technical specifications) have recently been introduced to focus on the system aspects of BESS as well as investigating the need for new standards. This series falls under the Technical Committee (TC) 120 work programme, with publication dates extending into 2025. Due to their particular relevance, a summary of these standards has been listed first.

A.2 TC 120 – 62933 series

Table 1: Standards and technical specifications already developed by IEC TC 120.

Standard ID	Title	Pub year	Lifecycle Stages	Brief scope
IEC 62933-1:2018	Electrical energy storage (EES) systems - Part 1: Vocabulary.	2018	All	Covers the detailed terminology within the series.
IEC 62933-2-1:2017	Electrical energy storage (EES) systems - Part 2-1: Unit parameters and testing methods - General specification.	2017	Design & Planning Installation & Commissioning Operation & Maintenance	Formally defines EESS parameters such as active and reactive power, round trip efficiency, expected service life etc., and formally sets out how to verify these parameters in testing.
IEC TS 62933-2-2:2022	Electrical energy storage (EES) systems - Part 2-2: Unit parameters and testing methods - Application and performance testing.	2022	Design & Planning Installation & Commissioning Operation & Maintenance	Defines testing methods and duty cycles to validate the EES system's technical specification for all involved parties with the system to evaluate performance for various applications. A reference document for selecting testing items and their evaluation methods.
IEC TS 62933-3-1:2018	Electrical energy storage (EES) systems - Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification.	2018	Design & Planning Installation & Commissioning Operation & Maintenance	Provides requirements, guidelines, and references when EESS are designed, controlled, and operated for energy intensive, islanded grid, and backup power supply applications.
IEC TS 62933-3-3:2022	Electrical energy storage (EES) systems - Part 3-3: Planning and performance assessment of electrical energy storage systems - Additional requirements for energy intensive and backup power applications.	2022	Design & Planning Installation & Commissioning Operation & Maintenance	Provides requirements, guidelines, and references when EES systems are design, controlled, and operated for three applications; energy intensive applications, islanded grids, and internal grids/backup power supplies.
IEC TS 62933-4-1:2017	Electrical energy storage (EES) systems - Part 4-1: Guidance on environmental issues - General specification.	2017	All	Assesses the interaction of the EESS with the environment across its entire lifecycle and how adverse mutual effects on the EESS/environment may be considered and mitigated.

Standard ID	Title	Pub year	Lifecycle Stages	Brief scope
IEC TS 62933-5-1:2017	Electrical energy storage (EES) systems - Part 5-1: Safety considerations for grid-integrated EES systems - General specification.	2017	Design & Planning Installation & Commissioning	Specifies safety considerations (e.g. hazards identification, risk assessment, risk mitigation) applicable to EES systems integrated with the electrical grid. It provides criteria to foster the safe application and use of EESS of any type or size intended for grid-integrated applications.
IEC 62933-5-2:2020	Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid-integrated EES systems - Electrochemical-based systems.	2020	Design & Planning Installation & Commissioning Operation & Maintenance	Provides further safety provisions that arise due to the use of an electrochemical storage subsystem (for example - a battery system) in EESS that are beyond the general safety considerations described in 62933-5-1. Risks can depend on many factors including location, chemistry, and the size/scale (for example- power) of the BESS and will need to be assessed accordingly.
IEC 62933-5-3	Electrical energy storage (EES) systems Part 5-3: Safety requirements when performing unplanned modification of electrochemical based EES systems.	2024	Operation & Maintenance	Provides guidance for the steps and activities to be carried out when modifications are made to a BESS during its operational lifetime.
IEC 62933-4-4	Electrical energy storage (EES) systems- Part 4-4: Standard on environmental issues battery-based energy storage systems (BESS) with reused batteries – requirements.	2023	All	Provides guidance around general environmental requirements, and specific environmental requirements of EESS.

Table 2: Standards and technical specifications under development by IEC TC 120.

Standard #	Name	Forecast pub year	Scope
IEC 62933-1 ED2	Electrical energy storage (EES) systems - Part 1: Vocabulary.	2024	Revision of IEC 62933-1:2018 ED1. Covers the detailed terminology within the series.
IEC TS 62933-2-3 ED1	Electric Energy Storage (EES) Systems - Part 2-3: Unit parameters and testing methods - Performance assessment test after site operation.	2025	Defines unit parameters and testing methods to assure the system capability and performance of EESS.
IEC 62933-3-1 ED1	Electrical energy storage (EES) systems - Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification.	2025	Provides guidance for planning and installation of EESS. Provides standards and other deliverables for use by the designing, planning, installation, and commissioning of power systems.
IEC TR 62933-4-200 ED1	Electrical Energy Storage (EES) Systems - Part 4-200: Guidance on environmental issues - Greenhouse gas (GHG) emission assessment by electrical energy storage (EES) systems.	2024	Provides guidance around general environmental requirements, and specific environmental requirements of EESS.
IEC 62933-4-2 ED1	Electric Energy Storage Systems - Part 4-2- Assessment of the environmental impact of battery failure in an electrochemical based storage system.	2024	Provides guidance around general environmental requirements, and specific environmental requirements of EESS.
IEC 62933-4-3 ED1	Electrical energy storage (EES) systems - Part 4-3: The protection requirements of BESS according to the environmental conditions and location types.	2025	Provides guidance around general environmental requirements, and specific environmental requirements of EESS.
IEC 62933-5-1 ED1	Electrical energy storage (EES) systems - Part 5-1: Safety considerations for grid-integrated EES systems - General specification.	2025	Revision of IEC 62933-5-1:2017. Specifies safety considerations (e.g., hazards identification, risk assessment, risk mitigation) applicable to EES systems integrated with the electrical grid.

Standard #	Name	Forecast pub year	Scope
IEC 62933-5-2 ED2	Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid-integrated EES systems - Electrochemical-based systems.	2025	Revision of IEC 62933-5-2:2020. Provides further safety provisions for an electrochemical storage subsystem in EESS that are beyond the general safety considerations described in 62933-5-1. Covers risk assessment, identification, and mitigation of hazards, across 5 unique EESS classes based on electrochemistry.
IEC 62933-5-4 ED1	Electrical energy storage (ESS) systems Part 5-4 – Safety test methods and procedures for grid integrated EES systems – Lithium-ion battery-based systems.	2025	Provides guidance, requirements, and test methods for lithium-ion based EESS, with recommendations to prevent or mitigate accidental effect.

A.3 Electrical system design and protection standards

This section summarises core standards which cover the design, building and testing of electrical systems. These standards, summarised in Table 3, underpin many of those referenced elsewhere in this document. Table 3 references standards for both LV and HV systems and these will apply to different aspects of a BESS development.

Table 3: Standards for the design, building and testing of HV and LV electrical systems

Standard ID	Title	Pub year	Brief scope
BS EN IEC 61936-1	Power installations exceeding 1 kV AC and 1,5 kV DC	2021	Specifies requirements for the design, erection, and verification of high voltage power installations greater than 1 kV AC and 1.5kV DC. The requirements are intended to provide for the safety of persons, livestock and property against electrical hazards and enable proper functioning of electrical installations.
BS EN 50522	Earthing of power installations exceeding 1 kV AC	2022	Specifies requirements for the design and erection of earthing systems for electrical installations in systems with nominal voltage above 1 kV AC and nominal frequency up to and including 60 Hz
BS 7671:2018+A 2:2022	IET Wiring Regulations (18^{th} Edition)	2022	Sets out requirements that apply to the design, erection and verification of all new electrical installations and additions and alterations to existing electrical installations in the UK. Coverage of this standard includes electrical safety, protection and earthing of installations with nominal voltages up to and including 1 000 V AC or 1 500 V DC.

A.4 Other key standards and guidance

A.4.1 UL standards

UL is an independent product safety certification organisation which, in conjunction with other organisations and industry experts, publishes consensus-based safety standards. They have recently developed battery storage standards which are in use both nationally and internationally. For lithium batteries, key standards are:

- **UL 1642: Standard for Safety of Lithium Batteries (2012).** Covers component-level testing of lithium cells. Battery-level tests are covered by UL 2054.
- **UL 1973: Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications (2018).** Applies to battery cells and modules used for domestic, commercial and grid-scale storage. Defines requirements for cells, batteries and battery systems for stationary systems (e.g. for use with solar PV), as well as EVs and LER. Non-technology specific but does include testing criteria for many battery chemistries, including Li-ion, Ni-Cd, lead-acid, sodium and flow batteries and ultracapacitors.
- **UL 9540: Standard for Safety for Energy Storage Systems and Equipment (2020).** Far-reaching standard for energy storage safety, setting out a safety analysis approach to assess H&S risks and enable determination of separation distances, ventilation requirements and fire protection strategies. References other UL standards such as UL 1973, as well as ASME codes for piping (B31) and pressure vessels (B & PV).

A.4.2 NFPA

The National Fire Protection Association (NFPA), a global self-funded non-profit organization, compiles research through the Fire Protection Research Foundation and collaborates with research institutions to gather evidence and data that helps shape their published standards:

- **NFPA 1: Fire Code (2018).** Addresses minimum requirements for building construction, operation and maintenance, fire department access, and hazardous materials necessary to establish a reasonable level of fire safety and property protection in new and existing buildings. Draws requirements from 57 other NFPA codes and standards, providing wide coverage when conducting reviews and inspections.
- **NFPA 855: Standard for the Installation of Stationary Energy Storage Systems (2023).** Addresses minimum requirements for mitigating hazards associated with EESS. Applies to many types of EESS – electrochemical (including li-ion, lead acid, ni-cad, sodium, flow), supercapacitor, SMES, flywheel, CAES. Applies to a range of lifecycle stages – design, construction, installation, commissioning, operation, maintenance, and decommissioning. Defines requirements for equipment specification, electrical installation, system location and separation, ventilation and smoke detection, fire control and suppression, and emergency planning (e.g. shutdown procedures, removal of damaged equipment).

A.4.3 FM Global

FM Global is an American mutual insurance company that specializes in loss prevention services. FM Global publish 'Property Loss Prevention Data Sheets' on a variety of topics which form a FM Global standard. These are updated annually and designed to reduce the chance of property loss due to fire, weather conditions, and failure of electrical or mechanical equipment. The publication of main relevance to this report is Property Loss Prevention Data Sheet "**5-33 - Lithium-Ion Battery Energy Storage Systems**" which provides a range of guidance on safe design and operation.

A.5 Standards categorised by development lifecycle

A.5.1 Design and Planning

Design & Planning			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN IEC 62933-1:2018	Electrical Energy Storage (EES) systems. Part 1: Terminology.	2018	Covers the detailed terminology within the standard. A distinction is made between low, medium, and high voltage Electrical energy storage systems (EESS) and residential EESS, commercial and industrial EESS and utility EESS. (See IEC 60050 for voltage level definitions)
PD IEC/TS 62933-3-2:2022	Electrical energy storage (EES) systems – Planning and performance assessment of electrical energy storage systems. Additional requirements for power intensive and renewable energy sources integration related applications.	2023	Provides the requirements for power intensive and renewable energy sources integration related applications of EESS, including grid integration, performance indicators, sizing and planning, operation and control, monitoring and maintenance.
BS EN IEC 62933-5-2:2020	Electrical energy storage (EES) systems - Safety requirements for grid-integrated EES systems. Electrochemical-based systems.	2020	Provides further safety provisions for an electrochemical storage subsystem in EESS that are beyond the general safety considerations described in 62933-5-1. Risks can depend on many factors including location, chemistry, and the size/scale of the BESS and will need to be assessed accordingly. Covers risk assessment, identification, and mitigation of hazards, across 5 unique EESS classes based on electrochemistry.
BS EN 62933-5-3	Electrical energy storage (EES) systems - Part 5-3. Safety requirements for electrochemical based EES systems considering initially non-anticipated modifications, partial replacement, changing application, relocation and loading reused battery.	2021	Provides guidance for the steps and activities to be carried out when modifications are made to a BESS during its operational lifetime.
BS EN IEC 62477-1	Safety requirements for power electronic converter systems and equipment	2023	Provide requirements for power electronic converter systems. These are typically used to covert the DC output of batteries to a grid compatible AC frequency.

Design & Planning			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN 547-1:1996+A1:2008	Safety of machinery. Human body measurements. Part 1 – Principles for determining the dimensions required for openings for whole body access into machinery.	1997	Provides the guidance for human dimensions required to safely design the storage facilities for ESS
BS EN 547-2:1996+A1:2008	Safety of machinery. Human body measurements. Part 2 – Principles for determining the dimensions required for access openings.	1997	Specifies the dimensions of openings for access as defined in BS EN 547-1
BS EN 547-3:1996+A1:2008	Safety of machinery. Human body measurements. Part 3 – Anthropometric data.	1997	Specifies current requirements for human body measurements (anthropometric data) that are required by BS EN 547-1 and BS EN 547-2 for the calculation of access opening dimensions as applied to machinery.
BS EN IEC 60079-7:2015+A1:2018	Explosive atmospheres - Equipment protection by increased safety "e".	2019	Specifies the requirements for the design, construction, testing, and marking of electrical equipment and Ex Components with type of protection increased safety "e" intended for use in explosive gas atmospheres.
BS EN 60079-14:2014	Explosive atmospheres Part 14: Electrical installations design, selection, and erection.	2016	Contains the specific requirements for the design, selection, erection, and initial inspection of electrical installations in, or associated with, explosive atmospheres. The requirements of this standard apply only to the use of equipment under standard atmospheric conditions as defined in IEC 60079-0.
BS EN IEC 60364-5-57	Low-voltage electrical installations. Part 5: Selection and erection of electrical equipment - Clause 57: Erection of stationary secondary batteries.	2022	Provides recommendations for the design, erection, correct use, and protection of installations with secondary stationary battery storage.
BS EN IEC 61000-6-2:2019	Generic standards. Immunity standard for industrial environments.	2019	Defines the immunity test requirements for equipment specified in the scope in relation to disturbances, including electrostatic discharges. Apples to electrical equipment intended to be operated in industrial locations.

Design & Planning			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN IEC 61000-6-5	Generic standards. Immunity for equipment used in power station and substation environment.	2018	Specifies Electromagnetic compatibility (EMC) immunity requirements for electrical equipment intended for use in power stations and substations.
BS EN 61000-6-7	Electromagnetic compatibility (EMC) - Part 6-7: Generic standards - Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations.	2015	Defines immunity test requirements for equipment in relation to continuous and transient, conducted, and radiated disturbances, including electrostatic discharge.
BS EN 61427-1:2013	Secondary cells and batteries for renewable energy storage. General requirements and methods of test - Photovoltaic off-grid application.	2014	Provides general information relating to the requirements for secondary batteries used in photovoltaic energy systems (PVES) and the typical methods of test used for the verification of battery performances for batteries used in off-grid applications.
BS EN 61427-2:2015	Secondary cells and batteries for renewable energy storage. General requirements and methods of test - On-grid applications.	2016	Provides testing methods and general requirements of secondary cells used in on-grid EES, tests for the verification of their endurance, properties, and electrical performance.
BS EN 62305-2:2012	Protection against lightning - Risk management.	2013	Outlines risk assessment for a structure or service from lightning flashes to the earth. Allows for the selection of appropriate protection measures to reduce the risks to below the tolerable limit.
BS EN 62305-3:2011	Protection against lightning. Physical damage to structures and life hazard.	2011	Sets out the requirements needed to protect buildings and structures against physical damage by implementing a lightning protection system (LPS). Provides guidance on how to protect living beings against injury in proximity to an LPS.

Design & Planning			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN IEC 62458-6:2021	Safety requirements for secondary batteries and battery installations – safe operation of stationary lithium-ion batteries.	2022	Describes the principal measures for protections during normal operation or under expected fault conditions against hazards. Provides requirements on safety aspects associated with the installation, use, inspection, and maintenance and disposal of lithium-ion batteries used in stationary applications.
BS EN IEC 62619:2022	Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for secondary lithium cells and batteries, for use in industrial applications.	2022	Specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications, including stationary applications.
BS EN IEC 63056:2020	Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for secondary lithium cells and batteries, for use in electrical energy storage systems.	2021	Under the umbrella standard BS EN IEC 62619. Specifies requirements and tests for the product safety of secondary lithium cells and batteries used in EESS.

A.5.2 Transportation

Transportation			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN IEC 62933-5-2:2020	Electrical energy storage (EES) systems - Safety requirements for grid-integrated EES systems. Electrochemical-based systems.	2020	Provides further safety provisions for an electrochemical storage subsystem in EESS that are beyond the general safety considerations described in 62933-5-1. Risks can depend on many factors including location, chemistry, and the size/scale of the BESS and will need to be assessed accordingly. Covers risk assessment, identification and mitigation of hazards, across 5 unique EESS classes based on electrochemistry.
BS EN IEC 62281:2019+A1 :2021	Safety of primary and secondary lithium cells and batteries during transport	2021	Specifies test methods and requirements for primary and secondary lithium cells and batteries to ensure their safety during transport other than for recycling and disposal.

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A.5.3 Installation and Commissioning

Installation and Commissioning			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN IEC 62933-1:2018	Electrical Energy Storage (EES) systems. Part 1: Terminology.	2018	Covers the detailed terminology within the standard. A distinction is made between low, medium, and high voltage Electrical energy storage systems (EESS) and residential EESS, commercial and industrial EESS and utility EESS. (See IEC 60050 for voltage level definitions)
BS EN IEC 62933-2-1:2018	Electrical energy storage (EES) systems. Part 2-1: Unit parameters and testing methods - General specification.	2019	This formally defines EESS parameters such as active and reactive power, round trip efficiency, expected service life etc., and formally sets out how to verify these parameters in testing.
PD IEC TS 62933-2-2:2022	Electric Energy Storage Systems–part 2-2: unit parameters and testing methods–applications and Performance testing.	2022	Defines testing methods and duty cycles to validate the EES system's technical specification for all involved parties with the system to evaluate performance for various applications. A reference document for selecting testing items and their evaluation methods.
PD IEC TS 62933-4-1:2017	Electrical Energy Storage (EES) systems. Part 4-1: Guidance on environmental issues - General specification.	2018	Assesses the interaction of the EESS with the environment across its entire life cycle and how adverse mutual effects on the EESS/environment may be considered and mitigated.
BS EN IEC 62933-5-2:2020	Electrical energy storage (EES) systems - Safety requirements for grid-integrated EES systems. Electrochemical-based systems.	2020	Provides further safety provisions for an electrochemical storage subsystem in EESS that are beyond the general safety considerations described in 62933-5-1. Risks can depend on many factors including location, chemistry, and the size/scale of the BESS and will need to be assessed accordingly. Covers risk assessment, identification and mitigation of hazards, across 5 unique EESS classes based on electrochemistry.

Installation and Commissioning			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN 62933-5-3	Electrical energy storage (EES) systems - Part 5-3. Safety requirements for electrochemical based EES systems considering initially non-anticipated modifications, partial replacement, changing application, relocation and loading reused battery	2021	Provides guidance for the steps and activities to be carried out when modifications are made to a BESS during its operational lifetime.
BS EN 50549-1:2019	Requirements for generating plants to be connected in parallel with distribution networks. Part 1: Connection to a LV distribution network – Generating plants up to and including Type B	2019	First part of multi-series standard that covers specifications for distribution networks
BS EN 50549-2:2019	Requirements for generating plants to be connected in parallel with distribution networks - Connection to a MV distribution network. Generating plants up to and including Type B	2019	Generating plants connected to a MV distribution network fall into the scope of EN 50549–2
BS EN 547-1:1996+A1:2008	Safety of machinery. Human body measurements. Part 1 – Principles for determining the dimensions required for openings for whole body access into machinery.	1997	Provides the guidance for human dimensions required to safely design the storage facilities for ESS
BS EN 547-2:1996+A1:2008	Safety of machinery. Human body measurements. Part 2 – Principles for determining the dimensions required for access openings.	1997	Specifies the dimensions of openings for access as defined in BS EN 547-1
BS 5839-1:2017	Fire detection and alarm systems for buildings - Code of practice for the design, installation, commissioning, and maintenance of systems in non-domestic premises.	2022	Fire safety standard on best practices for fire alarm systems for buildings. Provides recommendations for all lifecycle stages of the buildings for ESS
BS EN IEC 60079-7:2015+A1:2018	Explosive atmospheres - Equipment protection by increased safety "e".	2019	Specifies the requirements for the design, construction, testing, and marking of electrical equipment and Ex Components with type of protection increased safety “e” intended for use in explosive gas atmospheres.

Installation and Commissioning			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN 60079-13:2017	Explosive atmospheres - Equipment protection by pressurized room "p" and artificially ventilated room "v".	2017	Contains the specific requirements on explosive atmospheres for all rooms, alongside additional requirements for pressurised and artificially ventilated rooms.
BS EN 60079-14:2014	Explosive atmospheres Part 14: Electrical installations design, selection, and erection.	2014	Contains the specific requirements for the design, selection, erection, and initial inspection of electrical installations in, or associated with, explosive atmospheres. The requirements of this standard apply only to the use of equipment under standard atmospheric conditions as defined in IEC 60079-0.
BS EN 60079-29-1:2016+A1:2022	Explosive atmospheres - Gas detectors. Performance requirements of detectors for flammable gases.	2022	Covers general requirements for constructing and testing gas detectors that detect and measure flammable gas or vapour concentrations with air.
BS IEC 60364-4-44AMD2	Low-voltage electrical installations. Part 4-44. Protection for safety. Protection against voltage disturbances and electromagnetic disturbances.	2016	Provides requirements for the design and segregation of power cables to protect against disturbances.
BS HD 60364-4-46	Low-voltage electrical installations. Part 4-46. Protection for safety. Isolation and switching.	2014	Provides requirements and recommendations around non-automatic local and remote isolation and switching measures, to prevent or remove dangers associated with electrical installations.
BS EN IEC 60364-5-57	Low-voltage electrical installations. Part 5: Selection and erection of electrical equipment - Clause 57: Erection of stationary secondary batteries.		Provides recommendations for the design, erection, correct use, and protection of installations with secondary stationary battery storage.
BS EN 60896-11:2003	Stationary lead-acid batteries. General requirements and methods of test – vented types.	2003	Specifies general requirements, the main characteristics, and the corresponding test methods associated with all types and construction modes of lead-acid stationary batteries, excluding valve regulated types.

Installation and Commissioning			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN 60896-21:2004	Stationary lead-acid batteries – valve regulated types. Methods of test.	2005	Specifies the test methods for all types and constructions of valve-regulated stationary lead acid cells and monobloc batteries used in standby power applications.
BS EN 60896-22:2004	Stationary lead-acid batteries – valve regulated types. Requirements.	2005	Provides guidance on suitable requirements for valve-regulated stationary lead acid batteries and monobloc batteries used in standby power applications. Used in conjunction with BS EN 60896-21.
BS EN 61000-1-2:2016	Electromagnetic compatibility (EMC) directive – General. Methodology for the achievement of functional safety of electrical and electronic systems including equipment with regard to electromagnetic phenomena.	2016	Provides guidance on the methodology for the achievement of functional safety of electrical and electronic systems including equipment concerning electromagnetic phenomena to ensure functional safety.
BS EN 61000-6-7	Electromagnetic compatibility (EMC) - Part 6-7: Generic standards - Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations.	2015	Defines immunity test requirements for equipment in relation to continuous and transient, conducted, and radiated disturbances, including electrostatic discharge.
BS EN 61427-1:2013	Secondary cells and batteries for renewable energy storage. General requirements and methods of test - Photovoltaic off-grid application.	2014	Provides general information relating to the requirements for secondary batteries used in photovoltaic energy systems (PVES) and the typical methods of test used for the verification of battery performances for batteries used in off-grid applications.
BS EN 61427-2:2015	Secondary cells and batteries for renewable energy storage. General requirements and methods of test - On-grid applications.	2016	Provides testing methods and general requirements of secondary cells used in on-grid EES, tests for the verification of their endurance, properties, and electrical performance.
BS EN 62305-1:2011	Protection against lightning. General principles.	2011	Specifies general principles to be followed for protection of structures against lightning, including their installations and contents, as well as persons.

Installation and Commissioning			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN 62305-2:2012	Protection against lightning - Risk management.	2013	Outlines risk assessment for a structure or service from lightning flashes to the earth. Allows for the selection of appropriate protection measures to reduce the risks to below the tolerable limit.
BS EN 62305-3:2011	Protection against lightning. Physical damage to structures and life hazard.	2011	Sets out the requirements needed to protect buildings and structures against physical damage by implementing a lightning protection system (LPS). Provides guidance on how to protect living beings against injury in proximity to an LPS.
BS EN IEC 62458-6:2021	Safety requirements for secondary batteries and battery installations – safe operation of stationary lithium-ion batteries.	2022	Describes the principal measures for protections during normal operation or under expected fault conditions against hazards. Provides requirements on safety aspects associated with the installation, use, inspection, and maintenance and disposal of lithium-ion batteries used in stationary applications.

A.5.4 Operation and Maintenance

Operation and Maintenance			
Standard ID	**Title**	**Pub year**	**Brief scope**
PD IEC TS 62933-2-2:2020	Electric Energy Storage Systems–part 2-2: unit parameters and testing methods–applications and Performance testing.	2020	Defines testing methods and duty cycles to validate the EES system's technical specification for all involved parties with the system to evaluate performance for various applications. A reference document for selecting testing items and their evaluation methods.
PD IEC TS 62933-4-1:2017	Electrical Energy Storage (EES) systems. Part 4-1: Guidance on environmental issues - General specification.	2017	Assesses the interaction of the EESS with the environment across its entire life-cycle and how adverse mutual effects on the EESS/environment may be considered and mitigated.
BS EN IEC 62933-4-2	Electric Energy Storage Systems - Part 4-2. Assessment of the environmental impact of battery failure in an electrochemical based storage system.	2021	Defines the requirements and structure for the evaluation and reporting of the impact on the environment, from a failure of the electrochemical core of the BESS or cell stack due to internal and exogenous causes.
BS EN IEC 62933-5-2:2020	Electrical energy storage (EES) systems - Safety requirements for grid-integrated EES systems. Electrochemical-based systems.	2020	Provides further safety provisions for an electrochemical storage subsystem in EESS that are beyond the general safety considerations described in 62933-5-1. Risks can depend on many factors including location, chemistry, and the size/scale of the BESS and will need to be assessed accordingly. Covers risk assessment, identification and mitigation of hazards, across 5 unique EESS classes based on electrochemistry.
BS EN 62933-5-3	Electrical energy storage (EES) systems - Part 5-3. Safety requirements for electrochemical based EES systems considering initially non-anticipated modifications, partial replacement, changing application, relocation and loading reused battery.	2021	Provides guidance for the steps and activities to be carried out when modifications are made to a BESS during its operational lifetime.

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Operation and Maintenance			
Standard ID	Title	Pub year	Brief scope
BS EN 50549-1:2019	Requirements for generating plants to be connected in parallel with distribution networks. Part 1: Connection to a LV distribution network – Generating plants up to and including Type B.	2019	First part of multi-series standard that covers specifications for distribution networks
BS 5839-1:2017	Fire detection and alarm systems for buildings - Code of practice for the design, installation, commissioning, and maintenance of systems in non-domestic premises.	2022	Fire safety standard on best practices for fire alarm systems for buildings. Provides recommendations for all lifecycle stages of the buildings for ESS
BS EN 60079-13:2017	Explosive atmospheres - Equipment protection by pressurized room "p" and artificially ventilated room "v".	2017	Contains the specific requirements on explosive atmospheres for all rooms, alongside additional requirements for pressurised and artificially ventilated rooms.
BS EN 60079-29-1:2016+A1:2022	Explosive atmospheres - Gas detectors. Performance requirements of detectors for flammable gases.	2022	Covers general requirements for constructing and testing gas detectors that detect and measure flammable gas or vapour concentrations with air.
BS EN IEC 60079-7:2015+A1:2018	Explosive atmospheres - Equipment protection by increased safety "e".	2019	Specifies the requirements for the design, construction, testing, and marking of electrical equipment and Ex Components with type of protection increased safety “e” intended for use in explosive gas atmospheres.
BS EN 60364-4-41AMD1	Low voltage electrical installation. Part 4-41. Protection for safety. Protection against electric shock.	2015	Specifies essential requirements regarding protection against electric shock, including basic protection and fault protection of persons and livestock. Deals with the application and co-ordination of these requirements in relation to external influences.
BS EN IEC 60364-5-57	Low-voltage electrical installations. Part 5: Selection and erection of electrical equipment - Clause 57: Erection of stationary secondary batteries.	2022	Provides recommendations for the design, erection, correct use, and protection of installations with secondary stationary battery storage.

Operation and Maintenance			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN 60896-11:2003	Stationary lead-acid batteries. General requirements and methods of test – vented types.	2003	Specifies general requirements, the main characteristics, and the corresponding test methods associated with all types and construction modes of lead-acid stationary batteries, excluding valve regulated types.
BS EN 60896-21:2004	Stationary lead-acid batteries – valve regulated types. Methods of test.	2005	Specifies the test methods for all types and constructions of valve-regulated stationary lead acid cells and monobloc batteries used in standby power applications.
BS EN 60896-22:2004	Stationary lead-acid batteries – valve regulated types. Requirements.	2005	Provides guidance on suitable requirements for valve-regulated stationary lead acid batteries and monobloc batteries used in standby power applications. Used in conjunction with BS EN 60896-21.
BS EN 61000-1-2:2016	Electromagnetic compatibility (EMC) directive – General. Methodology for the achievement of functional safety of electrical and electronic systems including equipment with regard to electromagnetic phenomena.	2016	Provides guidance on the methodology for the achievement of functional safety of electrical and electronic systems including equipment concerning electromagnetic phenomena to ensure functional safety.
BS EN 61427-1:2013	Secondary cells and batteries for renewable energy storage. General requirements and methods of test - Photovoltaic off-grid application.	2014	Provides general information relating to the requirements for secondary batteries used in photovoltaic energy systems (PVES) and the typical methods of test used for the verification of battery performances for batteries used in off-grid applications.
BS EN 61427-2:2015	Secondary cells and batteries for renewable energy storage. General requirements and methods of test - On-grid applications.	2016	Provides testing methods and general requirements of secondary cells used in on-grid EES, tests for the verification of their endurance, properties, and electrical performance.

Operation and Maintenance			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN IEC 62458-6:2021	Safety requirements for secondary batteries and battery installations – safe operation of stationary lithium-ion batteries.	2022	Describes the principal measures for protections during normal operation or under expected fault conditions against hazards. Provides requirements on safety aspects associated with the installation, use, inspection, and maintenance and disposal of lithium-ion batteries used in stationary applications.
BS EN IEC 62619:2022	Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for secondary lithium cells and batteries, for use in industrial applications.	2022	Specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications, including stationary applications.
BS EN IEC 63056:2020	Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for secondary lithium cells and batteries, for use in electrical energy storage systems.	2021	Under the umbrella standard BS EN IEC 62619. Specifies requirements and tests for the product safety of secondary lithium cells and batteries used in EESS.
IEC 62933-5-3	Electrical energy storage (EES) systems Part 5-3: Safety requirements when performing unplanned modification of electrochemical based EES systems.	2024	Provides guidance for the steps and activities to be carried out when modifications are made to a BESS during its operational lifetime.

A.5.5 Decommissioning and End-of-Life

Decommissioning and End-of-Life			
Standard ID	**Title**	**Pub year**	**Brief scope**
BS EN IEC 62933-5-2:2020	Electrical energy storage (EES) systems - Safety requirements for grid-integrated EES systems. Electrochemical-based systems.	2020	Provides further safety provisions for an electrochemical storage subsystem in EESS that are beyond the general safety considerations described in 62933-5-1. Risks can depend on many factors including location, chemistry, and the size/scale of the BESS and will need to be assessed accordingly. Covers risk assessment, identification, and mitigation of hazards, across 5 unique EESS classes based on electrochemistry.
BS EN 62933-5-3	Electrical energy storage (EES) systems - Part 5-3. Safety requirements for electrochemical based EES systems considering initially non-anticipated modifications, partial replacement, changing application, relocation and loading reused battery.	2021	Provides guidance for the steps and activities to be carried out when modifications are made to a BESS during its operational lifetime.
BS EN 61427-1:2013	Secondary cells and batteries for renewable energy storage. General requirements and methods of test - Photovoltaic off-grid application.	2014	Provides general information relating to the requirements for secondary batteries used in photovoltaic energy systems (PVES) and the typical methods of test used for the verification of battery performances for batteries used in off-grid applications.
BS EN 61427-2:2015	Secondary cells and batteries for renewable energy storage. General requirements and methods of test - On-grid applications.	2016	Provides testing methods and general requirements of secondary cells used in on-grid EES, tests for the verification of their endurance, properties, and electrical performance.
BS EN IEC 62458-6:2021	Safety requirements for secondary batteries and battery installations – safe operation of stationary lithium-ion batteries.	2022	Describes the principal measures for protections during normal operation or under expected fault conditions against hazards. Provides requirements on safety aspects associated with the installation, use, inspection, and maintenance and disposal of lithium-ion batteries used in stationary applications.

Annex B - Principal Hazards

B.1 Hazards associated with battery systems

Table 4: Example hazards associated with li-ion battery storage technologies

Hazard	Initiating Event
Fire [23, 24, 25]	• The thermal runaway of the batteries. • A short-circuit event of the internal electrodes (for example through the formation of dendrites[7]), which leads to thermal runaway. • Overvoltage/overcharge, which builds internal pressure, eventually venting explosive gasses for some chemistries and housing types. • External electrical short circuit potentially leading to high discharge current (e.g. due to degraded insulation, mechanical damage, incorrect wiring) • Sustained electrical arc fault leading to ignition of cable or surrounding material • Excessively high discharge demand on the battery system (e.g. during testing or use for fast discharge services beyond those which designed for) • Build up and ignition of flammable gases through normal operation (e.g. continuous release of hydrogen from vented batteries) • Inadequate management of operating environment (e.g. temperature, humidity, dust and particulate matter) • Cascading failure/thermal effects from adjacent battery cells within pack • Exposure to external flame/surrounding fire • Emergency services unable to respond effectively if unaware of presence/size/type of system
Explosive hazards (explosive gas or battery rupture hazard) [26]	• Thermal runaway leading to the release of explosive gases (e.g. Li-ion releases hydrogen during faulted conditions) • Build up and ignition of flammable gases through normal operation (e.g. continuous release of hydrogen from vented batteries) • Release of flammable gases due to overcharging • Cascading failure/thermal effects from adjacent battery cells within pack • Exposure to external flame/surrounding fire
Exposure to harmful chemicals or substances	• Maintenance, disposal or recycling of certain battery types • Leakage of electrolyte
Exposure to toxic gases [27]	• Battery fire • Vented toxic gas due to battery overcharging or exposure to fault conditions
Electric shock	• Electrical short circuit (e.g. loose connection to a casing) • Rise of earth potential (e.g. due to ineffective system earthing) • Accidental contact during installation, inspection, maintenance • Network backfeeding (i.e. incorrectly supplying the electrical network during an outage)

[7] Over the thousands of cycles that lithium batteries are subject to, lithium-ion batteries form lithium dendrites, which are solid, tree-like structures that grow as solid lithium is deposited onto the forming dendrites. In addition to reducing the available active lithium and reducing the performance of the battery, these dendrites grow from the negative electrode and can cause a short circuit in the cell, leading to fire risk by thermal runaway, fires and explosions [28].

Hazard	Initiating Event
Exposure to extreme heat, acoustic noise, pressure or light (e.g. hazards associated with an arc flash/blast)	• Arc flash (primarily on the DC side) caused by accidental contact, corrosion, dropped tools, incorrect work procedures etc. A plasma arc is established from current flowing through ionised air and can rapidly lead to extreme temperatures (enough to explosively vaporise conductive metals) and light. • Arc blast can follow the arc flash through the instantaneous expansion of gas at the point of fault.
Injury caused by movement of cables/components through electromechanical stresses	• Electromagnetic forces are induced in conductors by the currents flowing through them. Where such electromagnetic forces interact on parallel conductors, they cause stresses which must be taken into account. The force is proportional to current magnitude and is therefore largest during high current discharge events such as electrical faults.
Hazards associated with movement, handling, movement of equipment etc.	• Lifting, placement of battery systems • Seismic activity (limited issue in the UK)

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