WORLD BANK GROUP
THE WORLD BANK IBRD • IDA | IFC International Finance Corporation | MIGA Multilateral Investment Guarantee Agency

Environmental, Health, and Safety Guidelines

BATTERY ENERGY STORAGE SYSTEMS

2026

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1 INTRODUCTION

1. The Environmental, Health, and Safety Guidelines (EHS Guidelines) are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP).[1] They are comprised of the General Environmental, Health, and Safety Guidelines (General EHS Guidelines) and Industry-specific Sector Guidelines (Industry Sector EHS Guidelines). The General EHS Guidelines present common environmental, health, and safety (EHS) issues that potentially apply across industry sectors. The Industry Sector EHS Guidelines present EHS issues specific to each industry sector.

2. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as described in their respective policies and standards. The Industry Sector EHS Guidelines are designed to be used together with the General EHS Guidelines. For complex projects, multiple Industry Sector EHS Guidelines may be relevant. A complete list of Industry Sector EHS Guidelines can be found at www.ifc.org/ehsguidelines.

3. The EHS Guidelines specify the performance levels and measures that are generally considered to be GIIP and achievable in new facilities by using existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve establishing site-specific targets, with an appropriate timetable for achieving them.

4. The applicability of EHS Guidelines should be tailored to the hazards and risks identified for each project based on results of an impact assessment that considers site-specific variables, such as host country context, assimilative capacity of the environment, and other project-specific factors. The applicability of specific technical recommendations should follow GIIP and be based on the professional opinion of qualified and experienced professionals. When a host country's regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent measures than those in the EHS Guidelines are appropriate due to specific project circumstances, a detailed justification for any proposed alternatives is needed as part of the site-specific assessment and should demonstrate that the alternate performance levels are protective of human health and the environment.

5. The scope of the EHS Guidelines includes environmental, occupational health and safety, and community health and safety aspects. Guidance on social aspects is not included and can be found in relevant Guidance Notes to IFC/MIGA Performance Standards, relevant Guidance Notes to World Bank E&S Standards, and various other World Bank Group good practice publications.

[1] GIIP is defined as the professional skill, diligence, prudence, and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of prevention and control techniques available to a project may include, but are not limited to, varying levels of EHS capabilities and capacities, and financial and technical feasibility.

2 APPLICABILITY

6. The EHS Guidelines for Battery Energy Storage Systems (BESS) apply to the full life cycle of stationary power storage systems. They are not applicable to batteries used in electric vehicles; small devices such as laptop computers, smartphones or power tools; uninterruptible power supply (UPS) systems used to provide constant power to computers; or residential-scale electricity storage systems. Annex A provides a summary of industry activities.

7. EHS issues associated with co-location of BESS facilities within intermittent power generation sources such as solar photovoltaic and wind power facilities, and grid connection, should be evaluated in the impact assessment. Industry-specific EHS Guidelines are available for other sectors.

3 DESIGN CONSIDERATIONS

8. This section summarizes key aspects related to project siting and design for this industry sector. Design considerations for buildings and ancillary facilities that are common to various industry sectors are detailed in the General EHS Guidelines.

9. BESS project design can be broadly separated into the following considerations:

- Siting
- Equipment selection
- Facility design

3.1 Siting

10. BESS facilities can be sited in urban cities or undeveloped areas where risk-based siting criteria are met. Important siting factors include the following:

- Proximity to power infrastructure (near a generation source, a power system substation, or a major power user)
- Access to a power grid connection with adequate capacity
- Sufficient area to provide spacing between equipment and setbacks from adjoining land uses, both of which are informed by equipment selection (Section 3.2), facility design, and hazard mitigation analysis (HMA) (Section 3.3)
- Generally flat land with geotechnical capacity to support heavy components and related infrastructure
- Consideration of natural hazards such as flooding, wildfires, hurricanes, including climate change projections
- Access for firefighting and emergency response or account for self-sufficiency when siting in undeveloped areas

11. BESS serving a commercial or industrial activity are commonly located within the commercial or industrial setting they serve and tend to be located closer to other activities where people are present, while utility-scale BESS often are located in areas with less human activity and would normally only be accessible to specially trained, qualified, and authorized staff.

12. Appropriate distance from surrounding land uses will vary depending on the types of equipment at the BESS facility, results of equipment testing and specifications, and the nature of the land use. Further guidance is available from internationally recognized references for BESS facility design and construction (see table 1).

3.2 Equipment Selection

13. The main equipment at a BESS facility consists of integrated systems with racks of battery modules stacked within enclosures and accessed through cabinet doors for servicing (see Annex A). Cabinet or enclosure-based designs are preferred because they prevent workers from becoming trapped during fire or other upset conditions and limit the volume of enclosed space where flammable or explosive gases could accumulate.[2]

14. Lithium-ion batteries commonly used in BESS contain electrolytes that may be released if a battery fails due to abuse conditions, such as crushing, overcharging, or overheating. Vented electrolyte can generate flammable, explosive, and toxic gases within BESS enclosures and present risks for workers and surrounding assets.

15. To prevent and control these risks, safety considerations in the design, monitoring, and control, include the following:[3]

- Detection and alarm systems that are adequate for the type of battery chemistry and design of the fire detection system, which may include smoke, flammable or explosive gases (e.g., hydrogen or hydrocarbons), carbon monoxide, and/or heat, with visible and audible notifications
- Automatic system response, including integration of detection systems with BESS controls to initiate system shutdown and alert personnel when hazardous conditions are detected. Notifications may include on-site alarms and signals to centralized monitoring services for off-site response
- Enclosure ventilation systems designed to introduce fresh air and dilute released gases before they reach flammable or explosive concentrations
- Design features to control explosion energy, where applicable, to reduce the risk of injury or property damage
- Thermal management systems, including heating, ventilation and air conditioning (HVAC), capable of maintaining acceptable battery cell temperatures and enclosure humidity during charging, discharging, and rest periods under expected

[2] Some earlier designs placed racks in rooms or buildings where people enter to conduct service and maintenance. These types of "walk-in" designs, which are largely obsolete, inherently introduce higher risk for workers.
[3] EASE, *Safety Best Practices*.

site and climatic conditions. HVAC systems should be designed to manage temperature extremes, rapid temperature changes, and humidity fluctuations, and should use non-flammable refrigerants

- Battery management systems (BMS) that monitor, control, and protect battery cells safety and reliability by:
  - Continuously monitoring voltage, current, and temperature to maintain operation within safe limits
  - Balancing cells for uniform charge and discharge distribution across circuits
  - Transmitting operational data to a higher-level management system for analysis, risk mitigation, and record-keeping
  - Maintaining operational continuity and/or enabling safe shutdown by securing the BMS power supply during safety-critical conditions
- Electrical and mechanical protection measures, including protection against overcharging, over-discharging, internal and external short circuits, mechanical damage from external forces (including seismic events), and fire propagation within and between enclosures (see table 1)
- Robustness of design to withstand site-specific environmental and physical risks, including dust, corrosive soils or atmospheres, theft of cables or hardware, vandalism, and pest damage

16. Some newer BESS designs do not incorporate fire suppression systems, as laboratory testing has indicated limited effectiveness in extinguishing lithium-ion battery fires. However, certain older BESS installations may still be equipped with such systems, which would activate in the event of a fire. Fire and explosion risks, potential impacts, and additional prevention and response measures are discussed in Sections 4.1.2, 4.2.2, and 4.3.3.

17. Applicable codes and standards, including those listed in table 1, and their updated editions, establish safety measures for BESS design, installation, and verification. As codes and standards are regularly updated, the latest editions should be referenced.

Table 1. Codes and standards

Code or standard		Applicability for BESS design
NFPA 855	Standard for the Installation of Stationary Energy Storage Systems	Incorporates references to several applicable standards, including International Fire Code; National Fire Protection Association (NFPA); and Underwriters Laboratory Standards and Engagement (UL)
NFPA 68	Standard on Explosion Protection by Deflagration Venting	Outlines requirements for safely venting and directing energy away from occupied or sensitive areas in the event of an explosion
NFPA 69	Standard on Explosion Prevention Systems	Provides guidance for the design of systems aimed at explosion prevention
NFPA 70E	Standard for Electrical Safety in the Workplace	Includes requirements for electrical risk assessment and arc-flash labeling that feed design-informed isolation, clearances, and PPE categories
UL 9540	Energy Storage Systems and Equipment	Certification standard that governs the design, construction, and testing of energy storage systems, particularly those used in utility-scale BESS
UL 9540A	Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	Referenced as part of UL 8540; enables an understanding of fire behavior and propagation within battery systems; involves sequential testing from individual battery cells to modules comprised

Table 1. Codes and standards		
Code or standard		Applicability for BESS design
		of multiple cells, and ultimately to complete units containing multiple modules
UL 1642	Standard for Lithium Batteries	Confirms baseline lithium cell safety, forming the foundation upon which module, pack, and system-level BESS safety standards are built
UL 1741	Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources	Governs how the BESS electrically interfaces with the grid, ensuring safe, compliant, and stable operation under normal and abnormal grid conditions
CSA TS-800:24	Large-Scale Fire Test Procedure	Addresses fire propagation by evaluating the potential for fire to spread to adjacent equipment when a unit is subjected to large-scale fire conditions
ANSI/CAN/UL 1973	Batteries for Use in Stationary and Motive Auxiliary Power Applications	Covers safety considerations for rechargeable battery systems used in stationary energy storage and motive auxiliary power applications, including UPS, light electric rail, and vehicle auxiliary power systems, while excluding batteries intended for traction propulsion.
IEC 62933-5-3:2023	Electrical Energy Storage (EES) Systems – Part 5-3: Safety Requirements for Grid-integrated EES systems - Performing Unplanned Modification of Electrochemical Based System	Applies to grid-connected BESS where unplanned modifications may occur during the system lifecycle (e.g., component replacement, capacity expansion, control upgrades)
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	Applies at the cell and battery module level for lithium batteries used in industrial BESS; defines the minimum safety performance of lithium cells and battery modules that underpin safe BESS system design
IEC 62485-5:2020	Safety Requirements for Secondary Batteries and Battery Installations – Part 5: Safe Operation of Stationary Lithium Ion Batteries	Applies to stationary lithium-ion battery installations, including BESS enclosures, rooms, and containers; guides the safe physical integration and operation of lithium-ion batteries within buildings and fixed installations
IEC 63056	Safety Requirements for Secondary Lithium Cells and Batteries for Use in Electrical Energy Storage Systems	Defines battery system-level safety requirements to confirm lithium battery packs are intrinsically safe before integration into a larger BESS
IEEE 1547:2018	Standard for Interconnection and Interoperability of Distributed Energy Resources with Electric Power System Interfaces	Governs how a BESS behaves electrically and functionally at the grid interface to support grid stability, interoperability, and utility-approved operation

18. Although there is no single, unified design standard for BESS, applying internationally recognized standards and associated testing and verification methods support the safe design and performance of battery cells, modules, and racks, including resistance to thermal runaway, mechanical stress, and electrical faults. Specifying equipment that complies with internationally accepted standards can significantly reduce technology and safety risks. In addition, some countries and regions have regulatory requirements related to batteries and waste battery management.

3.3 Facility Design

19. BESS facilities are subject to hazards such as thermal runaway, a chemical reaction within battery cells that can propagate to adjacent cells and can lead to fire. Thermal runaway is typically preceded by a rapid temperature spike caused by short circuits or other electrical faults and once initiated, releases significant heat and pressure. During thermal runaway, lithium-ion battery cells

may rupture and release toxic and flammable gases, which can result in fire and/or explosion (see Section 4.2.2). To inform effective design mitigations, an HMA, also defined as a qualitative risk assessment (QRA), is conducted. An HMA identifies hazards, evaluates potential consequences, and defines measures to prevent or limit events such as fires, explosions, and hazardous gas releases. Cumulative risks associated with co-location of BESS projects, especially when different battery types or chemistries are involved, should also be considered. General guidance on electrical, fire, and community safety is available in the General EHS Guidelines.

20. EHS considerations in the design of BESS facilities should consider the phases of construction, operation and maintenance, as well as future battery capacity augmentation and potential emergency situations. These considerations include the following:

- Allowing for adequate spacing of BESS enclosures, power conversion systems (PCS), transformers, cabling, maintenance access (vehicles, equipment, personnel), spare parts storage, stormwater control or retention, and perimeter security
- Maintaining adequate separation between BESS enclosures to prevent fire propagation and explosion impact within the facility and beyond its boundary. The separation principle is to prevent a fire or explosion in one enclosure from spreading to neighboring enclosures or outside the facility boundary. Minimum distances will vary depending on relevant technology and site-specific factors; however, distances should follow manufacturer recommendations and be supported by largescale fire testing of equipment of the same scale and type.[4]
- Incorporating noise attenuation measures where nearby noise sensitive receptors are present
- Assessing potential fire-related pollution (see Section 4.1.2) by performing a firewater discharge risk assessment, which may result in the facility design including containment measures, as appropriate, when sensitive areas, drinking water sources, or regulated runoff zones are present and can be impacted

4 CONSTRUCTION AND OPERATIONAL CONSIDERATIONS

21. This section provides a summary of sector-specific EHS risks typically associated with the construction and operational phases and provides guidance for mitigation and management measures. Where there are unique aspects to the construction, refurbishment, and decommissioning of this industry sector, guidance is also included. Recommendations for EHS issues and management common to the construction, refurbishment, and decommissioning phases, are provided in the General EHS Guidelines.

[4] UL, *9540*; NFPA, *855*.

4.1 Environment

22. Key environmental issues for this industry sector include:

- Waste management
- Fire-related pollution

4.1.1 Waste Management

23. Waste is generated during construction, operation, augmentation and decommissioning of BESS. While most waste streams are addressed under the General EHS Guidelines, BESS present specific risks in the management of batteries including handling and transportation, which may constrain options for reuse, recycling, or final disposal.

24. During operations, batteries may be augmented or replaced to maintain facility performance, and other equipment such as PCS, HVAC, and controls may need mid-life replacement or overhaul. Typical waste from spent batteries or end-of-life BESS includes battery cells containing metallic foils (aluminum, copper), hazardous precious metals (lithium, nickel, manganese), graphite anodes, and aluminum or other metallic or non-metallic cell case, and other electrical and structural components (plastic conduits, insulation, steel enclosures, foundations). Improper management of BESS waste may result in environmental contamination and fire and explosion hazards. These risks are heightened in jurisdictions where battery recycling or hazardous waste disposal infrastructure is limited.[5]

25. Mitigation measures for BESS waste management include the following:

- Defining the facility design life and documenting expected battery and system component lifetimes, including augmentation and replacement strategy and schedules during project design, operation and maintenance
- Screening and prioritizing battery suppliers that offer end-of-life planning and take-back arrangements, particularly in contexts where licensed recycling or hazardous waste treatment facilities are limited or unavailable. Preference should be given to those with the capacity for safe handling, transport, recycling and/or disposal of spent batteries, and those that support circular economy approaches such as reuse, repurposing, recycling and recovery of key materials.[6]
- Promoting upstream reuse and recovery of spent batteries, including repurposing, refurbishment, or recycling, where feasible; through qualified suppliers, manufacturers or recyclers, prior to final disposal. Offsite shipment of batteries should meet applicable requirements for transboundary movements, including traceability.[7]

[5] Some jurisdictions may not have suitable BESS recycling or disposal facilities and external options need to be considered. Some jurisdictions may have extended producer responsibility requirements for project-level producers, including labeling, collection, storage and transport, where formal infrastructure may be lacking.

[6] EU 2023/1542, *Batteries and Waste Batteries*. This EU regulation promotes circular economy for batteries, establishes extended producer responsibility, and minimum recycled content targets, recycling efficiency targets and traceability tools to reduce reliance on primary raw materials.

[7] Basel Convention, *Transboundary Hazardous Waste;* Rotterdam Convention, *Trade of Hazardous Chemicals.* Where relevant, international conventions on transboundary hazardous waste should be applied.

- Implementing a decommissioning plan that defines repurposing, refurbishment, recycling, and disposal methods for batteries, racks, wiring, enclosures, and other components, with the objective of maximizing recovery of metals such as steel, copper, aluminum, nickel, and manganese to prevent environmental contamination[8]
- Planning for safe handling, interim storage, and transportation of used or damaged batteries, including fire protection, containment and emergency response measures

4.1.2 Fire-related Pollution

26. This section focuses on air emission, water runoff, and soil and groundwater contamination resulting from accidental BESS fire and fighting response. Aspects related to fire hazard and emergency response are described in Section 4.2.2, and BESS fire risks to nearby communities is described in Section 4.3.3.

27. BESS facilities store substantial amounts of energy and carry risks of thermal runaway and fire. BESS are composed of a combination of metals, plastics, and organic solvents and thus, in a fire, can generate toxic smoke with characteristics similar to other mixed-materials fires, such as car or residential fires. In the event of a fire, BESS smoke emissions may contain harmful and toxic constituents such as particulate matter, volatile organic compounds (VOCs), hydrogen fluoride (HF), and carbon monoxide (CO). The severity of smoke toxicity exposure risk depends on fire magnitude, facility layout, proximity to receptors, and atmospheric dispersion conditions.[9]

28. Industry guidance generally advises against applying water directly on an active BESS fire, instead recommending monitoring and containment to prevent fire spread from one enclosure to another, while allowing the affected battery system to self-extinguish.[10] Some BESS may have automatic or manually triggered water-based fire suppression systems incorporated. BESS facilities may also install fire hydrants or water may be applied by fire brigades to control and contain a fire to protect adjacent structures from heat propagation or damage. If water is used for fire suppression or containment, the resulting firewater runoff may become contaminated with electrolyte residues or combustion by-products, which can in turn affect community water supplies or downstream uses. Mitigation measures include:

    - Containing and directing firewater runoff, where feasible, to engineered systems (e.g., drainage channels, sumps, or retention ponds), particularly where there is a risk of discharge to sensitive environments or groundwater (see Section 3.3)
    - Testing and managing collected runoff following the incident, and disposing of or releasing it in accordance with GIIP and applicable local regulations

[8] Aydin et al., *Energy Storage Procurement Study*.
[9] Aydin et al, *Energy Storage Procurement Study*; American Clean Power, *Assessment of Potential Impacts*. This fire safety review examined 35 documented BESS fires, including high-profile 2023 incidents in New York and Idaho that consumed substantial portions of the battery arrays involved. The assessment stated environmental “studies [that found airborne] emissions are largely confined to the immediate vicinity of the fire, with rapid dissipation and concentration reduction in open-air scenarios.” Post-incident monitoring at battery fires in California and New York that showed “no detectable hazardous concentrations” of toxic chemicals like hydrogen fluoride and hydrogen cyanide led local authorities to lift shelter-in-place orders.
[10] ACP, *First Responder Guide*. Factory Mutual Insurance Company, *Lithium Ion Battery Manufacturing;* Factory Mutual Insurance Company, *Lithium Ion Battery Storage*.

29. Post-deflagration environmental risks may also involve soil and groundwater contamination from firewater runoff and burnt materials. Following a BESS fire, operators should assess the extent of soil contamination and implement site remediation measures consistent with GIIP. Remediation activities should include site characterization, containment and removal of contaminated soils where necessary, and appropriate disposal or treatment in accordance with applicable regulations and recognized international standards for battery safety, fire response, and hazardous materials management, as discussed in the General EHS Guidelines.

4.2 Occupational Health and Safety

30. This section presents sector-specific considerations for occupational health and safety (OHS) hazards in this industry sector. OHS hazards common across sectors and related to construction activities are discussed in the General EHS Guidelines.

31. Major OHS risks in this industry sector include the following:

- Electrical safety
- Fire and explosion
- Chemical hazards
- Biological hazards

32. OHS risks should be assessed in an HMA (see Section 3.3). Potential hazards related to confined spaces should be avoided in the equipment selection, prioritizing cabinet enclosures (see Section 3.2). "Walk-in" BESS designs allowing personnel to enter inside the interior of an enclosure, room, or building present risks to workers, including exposure to hazardous atmospheres (such as the buildup of toxic or explosive gases), excessive heat, and risk of entrapment in the event of an emergency. Additional guidelines for confined space risks and mitigations are discussed in the General EHS Guidelines.

4.2.1 Electrical Safety

33. BESS facilities pose electrical hazards in the form of occupational exposure to energized systems and equipment during installation, commissioning, maintenance, operations and augmentation.[11] Utility-scale BESS equipment commonly has electrical potentials up to 1,500 volts with both direct current (DC) and alternating current (AC), with higher voltages possible at grid interconnection points. As with other electrical infrastructure, contact with or proximity to live electrical parts, faulty wiring, or improper grounding at a BESS facility can cause electrocution, shock, burns, or arc-flash injuries.[12]

34. All electrical work should be performed by qualified personnel following recognized electrical safety standards and procedures. Key practices include: worker and contractor onboarding and safety training, including contractors; safety-oriented equipment design;

[11] NFPA, *70E*.
[12] Arc-flash is the sudden release of energy from an electrical arc that can trigger explosions and fires, causing cause burns, vision or hearing loss, and potentially death.

warning placards; secured gates and cabinets; physical barriers to prevent unintended contact with electrically live components; lockout/tagout (LOTO) protocols to isolate energy sources during equipment servicing; and the use of properly rated tools and personal protective equipment (PPE), such as safety glasses, insulated gloves, and arc-rated clothing. Equipment should be clearly labelled, and any damaged components should be de-energized and repaired before use. Work at height or in confined spaces may require extra precautions due to increased hazard severity and reduced capacity for quick hazard avoidance.

35. Electrical hazards can persist even when a BESS is “fully discharged.” In this state, batteries are at the lowest normal operating voltage, which is not a zero-voltage condition. Disconnected or fully discharged battery cells can still present an electrical shock or arc-flash risks. This applies to new batteries being transported or installed in new facilities or during repairs, maintenance or augmentation, as well as used batteries removed during maintenance or decommissioning.

36. An electrical risk assessment consistent with NFPA 70E should be conducted prior to performing work on electrical systems. It should identify the hazards (incident energy) and preventive methods prior to carrying out the work, including task-based controls. It should address the potential for human error and the hierarchy of safety controls. Equipment should be labelled with the incident energy per NFPA 70E.

37. As part of the HMA (see Section 3.3), it may be appropriate to identify, evaluate, and mitigate potential hazards related to the BESS facility. The HMA should be periodically reviewed and updated. A hazard mitigation analysis using NFPA 70E serves to identify electrical hazards, evaluate risks including the local environment, and implement safety controls to operate safe electrical work and manage arc-flash, shock, and arc blast risks to properly.[13]

4.2.2 Fire and Explosion

38. BESS equipment failure can cause overheating, thermal runaway, and release liquids and gases from batteries. These materials may ignite immediately or accumulate, creating an explosion risk. Codes and standards described in Section 3.3 address safety measures to manage such risks.

39. To prevent fires within a BESS enclosure and/or fire propagation into nearby BESS enclosures in a facility, consider the following:

- Avoiding storage of combustible materials in or near BESS equipment
- Regularly removing vegetation in proximity to equipment through a vegetation management program
- Regularly maintaining and testing the functionality of automatic fire detection and alarm systems
- Developing and implementing a site safety plan that outlines safety measures and procedures for BESS operations and maintenance, guides safe work practices and verify safety standards are met. The plan should cover the risks of battery

[13] NFPA, *70E*.

transport into the facility during construction, and account for adequate training and equipment to prevent and combat fire risks during handling and storage.

- Developing a site-specific Emergency Preparedness and Response Plans (EPRP) with input from local fire departments and first responders, following the General EHS Guidelines
- Providing comprehensive training to facility workers and local emergency responders on BESS fire and smoke hazards, alarm detection and reporting systems, safe response procedures, methods to approach and access the BESS, reporting protocols, evacuation procedures, and maintaining safe distances
- Posting clear signage throughout the BESS facility for safe approach distances, unobstructed exits, and muster points
- Establishing and maintaining communication and mutual aid collaboration with local firefighting teams, including regular drills and annual training on current BESS fire response techniques, such as allowing fires to burn out while evaluating measures to control fire propagation into other BESS enclosures or other adjacent areas, through appropriate firefighting methods (e.g., depending on the situation, and after due assessment, water may be applied in areas surrounding the ignited BESS to limit propagation)

4.2.3 Chemical Hazards

40. Damaged battery cells can release hazardous or toxic materials, depending on their chemistry. If inhaled, these emissions may harm workers, and if not adequately vented, may accumulate and create an explosion hazard. For example, cells may emit gases such as HF, CO, and hydrogen, each of which pose distinct occupational health and safety risks. HF is a highly toxic and corrosive inhalation hazard with potential for severe respiratory injury and systemic effects; CO is a colorless, odorless toxic gas that rapidly impairs oxygen delivery and self-rescue capability; and hydrogen, while not toxic, can displace oxygen and contribute to fire and explosion hazards in confined or poorly ventilated spaces. Venting may also leave liquid or solid residues that are hazardous on contact.

41. Equipment selection and facility design should support early detection, ventilation, controlled shutdown, and safe evacuation to reduce risks to workers and emergency responders during abnormal and emergency conditions.

42. To mitigate chemical hazards, consider the following:

- Selecting equipment that supports early detection of damaged cells via a BMS and alert systems (see Section 3.2)
- Training workers on the chemical risks and safe evacuation away from equipment with signs of damage or gas emission
- Communicating with workers and first responders the gas composition of the battery cells and toxicity parameters, and raising awareness on the risks of hazardous gases or residues
- Wearing portable gas detectors to prevent exposure

4.2.4 Biological Hazards

43. Battery enclosures, control cabinets, and other electrical equipment at BESS facilities can be attractive shelters for snakes, arachnids, insects, and rodents. Regular facility maintenance should be carried out to prevent such infestations, while managing pest control per GIIP. Additional guidance on biological hazards and pest management is included in the General EHS Guidelines.

4.3 Community Health and Safety

44. This section presents sector-specific considerations for community health and safety (CHS) risks in this industry sector. CHS risks and hazards common across industries are described in the General EHS Guidelines.

45. The HMA/QRA (see Section 3.3) informs the setting of public safety acceptance criteria, setbacks and measures to protect communities neighboring the BESS facility. Major CHS risks in this industry sector include the following:

- Abnormal load transportation
- Facility access control
- Fire and explosion
- Noise

4.3.1 Abnormal Load Transportation

46. Transporting heavy or oversized BESS equipment during construction or decommissioning involves special vehicles, permits, and route planning. Whether new, decommissioned, or damaged, transporting BESS and some BESS components may be classified as special or hazardous materials transport and thus may require special communication and handling. Damaged battery modules often contain stranded energy, and their transport may require special placarding and packaging to prevent and contain fire.

47. Mitigation measures include the following:

- Assessing transportation logistics and requirements, including roadway and bridge capacities, culvert crossings, and clearances at overpasses, underpasses, and utilities, as well as any needed upgrades or repairs ahead of transportation
- Timing transportation to periods with less public activity on the route
- Communicating with local transport agencies and authorities on the road plan, including the potential need to adapt plans
- Coordinating with emergency responders on the transport planning for response in case of incidents

4.3.2 Facility Access Control

48. BESS facilities pose hazards to the public and should not be accessed by unauthorized people. Mitigation measures include the following:

- Installing a secure perimeter with a fence or wall at least two meters high, with locked entry points meeting NFPA 70 and NFPA 855 requirements to prevent unauthorized access[14]
- Requiring permit passes to enter the BESS facility with authorization
- Displaying signage in the facility perimeter and entry points identifying the facility name, battery technology, electrical hazards (e.g., high-voltage, arc-flash), fire suppression type (if any), and emergency contact information
- Locking equipment cabinets to ensure that live electrical equipment is inaccessible in the event of unauthorized site access
- Install a closed-circuit camera television (CCTV) for all access points to detect unauthorized entry

4.3.3 Fire and Explosion

49. This section discusses risks to community health and safety related to BESS fire and explosion. Section 4.2.2 presents additional detail related to prevention and mitigation of fire and explosion risks within a BESS facility.

50. The potential for BESS fires or explosions to affect nearby communities should be evaluated as part of the HMA to inform appropriate setbacks, equipment layout, emergency response planning and capabilities, and resource availability (see Section 3.3). Fire-related community impacts may include exposure to toxic air emissions and, where water is used for fire suppression, contamination of surface water or groundwater from firewater runoff contaminated with burnt equipment (see Section 4.1.2). If smoke is transported toward populated areas, including due to prevailing wind conditions, first responders may recommend precautionary evacuation, coordinated with the project. Mitigation measures include the following:

- Informing local communities and first responders about BESS-related risks and mitigation measures (e.g., meetings, training, and distribution of written materials)
- Establishing clear and accessible communication and coordinating with first responders and nearby communities in site-specific emergency preparedness and response plans (see Section 4.2.2)
- Conducting regular training exercises and emergency response drills with first responders and communities to test coordination, communication, and response effectiveness

[14] *NFPA 70, National Electrical Code. NFPA 855, Installation Stationary Energy Storage.*

4.3.4 Noise

51. Noise-producing components at operating BESS facilities may include high-frequency electrical switching noise from PCS, and compressor and fan noise from equipment cooling and ventilation systems. In some cases, site-specific noise assessments and mitigations may be appropriate depending on the facility size, equipment types, distances to facility boundaries, types of neighboring land uses, and distances to nearby receptors.

52. At utility-scale BESS facilities, noise generated from high-frequency switching of components within PCS equipment during high load can be the most problematic noise generation source. Large PCS equipment often has noise emissions specifications of less than 70 db(A) at 10 meters distance.

53. Mitigation measures in addition to those provided in the General EHS Guidelines include the following:

- Consider sound-absorbing perimeter walls
- Place noisy equipment away from receptors during facility planning
- Select low-noise equipment options or upgrades if available

5 PERFORMANCE INDICATORS AND MONITORING

54. This section describes relevant EHS performance indicators and industry benchmarks of GIIP for this industry sector. Indicators that are applicable across industries are available in the General EHS Guidelines.

5.1 Environmental Performance

55. Environmental monitoring programs should address significant impacts under normal operations and upset conditions, based on direct and indirect indicators applicable to the project. Monitoring should be conducted by trained specialists, use calibrated and maintained equipment, and follow GIIP methods to collect, verify, and analyze data. Results should be compared to applicable standards, and corrective actions implemented for any exceedances. Refer to the General EHS Guidelines for more information.

56. BESS facilities generally do not generate air emissions, effluents, or significant waste during operation, so environmental monitoring is less extensive than for other industrial activities. However, because they are net energy consumers and discharge only a fraction of the energy used to charge, BESS round-trip efficiency (RTE) should be tracked annually. The ratio of discharged to charged energy serves as a useful operational performance benchmark, with values dependent on facility design, battery type, and dispatching practices.

57. During the decommissioning of BESS facility components or the entire facility, an environmental performance metric should be used to quantify the proportion of materials reused or recycled versus the total materials removed from the site.

5.2 Occupational Health and Safety Performance

58. The working environment should be monitored to identify occupational hazards relevant to the project. Monitoring should be designed and implemented by accredited professionals as part of an OHS monitoring program, as provided in the General EHS Guidelines. Facilities should record occupational accidents and incidents and report significant accidents and injuries, including the frequency rates and associated lost time. This data should be benchmarked against international guidelines and standards.

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ANNEX A: GENERAL DESCRIPTION OF INDUSTRY ACTIVITIES

1. Battery Energy Storage Systems (BESS) store electricity in batteries for later redelivery. Because electricity generally cannot be stored without batteries, power system supply and demand need to be balanced in real time. When demand increases, generation increases; when demand decreases, generation decreases. In complex grids, with numerous supply sources and power users, some supply/demand balancing occurs when changes in individual user demand offset each other. BESS provide another tool for balancing supply and demand.

2. BESS are often paired with intermittent renewable power generation, such as solar, to store low-value or surplus power generated during sunny periods for later delivery after sunset. They can also be located near consumers or at intermediate points such as along transmission and distribution systems that link power generation sources with demand.

3. BESS can be deployed on a wide range of scales, and there is no universal standard for classifying the size of BESS. Regardless of scale, BESS facilities tend to use similar types of enclosures; the primary differences are the number of enclosures and the number and types of ancillary equipment.

   - Commercial or industrial BESS usually include one to several ground-mounted enclosures (e.g., 2MW / 10MWh).
   - Utility-scale BESS can include tens or hundreds of enclosures and ratings in the hundreds to thousands of MW and MWh.

4. BESS store energy in electrochemical battery cells, most commonly lithium-ion batteries, including the lithium iron phosphate (LFP) subtype. Alternative chemistries include sodium ion and lithium nickel manganese cobalt oxides (NMC).

5. BESS electricity storing and redelivery incur energy losses and can only return part of the energy stored. Lithium-ion BESS typically achieve 85% to 90% round-trip efficiency, influenced by usage frequency, charge/discharge rates, climate, duration of charge, and system age.

6. Charging during times of power surplus and discharging when demand exceeds supply is a primary means by which BESS add value, potentially yielding financial returns under certain market and contractual structures. BESS can also improve grid resilience and defer costly transmission or distribution line upgrades.

7. Although daily time-shifting is a common use, BESS can also integrate variable renewable facilities smoothly into the grid, provide frequency regulation by quickly adjusting output or consumption, and supply backup power to specific customers during distribution outages.

8. BESS facilities commonly include containerized enclosures housing many batteries and related equipment that control the system, maintain a suitable environment within the enclosure, and connect the BESS to an external power system.

9. The interior of BESS enclosures contains racks that house modules composed of many individual battery cells assembled into physical and electrical units (Figure A2). Battery cells come in configurations such as rigid cylinders, flexible foil pouches, and rigid rectangles called prismatic cells. Components of battery cells include anodes, cathodes, separators, electrolyte, terminals, and housing (Figure A3).

10. While BESS are often co-located with solar photovoltaic (PV) generation, their footprint is much smaller for the same electrical capacity. A 100 MW PV facility may require 150 to 200 hectares; a 100 MW/400 MWh BESS requires roughly 2 to 4 hectares.

11. Key BESS specifications and performance parameters include the following:

- Power rating (the amount of power it can produce or consume at a given time, typically in kW or MW)
- Energy storage capacity (typically in kWh or MWh)
- Round-trip efficiency (RTE)
- Standby consumption
- Battery lifetime/degradation profile

12. Lithium-ion batteries can cycle (charge and discharge) thousands of times during their useful lives. However, batteries degrade with each cycle, providing 80%-90% of their original capacity after some years. Systems are often initially overbuilt with reserve capacity and augmented periodically with additional batteries. Augmentation planning should consider physical space and financial/cost projections.[15]

13. The relationship between MW and MWh ratings is expressed in rated hours of storage. For instance, a 100 MW/400 MWh system can fully charge or discharge in 4 hours, or at a reduced power (e.g., 50 MW) in 8 hours.

14. BESS operate in three states: (1) charging by consuming power, (2) discharging by delivering power, or (3) not operating/remaining idle. Even when idle, they consume power for monitoring, controls, and climate management.

15. In addition to batteries, BESS contain many supporting systems and equipment: racks and mounting equipment; HVAC for temperature/humidity control, monitoring, and control systems; wiring for power, communications, and controls; protective enclosures; foundations; power conversion systems (PCS) for AC/DC conversion, and grid interconnection (Figure A4).

16. Construction activities for BESS facilities typically include clearing and grading the site; opening access routes; transporting materials and equipment; constructing foundations or driving of pile foundations; installing electrical and communication cables;

[15] Augmentation is the process of installing additional new batteries to an existing BESS to regain the system's capacity lost through degradation. Augmentation typically leaves existing (partially degraded) batteries in place although at some point later in a facility's life augmentation can also involve replacing old batteries.

unloading and installing equipment; commissioning individual pieces of equipment; and commissioning the facility as an integrated system.

17. Typical BESS facility design life is 15 to 30 years, depending on use and maintenance. Maintenance includes servicing equipment (e.g., air filters, fan motors), vegetation and dust control, pest management, component replacement, and battery augmentation. Decommissioning activities usually include removal of project infrastructure and site rehabilitation and in some instances, site remediation.

Figure A1. Illustration of BESS facility installation

Note: Approximately 140MW/ 560 MWH on 3 hectares

Figure A2. Components of a BESS

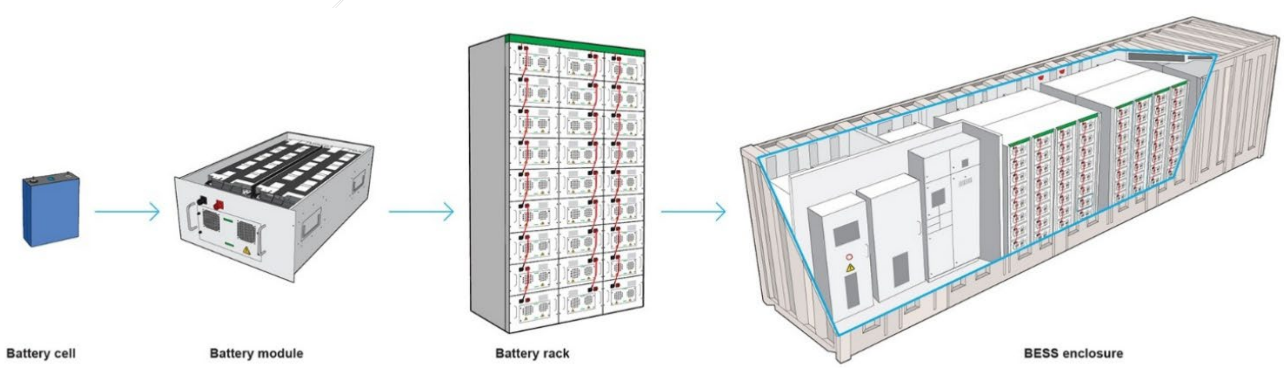

Figure A3: Example of prismatic cell exterior and schematic of cell interior

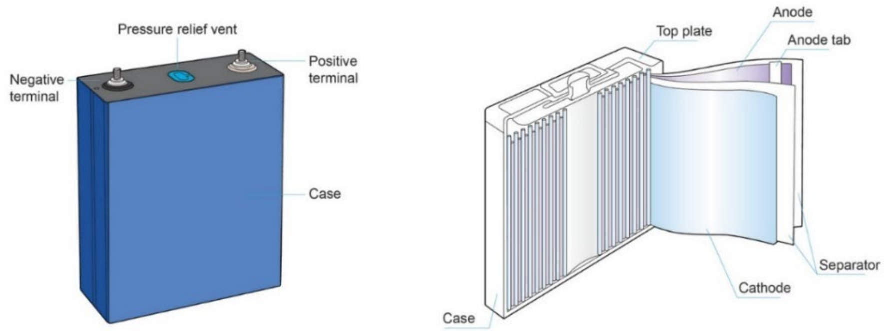

Figure A4: Example of BESS enclosure with interior components