ESA Corporate Responsibility Initiative: U.S. Energy Storage Operational Safety Guidelines

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The safe operation of energy storage applications requires comprehensive assessment and planning for a wide range of potential operational hazards, as well as the coordinated operational hazard mitigation efforts of all stakeholders in the lifecycle of a system from equipment design through decommissioning. Although the growth of the energy storage market has been more rapid in recent years, the industry can draw on earlier U.S. and international experience; code, standard, regulatory, and research bodies; and first responders to produce these Guidelines on hazard mitigation.

This guide is a product of the U.S. Energy Storage Association (ESA) Corporate Responsibility Initiative (CRI). In 2018, the ESA began coordination of the CRI, which launched in April 2019 with numerous industry leaders signing a pledge "to engage in a good-faith effort to optimize performance, minimize risk and serve as an exemplary corporate citizen in the manufacturing, deployment, implementation, and operation of energy storage projects across the United States." As of publication, 57 companies and organizations are signatories to the pledge.

The purpose of these Guidelines is to: (1) guide users to current codes and standards that support the safe design and planning, operations, and decommissioning of grid-connected energy storage systems, and (2) present many primary recommendations which can be used in hazard reduction and mitigation. It is not intended to provide an exhaustive list of guidelines for all operational hazards that could arise. ESA also published a more detailed white paper in September 2019 addressing one subset of hazards, *Operational Hazard and Risk Management: Lithium-Ion and Thermal Events*. Another related ESA CRI product is a template *Emergency Response Plan* written for energy storage site owners and operators to use in developing their own emergency response plans that suit site and application specifics and hazards. None of these documents fully address cybersecurity or hazards which may be encountered during decommissioning; these will require their own white papers and guidelines.

Legal Disclaimer

These operational Guidelines for energy storage are provided for information and guidance purposes only and establish a suggested format to be considered in the preparation of a hazard mitigation plan. Sections of these Guidelines may not be applicable to every site or technology, and the guidance offered should be modified to reflect specific conditions at each site. The U.S. Energy Storage Association assumes no responsibility or liability for the use of this guide. Site owners and operators are advised to consult with safety consultants and legal and insurance advisors concerning liability and other issues associated with the adoption and implementation of operational safety guidelines.

It is important to note that this guide is "living" and will require regular updates as experience is gained and newer technologies are deployed. Additionally, it should be flexible and easily understood, while supplying sufficient detail to enable personnel to implement necessary emergency procedures without question or delay in order to ensure continuity of operations.

Acknowledgements

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Acronyms & Abbreviations

AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
CRI	Corporate Responsibility Initiative
CSA	Canadian Standards Association
DNV-GL	A Norwegian management system certifier and risk management corporation formed by the merger of Det Norske Veritas and Germanischer Lloyd
DOT	U.S. Department of Transportation
E-ISAC	Electricity Information Sharing and Analysis Center
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ESA	The U.S. Energy Storage Association
ESIC	Energy Storage Integration Council (EPRI)
FAT	Factory Acceptance Testing
FMEA / FMECA	Failure Mode and Effects [and Criticality] Analysis
HVAC	Heating, Ventilation, and Air Conditioning
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFC	International Fire Code
NEC	National Electrical Code
NEC ES	NEC Energy Solutions, Inc.
NERC	North American Electric Reliability Corporation
NESC	National Electrical Safety Code (IEEE C2)
NFPA	National Fire Protection Association
NYSERDA	New York State Energy Research and Development Authority
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety and Health Administration
RCRA	Resource Conservation and Recovery Act
PPE	Personal Protective Equipment
SAT	Site Acceptance Testing
SCAM	Selection, Care, and Maintenance
UL	Underwriters Laboratories

1. Introduction

Although grid-connected energy storage systems have been in operation in the United States (U.S.) and abroad for some time, dramatic recent decreases in pricing, advances in technology, and demand for grid infrastructure resilience have driven exponential growth over the past few years. According to the most recent reports by Wood Mackenzie, U.S. battery storage deployments in particular have grown almost 600% percent from 2016 to 2019—in fact, that market nearly doubled in 2018 alone. The above factors foreshadow continued extraordinary growth. As the energy storage markets grow, the industry and stakeholders work to continually improve the planning, design, management, and response for a wide range of potential operational hazards.

This guide offers energy storage industry developers and their customers a set of guidance to further mitigate operational hazards among natural and thermal events, operational security, extreme weather, and decommissioning situations. This guide is meant to help identify and protect against potential physical and security hazards and is primarily concerned with the safety of the general public, personnel associated with energy storage operations and maintenance, and first responders. It predominantly focuses on battery energy storage, and less so on pumped hydropower, geologic compressed air, or other large non-battery sites. It does not identify potential financial or economic risks, nor does it deal directly with the actual physical construction of an energy storage site, which is governed in detail by local building, electrical, and other codes.

The best protection against physical and security hazards is proper preparation, design, and prevention, which should begin in the planning stages of any project. ESA, together with signatory organizations of its Corporate Responsibility Initiative (CRI), has also produced an Emergency Response Plan, a template document that addresses actions to be taken before and during an emergency associated with energy storage equipment and systems. For personnel and automated systems to take those actions, proper planning should be in place: emergency response staging areas, signage, and evacuation routes or muster points should be planned in advance. Sites, systems, and equipment should be designed to be safe from the start of the project. These Guidelines help plan for those issues, with references to other safety initiatives to ensure energy storage, and the associated electric power system, operate safely.

Aside from residential and vehicle applications, energy storage is a utility industry service relying on proven industrial equipment and machinery and high-voltage components akin to other utility sector services and components, and hazard mitigation is not unique to its use. In the electric power delivery system (generation, transmission, and distribution), utilities routinely and diligently make sure delivering electricity is safe by mitigating risks of fires associated with downed power lines, containing oil-filled transformers, and protecting other electrical equipment and the users of such. To create this guide, ESA has drawn on the expertise from many energy industries that have similar hazards. These Guidelines aim to identify and reference relevant codes and standards and ensure additional planning and protocols are in place to account for all facets of hazard prevention, mitigation, and response.

Advanced energy storage systems, including batteries with lithium-ion (Li-ion) chemistries, can be deployed safely and in ways that minimize hazards and with consideration for location.

Large-scale batteries are just one of the many resources of energy and infrastructure that utilities regularly monitor to identify any potential hazard, per the National Electrical Code (NEC), National Electrical Safety Code (NESC), and other codes and standards. All technologies currently operating on the grid should meet these requirements.[1] The energy storage industry is continually improving safety features with regulatory, codes, and standards bodies. Ultimately, energy storage safety is ensured through engineering quality and application of safety practices to the entire energy storage system.

Design and planning to prevent emergencies, and to improve any necessary response, is crucial. Safety design and planning is the responsibility of all stakeholders in the supply chain, those combining equipment into systems, and those planning a system or site – even before operators join the picture. Safety design and planning should also include communication with first responders, Authorities Having Jurisdiction (AHJs, or localities), and site neighbors. As the ESA CRI Emergency Response Plan illustrates, each of these entities should be involved in emergency planning and the periodic updating of such plans based on experience and changes to the site or equipment.

The majority of hazards described below are addressed in the numerous relevant international, national, or voluntary technical codes and certification standards that are listed in the Appendices. The storage industry holds itself to a high standard and participates in the codes and standards development process to accelerate the adoption of safety practices. In addition to standards, codes, and safety practices specifically focused on energy storage systems, there is a wide range of other applicable standards that apply to utility electrical equipment more broadly, for example on electrical substation safety practices, broader electrical codes, and general building codes.

Beyond established national and international codes, AHJ's may have additional rules that apply to an energy storage site. Because states and localities may have delayed adoption of the newest codes, it is important to review periodic updates to national and international codes, standards, regulations, and voluntary industry recommendations, since safety guidelines that are most aligned with advances in technology may be found in them.

2. Designing and Planning for Hazard Mitigation

Energy storage systems can be deployed in many diverse environments, serving many needs, from small, residential systems that serve a single-family home to multi-megawatt multi-enclosure standalone projects, to projects coupled with other resources, such as solar, wind or natural gas generation, and as a non-wire transmission and distribution alternative (NWA). Each of these scenarios will have a unique set of management needs, and understanding the unique hazards and risk factors present for a given project is key to planning and safe operation.

Designing equipment and system installation to reduce potential hazards is the first and most important step. Differing types of energy storage equipment, installation sites, performance characteristics, and environments mean that different approaches to hazard mitigation and

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[1] Importantly, codes and standards differ for lithium-ion consumer products.

safety are required. Not all portions of these Guidelines are relevant to every energy storage installation, and this guide cannot cover every potential risk factor or hazard.

The following questions present some first site details to consider:

- *Where is the site located?* What are the environmental conditions that may impact the site? What kind of weather does the site experience, and how exposed will it be to the elements? What kind of infrastructure surrounds the site? How long would it take for first responders to arrive in the event of an emergency?
- *Dedicated vs. non-dedicated:* Is the site a dedicated and standalone storage facility? Or, is it included in buildings not exclusively used by electrical or grid equipment, such as in someone's house, in an office building, near a hospital, or part of some other non-storage use location? How likely is it that someone without emergency response training will be in the vicinity during an emergency situation?

Next, a key part of formal risk management is **evaluation and hazard mitigation analysis**. Two methods are commonly employed for this purpose; the "Bowtie" method and Failure Modes and Effects Analysis (FMEA):

- The **bowtie method** is a formalized and visualized way to identify hazards, their causes, and consequences and to display them in one diagram in order to drive risk mitigation and avoidance. The bowtie diagram organizes threats and escalation factors that result in a top hazard event (as well as the barriers that could prevent that event) and its consequences (and the barriers to recovery). Its simplicity helps focus attention on actions that can be taken after an incident and, more importantly, preventative measures that can be taken in advance.
- A similar, comprehensive method of assessing risks is the **Failure Modes and Effects Analysis** (FMEA) which examines each item and its function for potential failure, the potential effects of those failures, the severity and class of those effects, the potential causes and mechanisms of the failures, the probability of occurrence of the failures, assessing the current design control for prevention and detection of the failures, and finally recommends actions and responsibility for execution of prevention, detection, and monitoring the results.[2] Four codes and standards are relevant to FMEA methods, including:
    - IEC 60812:2018, Failure modes and effects analysis (FMEA and FMECA): Explains how failure modes and effects analysis (FMEA), including the failure modes, effects and criticality analysis (FMECA) variant, is planned, performed, documented and maintained.
    - IEC 61025:2006, Fault Tree Analysis: Describes fault tree analysis and provides guidance on its application to perform an analysis, identifies appropriate assumptions, events and failure modes, and provides identification rules and symbols.

[2] https://www.epri.com/#/pages/sa/epri-energy-storage-integration-council-esic?lang=en-US

- IEC 61508, Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems: Covers those aspects to be considered when electrical/electronic/programmable electronic systems are used to carry out safety functions.
- UL 1973, Standard for Batteries for use in Stationary, Vehicle Auxiliary Power and Light Electric Rail Applications: These requirements cover battery systems as defined by this standard for use as energy storage for stationary applications such as for PV, wind turbine storage or for UPS, etc. applications.

Thermal Event Mitigation and Response Preparation

The flammability of different energy storage technologies, and potential for thermal runaway or externally instigated fire, varies greatly by technology. Not all responses will be appropriate for all technologies. Coordination with equipment manufacturers, system designers, and first responders is of the utmost importance in designing a safe system and planning emergency response protocols in advance of a system commencing operation. Consultations with equipment manufacturers should ensure sufficient availability of fire suppression systems. Nevertheless, the following broad recommendations are good practice in all scenarios.

Appropriate hazard detection systems, such as **smoke and flammable gas detectors,** should be present, with monitoring by control centers, to identify emergency situations of different types which will automatically sound an appropriate alarm and alert operators.

Thermal runaway protection, where a risk for a given energy storage technology and specific chemistry can vary significantly, should be incorporated to preclude, detect, and minimize[3] incidence and impacts from the cell- to system-level. On one side of the bowtie analysis, at the cell level such as for Li-ion cells, use of current-interrupt devices (CIDs), ceramic-coated separators, or technologies in development, such as solid polymer electrolytes, will help mitigate overheating that could lead to thermal runaway. At the system level, thermal runaway protection panels (as in New York State Energy Research and Development or NYSERDA rules); specialized Heating, Ventilation, and Air Conditioning (HVAC) systems; and measurement of temperature, current, and voltage are the most critical thermal runaway prevention technology protections.

Thermal protections should account not only for chemical thermal runaway events that begin within an energy storage system, but also for external sources of heat – from **environmental heat** of a hot summer day in an enclosed container in direct sun to **wildfires** encroaching on a site.

Thermal runaway mitigation can include proper cell and barrier design, early detection and battery management system forced shutdown, and annunciation at the battery level, as well as detection and suppression or containment techniques at the system level.

[3] Per NFPA 855 §10.3.

Sprinklers should be installed as required, and to a standard as set out in NFPA 13, which addresses sprinkler system design approaches, system installation, and component options to prevent fire deaths and property loss.

Because **water** as an extinguishing agent is commonplace, the appropriate use of water should be assessed, *i.e.* whether water reacts with the chemistries present or whether it is not an appropriate extinguisher class. The local fire department should be informed of appropriate fire suppression methods for the energy storage system type as identified by the equipment manufacturer.[4] Water is often a preferred method for extinguishing lithium-ion battery fires due to its cooling capabilities and ready availability; fire testing conducted by UL routinely uses water to extinguish lithium ion fires as do developers. Design and planning should ensure that water-based fire suppression does not cause short circuits in adjacent equipment which could create additional hazards. The use of gaseous clean fire suppression agents like FM-200 or Novec 1230 can be effective against incipient fires (those that have not involved or propagated to a large size).

- It can be unfeasible, or fatally cost-prohibitive to a project, to design for fully preventing fire-suppression water from exiting the site, much like for fire suppression in any normal building fire. However, consideration should be made to attempt to contain the resulting fire extinguishing runoff as well as the potential toxic release that may be present in the water or liquids after the fire has been safely and finally extinguished. Water runoff in fire testing laboratories is addressed in UL 9540A—which provides a test methodology for evaluating the fire characteristics of a battery energy storage system that undergoes thermal runaway—as to the buildings that host the fire testing, though water runoff from actual fires is likely treated by local codes. More guidance may also be found in ISO/TR 26368:2012, *Environmental Damage Limitation from Fire-Fighting Water Run-off,* which provides a summary of current approaches to controlling and reducing adverse environmental impacts caused by fire-water run-off.

The system should be electrically insulated to prevent **ground faults** and ensure that any ground fault that does occur is detected and the system (or affected rack/bank/section) safely shuts down automatically while alerting operators. While a single ground fault may not be dangerous, a second will result in a short circuit that could cause a fire.[5] Some developers have started to employ multiple independent internal inspections and tests to identify short and ground fault paths before the battery is placed in service.

With regard to **electrolyte spill** containment and management, IEEE 1578 should be followed for batteries such as lead acid and NiCd batteries that have acidic/basic (sulfuric acid or potassium hydroxide) aqueous electrolytes in liquid spillable form. IEEE 1578 provides descriptions of products, methods, and procedures relating to stationary batteries, battery electrolyte spill mechanisms, electrolyte containment and control methodologies, and firefighting considerations

[4] DNV-GL. DNVGL-RP-0043. September 2017.
[5] NEC. GSS® Design for Safety. February 2019.

Ventilation should be designed based on whether it would increase the severity of a fire versus whether fire or thermal events would produce flammable gases that could exacerbate a fire.[6] Where a system is sited within a building, ventilation should be designed with the building's own systems in mind to ensure any hazardous gases do not put building occupants at risk and storage system venting does not negatively interact with building ventilation (e.g. causing negative pressure situations that may draw gases back into other parts of the building via building HVAC).

Vented batteries such as lead acid or nickel cadmium should be provided with flame-arresting **safety caps**.[7]

Explosion prevention systems pertaining to the container, enclosure, or indoor installation should be designed and installed in accordance with NFPA 69, which provides requirements for installing systems for the prevention and control of explosions in enclosures that contain flammable concentrations of flammable gases, vapors, mists, dusts, or hybrid mixtures.

As documented in the ESA white paper, *Operational Risk Management in the U.S. Energy Storage Industry: Lithium-Ion Fire and Thermal Event Safety*, a broad range of codes, standards, and voluntary guidelines govern the prevention, mitigation, and response to thermal events in lithium-ion battery energy systems and contain additional guidance.

Additional Design Elements

Designing a system and site to **ensure access by personnel for maintenance under all possible operating states** can make operations and maintenance easier – and thus more readily managed – while also making it safer. Complicated or difficult access for O&M workers creates risk and discourages proper maintenance. Consideration of what types of personal protective equipment (PPE) will be required for operations and maintenance (O&M) activities is also important; equipment can be designed to reduce PPE needs, but also should be designed to be accessible and functional while workers are wearing the relevant PPE and completing their work.

Lighting should be available and sufficient for unplanned maintenance or emergency response for indoor systems per building codes, including when power supplies are down.

Remotely operated **video cameras** may provide additional monitoring capabilities for emergency situations in addition to security use (addressed later).

[6] DNV-GL. DNVGL-RP-0043. 2017.
[7] NYSERDA. *New York Battery Energy Storage System Guidebook for Local Governments*. March 2019.

Signage meeting the requirements of the American National Standards Institute's (ANSI) ANSI Z535,[8] NFPA 70,[9] and NFPA 855[10] should be posted listing potential hazards and PPE requirements at a minimum; signage should identify specific hazards, such as the NFPA hazard diamond (per NFPA 704[11]), and all applicable 'danger,' 'caution,' and 'warning' signal words. Evacuation routes and muster points should be clearly marked by signage as well. Pertinent contact information for the site operator, local emergency response, and site service providers (and others as relevant) should be posted in a readily accessible area that is unlikely to be substantially impacted by a fire or other emergency situation in or at the energy storage system itself (e.g. a site gate or exterior door). Locations of all emergency shutdown, electric power disconnection, and de-energizing switches should be conspicuously marked. Signage should be of durable material and printing that will survive plausible environmental damage and affixed in a manner that prevents simple removal. Provisions should be made for non-English speaking workers on site.

A **cybersecure-by-design** energy storage system begins in the planning and procurement stages. Design principles that will make a cyberattack less likely to succeed include:

- Procuring software and equipment from reputable suppliers to ensure equipment is both uncompromised and that it will receive regular manufacturer software security updates;
- Limiting access to operational technology to trusted and trained individuals, and limiting connectivity of the energy storage systems; and
- Governance and management protocols conceived in advance and regularly audited.

Commissioning ensures that a site or equipment has been installed in accordance to design and to a required level of quality. *EPRI's ESIC Energy Storage Commissioning Guide* addresses commissioning issues at length, as does NFPA 855, Chapter 6 for battery storage systems. Commissioning reports generally are shared with first responders in the process of discussing hazards, risks, installed mitigation (e.g., fire suppression), and response strategies.

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[8] ANSI Z535 provides the specifications and requirements to establish uniformity of safety color coding, environmental / facility safety signs and communicating safety symbols. It also enables the design, application, use and placement of product safety signs, labels, safety tags and barricade tape.
[9] NFPA 70, National Electrical Code, is the benchmark for safe electrical design, installation, and inspection to protect people and property from electrical hazards.
[10] NFPA 855 is the standard for the Installation of Stationary Energy Storage Systems: "This standard provides the minimum requirements for mitigating the hazards associated with ESS." The standard addresses where the technology is located, how it is separated from other components, the suppression systems in place, as well as ventilation, detection, signage, listings, and emergency operations associated with energy storage systems.
[11] NFPA 704 is the standard System for the Identification of the Hazards of Materials for Emergency Response: This standard presents a system of markings (commonly referred to as the "NFPA hazard diamond") that provides an immediate general sense of the hazards of a material and the severity of these hazards as they relate to emergency response.

Extreme Weather, Geologic, and Environmental Hazards

When planning an energy storage system, it is important to consider potential extreme weather events and environmental and geologic hazards. These include, but are not limited to, salt corrosion, hurricanes and tropical storms, tornadoes and severe storms, earthquakes and ground movement, wildfire, extreme heat, flooding, and incursions by flora and fauna. Adequate preparation for each of these will help secure the site and help prevent dangerous situations for personnel, equipment failure or damage, and avoidance of chemical releases or other environmental dangers.

Preparation begins during site selection: What are likely extreme weather events or other environmental hazards in the given region? What kind of severe weather events are visited on the site in a given year? Is the site located on a low-lying floodplain? Does the selected site give the energy storage system the best chance for long-term success?

Monitoring & Awareness: During operation, what are the plans to monitor for extreme weather or natural disasters? Who is tasked with tracking weather threats and making calls about shutdown protocols?

Action plans/Response procedures: A plan should be in place for what to do in the event of an extreme weather event or natural disaster and how to communicate with site owners/occupants, customers, and emergency personnel. Refer to ESA's draft Emergency Response Plan for possible contingencies.

Shutdown strategies/thresholds: Depending on the severity, duration, and type of extreme weather event or natural disaster, it may become necessary to shut down an energy storage system. Any system needs clearly defined protocols describing how and when to shut down systems and having trained staff on site during severe and hazardous weather. Determining the shutdown thresholds before they happen is critical.

- A shutdown is recommended when continued operation of the system would put lives of personnel or others in danger.
- A shutdown should be considered in the following instances: during an evacuation event; or if, by waiting longer, a system would become impossible to shut down.

Designing resilient systems: although it is impossible to design for any scenario, energy storage systems should be designed to withstand common and uncommon environmental hazards in the areas they will be deployed.

When a potential environmental threat can be reasonably predicted (e.g. hurricanes), operators may isolate electronics to reduce the potential for an incident should the system be damaged.

The physical enclosures or buildings should meet all applicable local code requirements (e.g. regarding wind speed) and be should envision readiness to withstand additional unexpected environmental emergency situations such as wildfire and hurricanes.

Drainage systems should ensure standing water moves off the site as rapidly as possible and account for risk of flash floods and extreme rainfall events. Maintenance of drainage systems is critical. In areas where **flooding** is common, systems should be built on high ground, or enclosures should be waterproof to a reasonable height.

Snow should be removed in a timely manner so as not to impede emergency or maintenance access and enclosures should be structurally capable of supporting snow loads, and/or shed snow, in accordance with applicable local building codes.

Earthquakes may strike with little to no advance warning. Sites in earthquake-prone regions should be seismic-hardened as per local building codes and, where relevant to the structure of the energy storage system site, align with the IEEE 693 Recommended Practice for Seismic Design of Substations.

Equipment should be appropriately shielded from **lightning** strikes and lightning rods should be affixed to taller structures, per fire codes NFPA 780, *Standard for the Installation of Lightning Protection Systems,* which provides lightning protection system installation requirements in buildings to safeguard people and property from fire risk and related hazards associated with lightning exposure. Lightning-driven surges are also addressed in UL 9540.

As ambient weather conditions in non-remarkable situations may also impact the operation of equipment, enclosures should be tightly controlled in temperature and protected against excess **humidity, salinity, and dust** ingress.

Enclosures should be designed to prevent **ingress of animals and plants**.

3. Operational Hazard Mitigation

Whether in ongoing, non-emergency situations or in an emergency, systems should be designed to include **redundancy** whenever possible, and as economical, to ensure safe system shutdown even if components have failed and ensure there is no situation when a single point of failure can defeat safety elements of a system.[12] They should also be **fail-safe**, ensuring that should they fail, it should be in a way that any danger of a thermal runaway or other dangerous event is minimized.[13] Battery management systems should be able to remain powered even if the rack is not (thus may require some type of backup power).

During the normal operation and maintenance of a site, much can – and should – be done that reduces risk and prepares a site for better emergency response. The U.S. Energy Storage Association offers a comprehensive Emergency Response Plan template for developers and site operators to use, including the following particularly important recommendations.

- Risk mitigation and emergency response **roles and responsibilities** should be clearly defined for all those involved in the planning, design, construction, installation, and operation of the storage system. Operators should be certified to EN-50110 (*European Standard for operation of electrical installations*) or NFPA 70 (*National Electrical Code*) or NFPA 70E (*Electrical Safety in the Workplace),*[14] which address safe electrical work procedures including safe working spaces, arc flash and electric shock hazards concerns. Operators should be trained to handle both electrical and non-electrical risks,

[12] DNV-GL. DNVGL-RP-0043. 2017.
[13] *Ibid*.
[14] NFPA 70E requirements for safe work practices to protect personnel by reducing exposure to major electrical hazards.

and both storage-specific and non-specific risks on site. Operator personnel should receive supplier- or manufacturer-approved training on the specific characteristics of the energy storage system.

- A **subject matter expert** should be contactable 24/7 and contact information for the SME on duty should be posted in a readily accessible location in addition to being supplied to first responders in advance.
- A variety of **emergency response drills** (such as fire, tornado, bomb threat, etc. as relevant to the site) are to be held by the site operator at minimum on a quarterly basis and should be documented. At least on an annual basis, the local Fire Department and other emergency response personnel should be requested to participate and assist with critique of evacuation drills. Table-top exercises are encouraged to familiarize relevant response personnel with procedures for different types of emergencies that could be encountered at the site.

Safety should be at the core of the operations manual. An **operations manual** for the system should include, at a minimum:[15]

- Emergency operation procedures
- Safety for all parts with high potential against earth (should be covered with an insulating medium)
- Cybersecurity
- Access restrictions and personnel training
- Procedures for entering and for working
- Minimum qualification requirements for people to enter the site/enclosure
- Minimum qualification requirements for people to work on the site/enclosure
- Work wear & PPE, as per NFPA 70E

Safe approach distances are established for equipment’s different failure modes, personnel are trained in these distances, and such information is communicated in writing to first responders during drills and other emergency response informational meetings.

Warning Systems and Alarms

Audible and visual (e.g., flashing lights) warning and alarm systems should be established that reflect **specific on-site hazard analyses**. Personnel should be trained on the significance of different alarms and their corresponding actions. They should be able to indicate an emergency situation to any individual within a range to be directly impacted by the incident.

Different alarms and indicators should be used to indicate different courses of action for different emergencies and staff should be trained in the actions to be taken. Status indicators should be simple enough to be interpreted by non-expert first responders.

[15] Based on DNV-GL. DNVGL-RP-0043. September 2017.

Alarms and warnings may vary, and have different responses, in internal (where energy storage system is in an enclosure or room that may be entered) and external situations.

Warning systems and alarms should be **tested** at least every six months or more frequently per manufacturer specifications or code requirements. Tests should be documented. All site personnel, as well as those offsite who are likely to hear or see an alarm, should be made aware of tests so as not to cause undue concern.

Provisions for non-English speaking workers on site should be included on all signage and communications.

Site and Equipment Maintenance

Many approaches can support site and equipment to be maintained in a manner that prevents hazards.

Factory acceptance testing (FAT) helps ensure the system's performance and compliance with codes, standards, rules, and regulations. **Site acceptance testing** (SAT) may be used to prove that equipment is installed correctly and interacts properly with the balance of system components.

Maintenance options should include:

- Clearance of vegetation within the site or which may present a flammability risk or impinge on the site, access, egress, or emergency response; decorative plantings and ground cover (grass, succulents, etc.) may be present so long as they do not present a fire propagation risk.[16]
- Access and egress routes should be kept clear.
- Drainage should kept clear
    - Water from firefighting should be prevented from flowing off site, particularly from entering waterways.
    - Opportunities for erosion or scouring from water flow should be controlled (recognizing risk of flash flooding or severe rainstorm runoff in addition to perennial waterways).
- Rust and UV deterioration mitigation should be maintained to ensure the integrity of enclosures, housings, support structures, etc.
- Fire extinguishers should be maintained as per NFPA 10, Standards for Portable Fire Extinguishers, which provides requirements to ensure that portable fire extinguishers will work as intended to provide a first line of defense against fires of limited size
- Fire suppression and ventilation systems should be maintained to ensure functionality, inclusive of automated activation.

[16] NYSERDA. *New York Battery Energy Storage System Guidebook for Local Governments*. March 2019. §8.F.

- Electrical checks (impedance monitoring, insulation condition, etc.) should be in accordance with the manufacturer's guidelines and schedule.
- Mechanical checks (torque, filter changes, seal checks, lubrication of hinges/motors, bulging batteries, sparks, hissing, damage to equipment, etc.) should be in accordance with manufacturer's guidelines and schedule.
- Warning systems and alarms should be tested periodically as per manufacturer guidelines.
- PPE should be maintained as per manufacturer guidelines and NFPA 70E §250, which describes safety-related maintenance requirements for personal safety and protective equipment. Some PPE has a selection, care and maintenance (SCAM) document that will instruct the end user on the limitations of the PPE and the proper maintenance of the PPE.
- Preventative maintenance schedules should be maintained and records kept of maintenance activities.

Operational Security

Energy storage sites and systems should be kept secure from both physical and cyber-threats, just as with any grid-connected resource.

Access to energy storage equipment should be firmly restricted, with sites and/or enclosures secured against very robust attempts at ingress. However, contact information for 24-hour response should be provided to ensure quick access, should first-responders need access in the event of an emergency situation. Access to a site or enclosure should be limited to trained personnel, or those escorted by trained personnel and records should be kept, ideally through automatic electronic means, of those entering and exiting a site.

In certain environments, **ballistic threats** may be a risk to energy storage sites.[17] When constructing and operating a site, fencing may be designed to disrupt the line of sight from those outside the fence line. Equipment and enclosures should be designed in such a way that ballistics-damaged equipment does not release hazardous material beyond the immediate location and in a manner that reduces risk of a broader incident (e.g. propagation of a thermal event).

The ESA Emergency Response Plan presents recommended response actions for many more unanticipated operational hazard remediation and in greater detail, including medical emergencies, non-emergency safety incidents, bomb threats, chemical agents, sabotage and vandalism, and active shooter incidents.

Cybersecurity has become increasingly important in the electric power sector as more systems rely on network connections for operation. Cybersecurity should be a top priority, as an attack

[17] As the 2013 Metcalf, California substation attack demonstrated, individuals with commercially available firearms can cause significant damage and disruption to electric power systems. Although not readily available at this time, ballistic protection such as is being developed by the Idaho National Laboratory may provide some measure of protection for especially critical equipment in the future.

from either a hostile party or accidental operational malware can damage an energy storage system and represent a real threat to personnel safety. Energy storage systems should be secure by design, as discussed in Section 2. Once in operation, ensure continuous secure operation by monitoring, risk assessment, and patching. Site owners and operators should take holistic views of their cybersecurity, ensuring that Original Equipment Manufacturer (OEM) vendors, operators, and other staff active on the company's networks maintain good cyber hygiene.

As a first step, a process should be created and put in place to ensure continuous hardening of the energy storage system. The principle of hardening is making sure that the attack surface to site and equipment is limited by:

- Only necessary network service ports should be open; others should be closed.
- Only necessary software should be installed on the device; other software should be removed.
- Development environments and source code should not be installed on production devices.
- Remote access protocols that use plain text communication should not be used.
- Software that stores passwords unencrypted should not be used.
- When serious cyber intrusions are attempted or occur, contact the Federal Bureau of Investigation

Due to its complexity, cybersecurity merits a separate white paper and guidelines to thoroughly describe potential hazards and the industry's progress with hazard mitigation in this area. Additionally, many energy storage system operators in North America will be eligible to join the Electricity Information Sharing and Analysis Center (E-ISAC), a project of the North American Electric Reliability Corporation (NERC) to gather and analyze security data, share appropriate data about threats with stakeholders, coordinate incident management, and communicate strategies for cyber incident mitigation.[18, 19]

Other Physical Hazards

Equipment should be appropriately secured to prevent **tip-over**, accounting for maximum high-wind situations, plausible vehicle impacts, seismic events, and similar incidents. Similarly, wall-mounted systems should be secured in a manner and to a load-bearing capacity that makes **falling off** implausible in any plausible disaster situation or user error (e.g. stacking material atop the energy storage system – which should be prohibited).

The possibility of **vehicle impacts** should be mitigated. This may entail attention to the orientation of vehicle approaches near equipment and installation of bollards or other physical

[18] Electricity Information Sharing and Analysis Center. https://www.eisac.com/.
[19] National Governors Association. *Governors Staying Ahead of the Energy Innovation Curve: A Policy Roadmap for States*. July 2018.

barriers as needed. Work procedures should be designed to reduce vehicle movements directly towards equipment or unnecessary movements around equipment.

The location of **underground and overhead utility lines and equipment** should be recognized in any excavations or operation of tall equipment like bucket trucks or cranes. Where relevant, ‘max height’ signs can indicate risk from overhead lines. Signage or other markings may also indicate location of underground equipment; detailed records should be kept of underground lines or other equipment.

Communications and Training

In addition to strictly adhering to all relevant codes and standards, energy storage companies can earn increased confidence in their systems by customers, investors, code officials, and other stakeholders by following a number of practical Guidelines on safety and risk management communications, training, and ongoing operations:

- **Be proactive in communication.** Working proactively with the people involved in a site, and who would be involved in case of an emergency, reduces risk and ensures more effective responses. It is important to communicate to the public and to stakeholders that safety and operational tests are done at multiple levels and stages, with the coordination of appropriate jurisdictional bodies.
- **Create a Safety Culture**. Installers, owners, and operators should be active in creating and maintaining a safety culture. Safety culture requires a fresh look at all procedures, from the seemingly irrelevant and mundane to the most obviously critical to risk. A safety culture can ultimately lead to new and better product designs, and lead to reduced downtime, increased worker satisfaction, increased corporate reputation, and more.
- **Design for Passive Safety.** Design thinking with the end of safety in mind can obviate the need for more extensive protections later, such as stringent size and separation criteria, let alone extensive fire suppression mechanisms, etc.
- **Communicate Proactively with AHJs.** Inviting code inspectors to industry events and regional tutorials to educate on new technologies and new designs, and to communicate about proactive and remedial actions taken on foreign thermal events, ensures a level of understanding that is critical during emergencies and also may reduce resistance to energy storage technologies in the planning phase or projects.
- **Provide regular communication and outreach to insurers and bankers.** Education on risk management practices to insurers and bankers may lower the cost of capital for energy storage system projects and improve insurance rates.
- **Train EPCs/ integrators/ installers.** Having system integrators trained on some of the basic principles helps establish a baseline safety culture across a company’s brand.
- **Offer “fleet” warranties.** Similar to a factory recall, and priced in implicitly in first costs, fleet warranties can also be priced in explicit in O&M contracts. If a defect is found in one part of one installation, and if the defect is deemed likely to be manifest universally, the OEM repairs or replaces the part in all installations.

- **Retrospectively evaluate existing installations**. This practice ensures that installations that were installed according to earlier codes can still satisfy newer-evolved standards and codes. O&M contracts could include clauses for field updates to meet new stricter requirements, perhaps structured akin to an insurance contract.

Additional communications recommendations and training for emergency response situations are found in the September 2019 ESA Emergency Response Plan template.

4. Decommissioning

This guide presents only a short draft of top decommissioning initiatives at this time, and focuses on premature mortality of storage components. In 2020, the U.S. Energy Storage Association's Corporate Responsibility Initiative will publish an energy storage decommissioning paper that presents more comprehensive end-of-life and recycling information in order to communicate and enhance current guidelines in the U.S. and abroad.

Regulations governing decommissioning, recycling, and disposal of grid-connected energy storage systems are comparably nascent to the wide body of product and system design and installation codes and standards, although decommissioning-related rules are nonetheless in development in 2019.

All transportation of energy storage-related Lithium-ion components for continued use (i.e. non-recycling, non-disposal) should adhere to UN 38.3, UN Manual of Tests and Criteria, Transportation Testing for Lithium Batteries, which includes criteria, test methods and procedures for lithium-ion batteries.[20, 21]

Federally, the U.S. Department of Transportation (DOT) regulates transportation of hazardous materials including products used in grid-connected energy storage systems.

Hazardous materials regulations are subdivided by function into four basic areas:

- Procedures and/or Policies 49 CFR Parts 101, 106, and 107
- Material Designations 49 CFR Part 172
- Packaging Requirements 49 CFR Parts 173, 178, 179, and 180
- Operational Rules 49 CFR Parts 171, 173, 174, 175, 176, and 177

US DOT requirements for shipping lithium batteries (49 CFR 173.185) specify that batteries should meet UN 38.3 requirements (unless being transported for recycling). Transportation of energy storage related components depend on where the shipment originates and should comply with IMDG (International Maritime Dangerous Goods) code or US DOT (49 CFR 173.185). In the U.S., shipment of lithium batteries for recycling or disposal is governed by 49

[20] UNECE. *Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria: Sixth Edition*. 2015. https://www.unece.org/fileadmin/DAM/trans/danger/ST_SG_AC.10_11_Rev6_E_WEB.pdf
[21] 49 CFR §173.185(d)

CFR 173.185(d) which exempts UN 38.3 test requirements and UN specification packaging requirements.

The U.S. Environmental Protection Agency (EPA) regulates batteries destined for disposal or recycling under the Resource Conservation and Recovery Act (RCRA). Batteries destined for reuse are not subject to RCRA. RCRA places the obligation of waste classification on the waste generator, which should determine if the waste exhibits any of the characteristics of hazardous waste (ignitability, corrosivity, reactivity, toxicity). Universal Waste rules provide for a streamlined set of rules for properly managing waste batteries.

Some utility purchasers and state agencies are beginning to require transparency on developers' energy storage decommissioning plans in bids and state-funded programs. For example, Portland General Electric is now requiring explicit decommissioning responsibilities in its requests for proposals. NYSERDA's *New York Battery Energy Storage System Guidebook for Local Governments*[22] specifies that applicants for new energy storage projects have a decommissioning plan and a decommissioning fund. NYSERDA requires a narrative description of the decommissioning process, the estimated life of the energy storage system, details about the estimated cost of decommissioning and plans for ensuring its funding, and contingency plans for removal of damaged batteries. Moreover, it is becoming more common for contract language to specify that system decommissioning responsibilities lie with the operations and maintenance provider or engineering, procurement, and construction (EPC) contractor.

5. Other Non-Code Initiatives

DOE, Sandia National Laboratories, and Pacific Northwest National Laboratory

Under the purview of the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability Energy Storage Program, Sandia National Laboratories and the Pacific Northwest National Laboratory have produced numerous documents that are relevant to safety in advanced energy storage, including a 2014 Energy Storage Safety Strategic Plan and ensuing storage safety workshops. Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc. Pacific Northwest National Laboratory is operated by Battelle for the U.S. Department of Energy. Sandia is performing research in a number of areas on the reliability and safety of energy storage systems including simulation, modeling, and analysis, from cell components to fully integrated systems. Sandia also evaluates fundamental safety mechanisms for energy storage from cell to module level for applications ranging from electric vehicles to military systems.

EPRI Energy Storage Integration Council (ESIC)

In 2013, the Electric Power Research Institute (EPRI) established the Energy Storage Integration Council (ESIC), an open, technical forum to advance energy storage integration.

[22] NYSERDA. *New York Battery Energy Storage System Guidebook for Local Governments*. March 2019.

ESIC develops guidelines and tools to support the safe, reliable, cost-effective, environmentally responsible deployment of energy storage. ESIC currently has over 2000 participants from utilities, integrators, technology providers, developers, researchers, regulators, and others industry stakeholders. ESIC is focused on a variety of topics including energy storage project development, safety, communications, and commissioning/testing and is also the sponsor of StorageVET®, an estimation and economic modeling tool.

6. Conclusion

Energy storage technologies have been significantly growing in the U.S. and abroad, offering experience to developers and policymakers on their safe design, construction, management, and emergency response. Energy storage is a utility-scale industry relying on proven industrial equipment and machinery and high-voltage components, thus hazard mitigation is not unique to its use.

The safe operation of advanced energy storage systems requires the coordinated efforts of all those involved in the lifecycle of a system, from equipment designers, to OEM manufacturers, to system designers, installers, operators, maintenance crews, and finally those decommissioning systems, and, first responders. Coordination on hazard prevention and response is critical to ensure the safety of personnel, the public, and the environment.

As America expands its reliance on advanced energy storage systems, the U.S. Energy Storage Association continues to lead these prevention and response efforts with policymakers, codes and standards bodies, and other stakeholders to maximize the safe and effective use of energy storage technologies to help modernize U.S. electric grids. ESA will continue to update these and other valuable resources and guides for the public.

References and Resources

Department of Energy. *Energy Storage Safety Strategic Plan*. December 2014.

Department of Energy, Office of Electricity Energy Storage Program. *Energy Storage Safety – Information for the Fire Service*. June 2016.

DNV-GL. *Recommended Practice: Safety, Operation, and Performance of Grid-Connected Energy Storage Systems*, DNVGL-RP-0043. September 2017.

Electric Power Research Institute. *Energy Storage Safety: 2016, Guidelines Developed by the Energy Storage Integration Council for Distribution-Connected Systems*. June 2016.

Electric Power Research Institute. *ESIC Energy Storage Commissioning Guide*. Technical update, December 2018.

National Governors Association. *Governors Staying Ahead of the Energy Innovation Curve: A Policy Roadmap for States*. July 2018.

NEC ES. *Fire Detection and Suppression*. 2018.

NEC ES. *GSS® Design for Safety*. February 2019.

NYSERDA. *New York Battery Energy Storage System Guidebook for Local Governments*. March 2019.

Pacific National Laboratory and Sandia National Laboratories. *DOE OE Energy Storage Systems Safety Roadmap*. 2017.

Pacific National Laboratory and Sandia National Laboratories. *Energy Storage System Guide for Compliance with Safety Codes and Standards*. June 2016.

Pacific National Laboratory and Sandia National Laboratories. *Energy Storage System Safety: Development and Adoption of Codes and Standards.* 2018.

Pacific National Laboratory. *Overview of Development and Deployment of Codes, Standards, and Regulations Affecting Energy Storage System Safety in the United States*. August 2014.

Pacific National Laboratory. *Inventory of Safety-Related Codes and Standards for Energy Storage Systems*. September 2014.

Sandia National Laboratories. *Recommended Practices for Abuse Testing Rechargeable Energy Storage Systems (RESSs).* July 2017.

United Nations Economic Commission for Europe (UNECE). *UN Manual of Tests and Criteria, Sixth Revised Edition*. 2015.

U.S. Energy Storage Association. *Energy Storage Corporate Responsibility Initiative Emergency Response Plan.* September 2019.

Appendix A: Referenced Documents

This is a list of codes, standards, and other voluntary recommended practice documents that are discussed in this guide. This list is not exhaustive. Moreover, most of these codes and standards reference additional codes and standards within their text.

- ANSI Z535 Safety color code, environmental facility safety signs, criteria for safety symbols, and product safety sign & labels and accident prevention tags: "The ANSI Z535 Series provides the specifications and requirements to establish uniformity of safety color coding, environmental / facility safety signs and communicating safety symbols. It also enables the design, application, use and placement of product safety signs, labels, safety tags and barricade tape."
- DNVGL-RP-0043 Safety, Operation, and Performance of Grid-Connected Energy Storage Systems: "The objective of this RP is to provide a comprehensive set of recommendations for grid-connected energy storage systems. It aims to be valid in all major markets and geographic regions, for all applications, on all levels from component to system, covering the entire life cycle. End users, operators and other stakeholders will be able to take this RP as their single all-encompassing document for such systems, providing them with direct guidance or referencing through other guidelines and standards."
- EN-50110 Operation of electrical installations: "This European Standard is applicable to all operation of and work activity on, with, or near electrical installations. These are electrical installations operating at voltage levels from and including extra-low voltage up to and including high voltage."
- IEC 60812:2018 Failure modes and effects analysis (FMEA and FMECA): "Explains how failure modes and effects analysis (FMEA), including the failure modes, effects and criticality analysis (FMECA) variant, is planned, performed, documented and maintained. The purpose of failure modes and effects analysis (FMEA) is to establish how items or processes might fail to perform their function so that any required treatments could be identified. An FMEA provides a systematic method for identifying modes of failure together with their effects on the item or process, both locally and globally."
- IEC 61025:2006 Fault Tree Analysis (FTA): "Describes fault tree analysis and provides guidance on its application to perform an analysis, identifies appropriate assumptions, events and failure modes, and provides identification rules and symbols."
- IEC 61508 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems: "Covers those aspects to be considered when electrical/electronic/programmable electronic systems are used to carry out safety functions."
- IEEE 693 Recommended Practice for Seismic Design of Substations: "Seismic design recommendations for substations, including qualification of different equipment types are discussed. Design recommendations consist of seismic criteria,

qualification methods and levels, structural capacities, performance requirements for equipment operation, installation methods, and documentation."

- IEEE 1578 Recommended Practice for Stationary Battery Electrolyte Spill Containment and Management: "Descriptions of products, methods, and procedures relating to stationary batteries, battery electrolyte spill mechanisms, electrolyte containment and control methodologies, and firefighting considerations are provided."
- ISO/TR 26368:2012, Environmental Damage Limitation from Fire-Fighting Water Run-off: "This Technical Report provides a summary of current approaches to controlling and reducing adverse environmental impacts caused by fire-water run-off."
- NFPA 10 Standard for Portable Fire Extinguishers: "NFPA 10 provides requirements to ensure that portable fire extinguishers will work as intended to provide a first line of defense against fires of limited size."
- NFPA 13 Standard for the Installation of Sprinkler Systems: "NFPA 13 addresses sprinkler system design approaches, system installation, and component options to prevent fire deaths and property loss."
- NFPA 69 Standard for Explosion Prevention Systems: This standard provides requirements for installing systems for the prevention and control of explosions in enclosures that contain flammable concentrations of flammable gases, vapors, mists, dusts, or hybrid mixtures. It is intended for use by design engineers, operating personnel, and AHJs.
- NFPA 70 National Electrical Code®: "Adopted in all 50 states, NFPA 70, National Electrical Code is the benchmark for safe electrical design, installation, and inspection to protect people and property from electrical hazards."
- NFPA 70E Standard for Electrical Safety in the Workplace®: "NFPA 70E requirements for safe work practices to protect personnel by reducing exposure to major electrical hazards. Originally developed at OSHA's request, NFPA 70E helps companies and employees avoid workplace injuries and fatalities due to shock, electrocution, arc flash, and arc blast, and assists in complying with OSHA 1910 Subpart S and OSHA 1926 Subpart K."
- NFPA 70E §250 Describes safety-related maintenance requirements for personal safety and protective equipment.
- NFPA 704 Standard System for the Identification of the Hazards of Materials for Emergency Response: "This standard presents a simple, readily recognized, and easily understood system of markings (commonly referred to as the "NFPA hazard diamond") that provides an immediate general sense of the hazards of a material and the severity of these hazards as they relate to emergency response."
- NFPA 780 Standard for the Installation of Lightning Protection Systems: provides lightning protection system installation requirements in buildings to safeguard people and property from fire risk and related hazards associated with lightning exposure.

- NFPA 855 Standard for the Installation of Stationary Energy Storage Systems: "This standard provides the minimum requirements for mitigating the hazards associated with ESS." The standard addresses where the technology is located, how it is separated from other components, the suppression systems in place, as well as ventilation, detection, signage, listings, and emergency operations associated with energy storage systems.
- UL 1973 Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications: "These requirements cover battery systems as defined by this standard for use as energy storage for stationary applications such as for PV, wind turbine storage or for UPS, etc. applications."
- UL 9540 / CAN 9540 Standard for Battery Energy Storage Systems and Equipment: "These requirements cover energy storage systems that are intended to receive electric energy and then to store the energy in some form so that the energy storage system can provide electrical energy to loads or to the local/area electric power system (EPS) up to the utility grid when needed. The types of energy storage covered under this standard include electrochemical, chemical, mechanical and thermal."
- UL 9540A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems: "The test methodology in this document evaluates the fire characteristics of a battery energy storage system that undergoes thermal runaway. The data generated will be used to determine the fire and explosion protection required for an installation of a battery energy storage system intended for installation, operation, and maintenance."
- UN 38.3 UN Manual of Tests and Criteria, Transportation Testing for Lithium Batteries: The Manual of Tests and Criteria contains criteria, test methods and procedures to be used for classification of dangerous goods… as well as of chemicals presenting physical hazards.

Appendix B: Non-Referenced Related Documents

This is a list of standards, codes, and other documents that are related to the topics covered in these Guidelines. Please note that these documents are not specifically discussed in these Guidelines.

- CSA 22.1 Canadian Electrical Code, Part I Safety Standard for Electrical Installations: "This Code applies to all electrical work and electrical equipment operating or intended to operate at all voltages in electrical installations for buildings, structures, and premises, including factory-built relocatable and non-relocatable structures…"
- CSA 22.2 Canadian Electrical Code, No. 340 Battery Management Systems: "This standard covers the design, performance, and safety of battery management systems. Battery management systems are electronic or electromechanical systems that control or regulate a battery or batteries which may include external communication capabilities."
- FM Global 5-33 Property Loss Prevention Data Sheets: "[To] reduce the chance of property loss due to fire, weather conditions, and failure of electrical or mechanical equipment. They incorporate… property loss experience, research and engineering results, as well as input from consensus standards committees, equipment manufacturers and others."
- IEC 61511 Functional Safety – Safety Instrumented Systems for the Process Industry Sector: "Gives requirements for the specification, design, installation, operation and maintenance of a safety instrumented system so that it can be confidently entrusted to achieve or maintain a safe state of the process."
- IEC 62040 Uninterruptible Power Systems: "Applies to movable, stationary, fixed or built-in UPS for use in low-voltage distribution systems and that are intended to be installed in an area accessible by an ordinary person or in a restricted access area as applicable…"
- IEC 62477 Safety Requirements for Power Electronic Converter Systems and Equipment: "Applies to Power Electronic Converter Systems and equipment, their components for electronic power conversion and electronic power switching, including the means for their control, protection, monitoring and measurement, such as with the main purpose of converting electric power…"
- IEC 62619 Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes: Safety Requirements for Secondary Lithium Cells and Batteries, for Use in Industrial Applications: "Specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications including stationary applications."
- IEC 62909 Bi-Directional Grid Connected Power Converters: "Specifies general aspects of bi-directional grid-connected power converters (GCPC), consisting of a grid-side inverter with two or more types of DC-port interfaces on the application side…"

- IEEE 1547 Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces: "The technical specifications for, and testing of, the interconnection and interoperability between utility electric power systems (EPSs) and distributed energy resources (DERs) are the focus of this standard. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It also includes general requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for design, production, installation evaluation, commissioning, and periodic tests."
- IEEE 1635 Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications: "Vented lead-acid, valve-regulated lead-acid, and nickel-cadmium stationary battery installations are discussed in this guide, written to serve as a bridge between the electrical designer and the heating, ventilation, and air-conditioning designer."
- IEEE 1679 Guide for the Characterization and Evaluation of Lithium-Based Batteries in Stationary Applications: "Guidance for an objective evaluation of lithium-based energy storage technologies by a potential user for any stationary application is provided in this document."
- IEEE C2 National Electrical Safety Code: "This Code covers basic provisions for safeguarding of persons from hazards arising from the installation, operation, or maintenance of (1) conductors and equipment in electric supply stations, and (2) overhead and underground electric supply and communication lines. It also includes work rules for the construction, maintenance, and operation of electric supply and communication lines and equipment."
- IFC Chapter 12 Energy Systems International Fire Code: The provisions of this chapter shall apply to the installation, operation, and maintenance of energy systems used for generating or storing energy.
- ISO 3864 Graphical symbols: Safety colours and safety signs: "Establishes the safety identification colours and design principles for safety signs and safety markings to be used in workplaces and in public areas for the purpose of accident prevention, fire protection, health hazard information and emergency evacuation."
- NECA 416 Recommended Practice for Installing Energy Storage Systems: "Describes methods and procedures used for installing multiple types energy storage systems. It also includes information about controlling and managing energy storage systems, in addition to commissioning and maintaining energy storage systems."
- NFPA 1 Fire Code: "Advances fire and life safety for the public and first responders as well as property protection by providing a comprehensive, integrated approach to fire code regulation and hazard management."

- NFPA 791 Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation: "Covers recommended procedures for evaluating unlabeled electrical equipment for compliance with nationally recognized standards."
- NFPA 5000 Building Construction and Safety Code: "Provides requirements for those construction, protection, and occupancy features necessary to safeguard life, health, property, and public welfare and minimize injuries."
- OSHA 1910 Standard Interpretations: "Standard Interpretations are letters or memos written in response to public inquiries or field office inquiries regarding how some aspect of or terminology in an OSHA standard or regulation is to be interpreted and enforced by the Agency."
- OSHA 1926 Safety and Health Regulations for Construction: provides electrical and other safety requirements for the construction stage of projects.
- UL 810A Standard for Electrochemical Capacitors: "These requirements cover electrochemical capacitors for use in equipment such as electronic products, uninterruptible power supplies, emergency lighting, engine starting, and power equipment."
- UL 1642, Standard for Lithium Batteries: "These requirements cover primary (non-rechargeable) and secondary (rechargeable) lithium batteries for use as power sources in products."
- UL 1741 Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources: "These requirements cover inverters, converters, charge controllers, and interconnection system equipment intended for use in stand-alone (not grid-connected) or utility-interactive (grid-connected) power systems."
- UL 1974 Standard for Evaluation for Repurposing Batteries: "This standard covers the sorting and grading process of battery packs, modules and cells and electrochemical capacitors that were originally configured and used for other purposes, such as electric vehicle propulsion, and that are intended for a repurposed use application, such as for use in energy storage systems and other applications for battery packs, modules, cells and electrochemical capacitors."
- UL 2900 Standard for Software Cybersecurity for Network-Connectable Products; "This standard applies to network-connectable products that shall be evaluated and tested for vulnerabilities, software weaknesses and malware."
- UL 62109 Standard for Safety of Power Converters for Use in Photovoltaic Power Systems: "This standard defines the minimum requirements for the design and manufacture of PCE for protection against electric shock, energy, fire, mechanical and other hazards."