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Inventory of Safety-related Codes and Standards for Energy Storage Systems

with some Experiences related to Approval and Acceptance

September 2014

DR Conover

U.S. DEPARTMENT OF
ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99352

Department of Energy
Washington, DC 20585

Energy Storage for stationary applications is one of the fastest growing areas in the utility field. However, as the technology keeps expanding the need for safety and uniformity in standards also increases. Aware of this need, the DOE Office of Electricity held an Energy Storage Safety Workshop in February of 2014 to bring together those stakeholders concerned with the safe deployment of energy storage systems. One outcome of the workshop was the need to understand and organize the relevant codes, standards and regulations (CSR) governing energy storage installation and operation. This document not only provides an assemblage of the current CSR's relevant to energy storage applications, but also documents important "lessons learned" from developers who have gone through deployment activities. Given the growth of energy storage, the contents of this document will be maintained and updated on the DOE OE ESS website in order to provide a current guide of CSR's for all those working in energy storage. It is our hope that this document will eventually form the basis of a coherent and industry wide set of standards.

Imre Gyuk

Dr. Imre Gyuk
Program Manager
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U.S. Dept. of Energy

Summary

Purpose

The purpose of this document is to identify laws; rules; model codes; and codes, standards, regulations (CSR) specifications related to safety that could apply to stationary energy storage systems (ESS) and experiences to date securing approval of ESS in relation to CSR. This information is intended to assist in securing approval of ESS under current CSR and to identification of new CSR or revisions to existing CSR and necessary supporting research and documentation that can foster the deployment of safe ESS. For additional information on development and deployment of CSR see *Overview of Development and Deployment of Codes, Standards and Regulations Affecting Energy Storage System Safety in the United States* (Conover 2014).

Scope

This document is intended to cover all ESS technologies and installations. The information in this document, highlighted in the graphic below, represents a snapshot in time of a dynamic landscape associated with CSR development and deployment. As discussed in Section 3.0, this document will be used for a web-based database that can be regularly updated and maintained in support of the upcoming Strategy for Energy Storage Safety (DOE 2014). Note that safety in the context of this document includes ensuring that an ESS installation itself is secure from unwanted access (e.g., security of the site) but does not include software related safety (e.g., cybersecurity).

Current CSR documents that could apply to ESS are identified, and the scope of each document and thoughts for future action in identifying areas in those CSR that might need revision (modification to existing criteria or addition of new criteria) are presented.[1]	Experiences securing approval of ESS under current CSR are provided, along with details associated with the information and documentation needed to secure approval of ESS and any challenges associated with the approval.	Information needed to secure the approval of an ESS application on the basis of equivalency with current CSR that may not specifically address the intended ESS technology is provided.

[1] A future activity associated with the identified documents and in response to the *DOE OE Strategy for Energy Storage Safety* will include identification of needed revisions and the development and submittal of those revisions and necessary supporting documentation to the relevant voluntary sector standards development organization (SDO).

Observations

Sections 3.0, 4.0 and 5.0 of this document support the observations listed below.

More traditional energy storage technologies (e.g., lead-acid or NiCd batteries) that have been available for some time are currently addressed by CSR and can be more readily deployed when in compliance with those CSR than newer energy storage technologies that may not be specifically addressed in the current CSR.[2]

Newer energy storage technologies (both systems and system components) may have some standards available to guide the evaluation of the technology for safety; if not, existing standards may need to be revised or new standards will need to be developed as various storage technologies mature.

Standards for ESS components are important to facilitate the timely testing, review and approval of those components and deployment of the ESS in which they are applied, especially if the ESS is not a singular "product" but is instead an assembly of components where the ESS is constructed from those separate components at the installation site.

Codes, standards and regulations covering the application and installation of technology tend to lag technology development and are less likely to address newer energy storage technologies specifically, resulting in existing criteria being inappropriately applied to ESS installations.

The development of revisions to existing CSR or new CSR can be facilitated through the development of protocols, pre-standards, bench standards and other criteria that while not formally developed CSR can provide a basis for acceptance in the short term and serve as a resource for future CSR development.

While an entire ESS of its component parts can be approved in the absence of specific standards upon which to assess their safety, the process to secure such approval is challenging, not necessarily uniform, can rely on considerable supporting research and data and may have to be repeated for each proposed ESS installation.

Standards to address the safety of components and the entire ESS only cover the acceptability of the component itself or the entire ESS "product" for the intended purpose but do not address the safety of the ESS in relation to its installation environment.

An assessment of existing CSR in relation to current and anticipated ESS technology is needed to determine where revisions are needed to those CSR, if the ESS installation and application needs to be rethought because of those CSR and where additional research is needed to develop acceptable safety solutions that can be included in future CSR.

Any review of current CSR and experiences associated with the approval of ESS installations under them can foster the identification of and work on changes needed to existing and new, necessary CSR.

[2] Specific current CSR are provided in Section 3.0 but include model codes published by the ICC and standards published by NFPA, UL, LLC and others.

Until CSR specifically address a particular ESS technology and those CSR are adopted, the ESS in question will need to be assessed using alternative methods and materials (e.g., equivalent safety performance) provisions in current CSR or other criteria that may be considered relevant by the approval authority.
CSR covering the ESS technology and its installation must include consideration of facility management personnel, first responders and others who will have to address any incidents created by an ESS or impacting an ESS.
The availability of education, training and technical support will be critical to updating CSR, securing their adoption and realizing the level of safety intended by those CSR.
The range of ESS technologies in play as to type, chemistry, size, and other factors increases the amount of CSR related work needing to be accomplished.
The adoption and deployment of CSR can differ based on the location of the ESS in relation to the grid and ownership of the ESS.
The purpose of CSR in protecting the public safety and welfare demands that proponents of various ESS technologies collaborate on updating the CSR to address ESS safety.

Acronyms

AC	alternating current
AEST	Advanced Energy Storage Trial
AHJ	authority having jurisdiction
AIC	amps interruption current
AMCA	Air Movement and Control Association
AMM	alternative methods and materials
APCO	Association of Public-Safety Communications Officials International
ARRA	American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASME	American Society of Mechanical Engineers
ASQ	American Society for Quality
ASSE	American Society of Safety Engineers
ASTM	American Society for Testing and Materials International
AU	Australia
AWEA	American Wind Energy Association
BESS	battery energy storage system
BMS	battery management system
B-NICE	biological, nuclear, incendiary, chemical, explosive
CAGI	Compressed Air & Gas Institute
CBRNE	chemical, biological, radiological, nuclear, explosive
CES	Community Energy Storage (Unit)
CEV	controlled environmental vault
CGA	Compressed Gas Association
COBRA	chemical, ordinance, biological, radiological agents
CSA	Canadian Standards Association
CSR	codes, standards and regulations
CWA	CELENEC Workshop Agreement
DOE	U.S. Department of Energy
DOE OE	Office of Electricity Delivery and Energy Reliability
EASA	Electrical Apparatus Service Association, Inc.
EEE	electronic equipment enclosure
EMC	electromagnetic compatibility
EPRI	Electric Power Research Institute
EPS	electric power system
EPT	EaglePicher Technologies
ESA	Energy Storage Association
ESIC	Energy Storage Integration Council
ESS	energy storage systems

EUC	equipment under control
FAT	factory acceptance testing
FEB	field evaluation body
FTA	Fault Tree Analysis
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Mode, Effects and Criticality Analysis
GCI	Global Change Institute
HVAC	heating, ventilation, and air conditioning
HWIL	Hardware in the Loop
IAPMO	International Association of Plumbing & Mechanical Officials
IAS	International Accreditation Service
IBC	International Building Code
ICC	International Code Council
I-Codes	International Codes
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFC	International Fire Code
IgCC	International Green Construction Code
IMC	International Mechanical Code
IPC	International Plumbing Code
IRC	International Residential Code
ISE	interconnection system equipment
ISM	industrial, scientific, and medical
ISO	International Standards Organization
JPR	job performance requirements
LER	light electric rail
LESTA	large energy storage test apparatus
LEV	light electric vehicle
MESA	Modular Energy Storage Architecture
MSDS	Material Safety Data Sheets
NAATBatt	National Alliance for Advanced Technology Batteries
NBBPVI	National Board of Boiler and Pressure Vessel Inspectors
NBC	nuclear, biological, chemical
NBIC	National Board Inspection Code
NEC	National Electrical Code
NECA	National Electrical Contractors Association
NEMA	National Electrical Manufacturers Association
NERC	North American Electric Reliability Corporation
NESC	National Electrical Safety Code
NiCd	nickel cadmium (battery)

NFPA	National Fire Protection Association
NREL	National Renewable Energy Laboratory
NRTL	Nationally Recognized Testing Laboratory
NWIP	New Work Item Proposal
OCPD	overcurrent protective device
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
OSP	outside plant
PCS	Power Conversion System
PEARL	Professional Electrical Apparatus Recyclers League
PGMA	Portable Generator Manufacturers Association
PME	protective multiple earthing
PV	photovoltaic
PVES	photovoltaic energy systems
RESS	renewable energy storage system
RESU	Residential Energy Storage Unit
RFID	radio frequency identification
RIMS	Risk & Insurance Management Society
RTDS	Real Time Digital Simulation
RTU	remote thermal unit
SCE	Southern California Edison
SDO	standards development organization
SGIA	Small Generator Interconnection Agreement
SGIRM	Smart Grid interoperability reference model
SWC	surge withstand capability
TSP	Tehachapi Storage Project
UCI	University of California Irvine
UL, LLC	UL Limited Liability Corporation (formerly Underwriters Laboratories, Inc.)
UMC	Uniform Mechanical Code
UPC	Uniform Plumbing Code
UPS	uninterruptable power supply
USNC	U.S. National Committee
VLA	vented lead-acid (batteries)
VRLA	valve regulated lead acid (batteries)
WG	Working Group
WMD	weapons of mass destruction

Contents

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1.0 Introduction

1.1 Background

The U.S. Department of Energy (DOE) Office of Electricity Delivery and Energy Reliability (DOE OE) sponsored a workshop focused on identifying the key roadblocks to acceptance of energy storage systems (ESS) and needs associated with the validation of safety in ESS in February 2014 (Sandia and PNNL 2014). Those in attendance represented a wide range of stakeholders focused on ESS technology development, deployment, acceptance and use. The primary objective of this event was to secure input from ESS stakeholders on issues, needs, concerns, etc. related to the validation of ESS safety, challenges associated with addressing ESS acceptance through revision to current codes, standards and regulations (CSR) and what technical and policy initiatives would be needed to address those challenges. The long-term goal supported by this DOE OE initiative is to foster the timely acceptance of ESS that ensures the safety of the public as well as the property associated with ESS installations. The information and recommendations derived from this workshop supported the development of safety strategy supported by a multi-year roadmap of activities that would help realize that long-term goal.

Activities related to CSR development that address ESS safety, their adoption and deployment and the associated support infrastructure for those CSR such as conformity assessment[1] as well as needed education and training of all stakeholders impacting ESS deployment will occur over multiple years.[2] A key outcome of the workshop was the immediate need to identify short-term (~6 months to a year) activities to foster the deployment of safe ESS installations in parallel to the development and initial implementation of the longer-term ESS safety strategy.

This document is in response to a short-term need to identify current CSR that directly or indirectly apply to ESS, how ESS installations have been approved to date and what areas in CSR may be needed to be updated and revised to ensure that ESS installations are safe and can be more readily approved in the future. Without a concerted effort to ensure standards are available to test and validate the safety of ESS components and systems as well as CSR provisions addressing the safe installation of ESS in all intended locations, the cost of ESS installations could increase due to a myriad of different and potentially misapplied CSR. At worst, either CSR will be prohibitive or as ESS installations increase in number, the probability of a safety-related incident occurring that could affect the ESS industry would increase.

1.2 Overview

A short-term activity focused on the deployment of safe ESS is to determine the existing CSR that have been or could be applied to ESS. By conducting this inventory of existing CSR, the deployment of safe ESS can be facilitated in the future as shown in Figure 1.1.

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[1] Conformity assessment is considered a number of activities such as testing, listing, labeling, certification, accreditation, plan review, inspection and licensing that are focused on confirming that intended outcomes are secured and ensured (e.g., documentation and verification of compliance with CSR).
[2] While technologies and their associated safety impact vary, it can take up to 5 years after the conduct of research to develop the necessary standards and model codes, secure their adoption on a widespread basis and conduct needed education and outreach such that the technology is recognized and can be readily accepted and approved for installation and continued use.

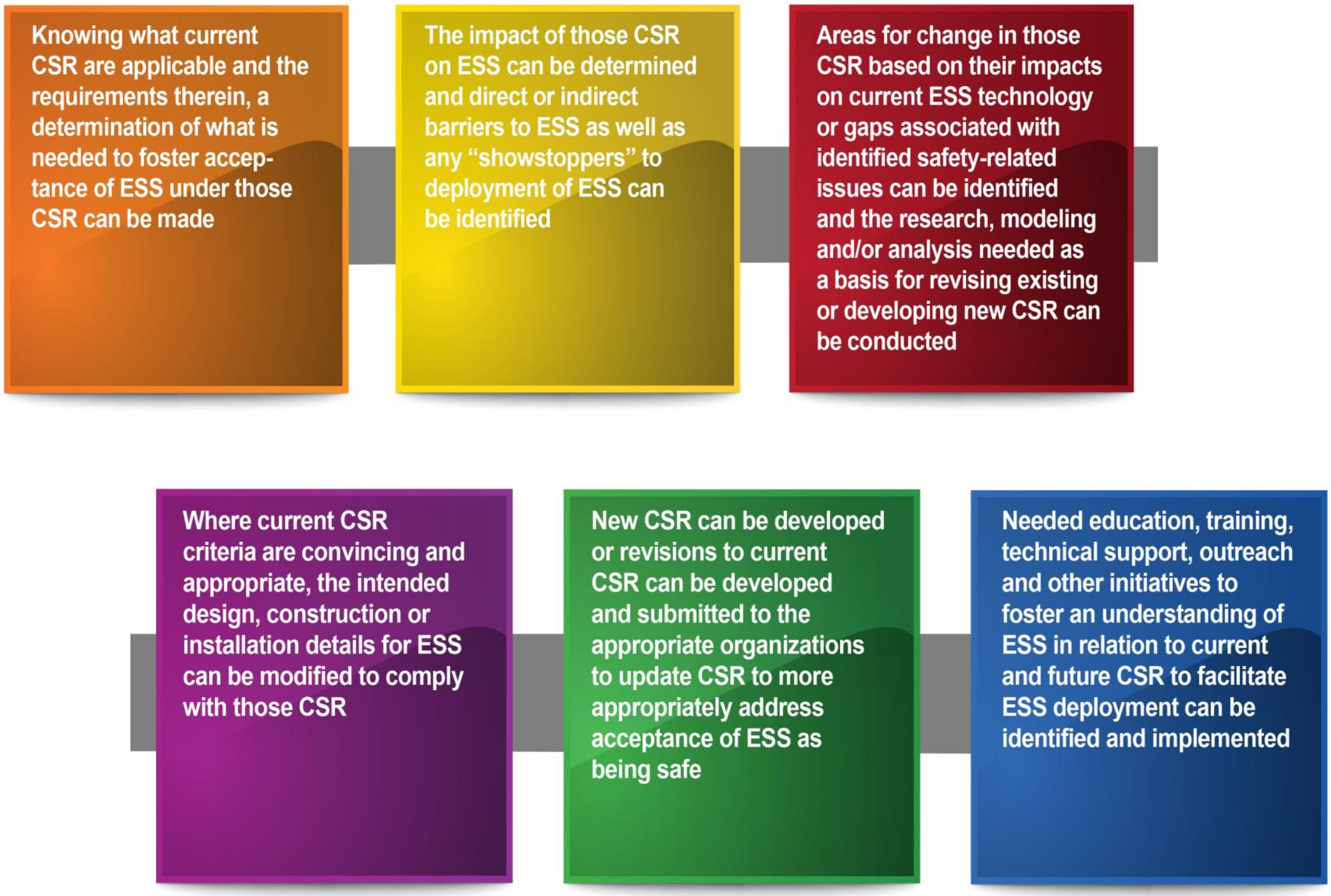

Figure 1.1. Future Deployment of Safe ESS

This short-term activity to foster the acceptance of safe ESS is intended to initiate a robust CSR activity that will serve as the foundation for a longer-term CSR activity to be included in the DOE ESS Safety Strategy developed pursuant to the February 2014 DOE ESS Safety Roadmapping Workshop (Sandia and PNNL 2014). It is envisioned that as activities are formally initiated later in 2014 to support the safety strategy, this document will serve as a key component in addressing the strategy and be transferred to a web-based database providing current and anticipated actions associated with identified CSR, research and documentation supporting CSR enhancements and information on how ESS installations are being approved and deployed. These and other suggested next steps are outlined in Section 6.0.

1.3 Scope

As previously noted, this document is intended to form the foundation of a dynamic resource that resides as a web-based database tied to and in support of the Strategy for Energy Storage Safety (DOE 2014). To address the short-term need for revisions to existing CSR or development of new CSR that may be needed to foster deployment of safe ESS, this document represents a particular view of current CSR criteria and experiences at one point in time. It is separated into three distinct focal areas: inventory of current CSR, experiences associated with ESS approvals under current CSR and background on performance-based approval paths under current CSR. This document is intended to serve as a starting point that can be used now and on which further input can be secured, resulting in a more robust source of information for future consideration and used as a basis for future action on CSR and needed research and documentation of ESS safety. Note that while conformity assessment[1] is a key component of CSR deployment and would involve among others testing laboratories, certification agencies, accreditation bodies, building and fire officials and others, this document does not provide detail on conformity assessment agencies or bodies in the same way that it provides information on SDOs. More information on conformity assessment is available in Appendix C of the *Overview of Development and Deployment of Codes, Standards and Regulations Affecting Energy Storage System Safety in the United States* (Conover 2014).

1.3.1 Inventory of Codes, Standards and Regulations

Within Section 3.0, all current CSR[2] that could apply even marginally to stationary ESS technology are identified. Identification is by document title and sponsoring organization as well as a statement of the scope of the document and comments related to the possible application of the document to an ESS and/or further work that may be needed to assess the need to update or enhance the document. On a longer term basis, the actual text of the criteria (based on any needed approvals of the copyright holder) could be included as well in the envisioned web-based database or a link provided to the standards development organization (SDO) that publishes the CSR. The intent of this inventory is to provide a comprehensive delineation of current CSR that could apply to ESS and in so doing assist the ESS industry to review CSR requirements and determine if revisions are warranted and then provide guidance in development of those revisions. Those revisions can then be pursued collaboratively by all interested parties and stakeholders.

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[1] Verification that what is intended is actually realized.

[2] This initial document is a starting point and is intended to identify relevant CSR and provide some nominal information about those documents. It is envisioned that through collaboration by interested parties and stakeholders, the listing of relevant CSR will grow and additional insight into the current criteria in those documents and necessary revisions will be pursued. One example of this evolution from information to action is a meeting of stakeholders on June 3, 2014 in Washington, D.C. for the purpose of discussing needed revisions to the National Electrical Code (NFPA 70) that are due on November 7, 2014 for consideration in the 2017 edition of the National Electrical Code (NEC).

In parallel to this identification and assessment of CSR, it is envisioned within the DOE ESS Safety Strategy (DOE 2014) that efforts will be undertaken independently to pursue testing, modeling and analysis of ESS to determine appropriate safety-related guidance and criteria. This approach recognizes that addressing CSR criteria associated with ESS safety must look at current CSR for guidance but also look at ESS technology, failure modes and effects and relevant research and documentation that support specific safety-related criteria that can inform development of appropriate safety-related CSR.

1.3.2 Experiences with ESS Installation Approvals

Section 4.0 documents how existing ESS installations, American Recovery and Reinvestment Act (ARRA) and non-ARRA funded and both utility and customer side of the meter, were reviewed and approved with respect to safety, the processes through which those approvals were conducted, the CSR criteria applied, the scientific and engineering basis supporting the validation of the system's safety and the documentation submitted to validate ESS safety. This information was contributed from ESS manufacturers, utilities and others involved with actual ESS installations. It is intended that this information further reinforce that in Sections 3.0 and 5.0 with respect to development of future CSR and securing approvals for ESS installations under current CSR.

1.3.3 Performance-based Review and Approval

Section 5.0 provides information on one approach that can be used in pursuing the acceptance of an ESS installation under current CSR. That approach is based on achieving equivalent performance to that resulting from compliance with current CSR (e.g., acceptance under alternative methods and materials [AMM]). This avenue also includes standards covering the approval of unlisted electrical equipment such as National Fire Protection Association (NFPA) 791-2012, *Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation* (ANSI 2012). The focus of this section is the AMM and other criteria in CSR that allow for acceptance on the basis of equivalent performance, the processes associated with applying these alternative approval approaches to technology acceptance, the criteria in the CSR that form the basis for acceptance and the experiences to date with ESS approvals. To some degree, Section 5.0 provides insight into securing short-term approvals where current CSR do not specifically address an ESS technology or the experiences to date with approvals suggest approaching approval through AMM as opposed to the literal application of the current CSR. Another approach to performance-based review and approval is the installation and on-site acceptance testing of a stationary ESS. This is conducted for each separate installation, and the approving authority or their agent(s) such as an accredited third party would determine the testing to be conducted and criteria that would be used to deem the ESS installation acceptable.

2.0 Inventory of Codes, Standards and Regulations Related to ESS Safety

As previously noted, this document is intended to provide a starting point for determining the provisions in current CSR that apply to ESS technology and that can serve as a starting point for assessing the impact of CSR on stationary ESS. There are separate presentations in Section 3.0 on documents covering the following:

These are presented separately in Sections 3.1 through 3.6 because they involve different types of documents, they each have a different and unique scope, are applied differently at different times and are likely adopted and compliance verified by different entities.[7]

In the interest of ensuring nothing is missed, this inventory addresses current CSR that directly and indirectly apply to ESS. A direct application is a provision that specifically calls out the ESS technology and is clearly applicable to the technology. An indirect application is where the ESS technology is not specifically named, but because of some characteristic of the ESS technology, the CSR would apply (e.g., limitations on storage and use of certain chemicals in buildings would be an indirect application because the term ESS is not used in the CSR, but the existence of the chemicals in the ESS could result in application of the CSR to the ESS) or could be used as a basis for criteria for ESS in the future.

Future work by stakeholders and interested parties pursuant to the ESS Safety Strategy (DOE 2014) that will focus on each specific CSR document, how it currently applies to ESS and based on that assessment what changes might be needed to update or enhance the document to address ESS more effectively. That work will also identify areas where new CSR may be needed. In parallel to this work, research, testing, modeling and analysis would be conducted to determine what is appropriate to address ESS safety to inform future CSR activities (e.g., without being directed based on current CSR determine what safety-related issues need to be addressed and how they should be addressed and with that information available use it to support future CSR work).

The following U.S. SDOs were contacted to secure firsthand information of standards they publish because some of their standards might have an impact on some aspect of an ESS or their scope is such that they could develop ESS-related documents in the future. The intent was to notify these SDOs of this ESS activity and provide them an opportunity to assist in identifying their documents that they would want included. Many, but not all responded and given a lack of response research was conducted in an attempt to identify relevant standards published by the SDO for inclusion in this document.

[7] In the future through a web-based database, it is intended that the CSR information in Section 3.0 will be identified and able to be sorted as to its applicability to a particular battery or technology type, ownership scenario, location relative to the utility meter, size or other relevant factors that might limit the scope and applicability of CSR presented.

A summary of each SDO contacted is presented below, which also helps in identifying SDOs that may have some relevance in development of CSR relevant to ESS and/or whose constituents could play a role in deployment of safe ESS. As the focus of this document is on U.S. activities, SDOs in other countries such as the Canadian Standards Association (CSA) are not included. The importance and value of SDOs in other countries and regionally and globally cannot be overstated. It is envisioned after the publication of this document and its transfer to a web-based database that SDOs in other countries can be included along with their ESS-relevant documents.

Air Movement and Control Association International, Inc. (AMCA) www.amca.org	AMCA is a non-profit organization of the world's manufacturers of related air system equipment, primarily but not limited to fans, louvers, dampers, air curtains, airflow measurement stations, acoustic attenuators and other air system components for industrial, commercial and residential markets. AMCA publishes and distributes standards, references and application manuals for specifiers and engineers with an interest in air systems for the selection, evaluation and troubleshooting of air system components. Many of AMCA's standards are accepted as American National Standards.
Association of Public-Safety Communications Officials International (APCO) www.apcointl.org	APCO International serves the needs of public safety communications practitioners worldwide – and the welfare of the general public as a whole – by providing expertise, professional development, technical assistance, advocacy and outreach.
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) www.ashrae.org	ASHRAE is a global society advancing human well-being through sustainable technology for the built environment. ASHRAE and its members focus on building systems, energy efficiency, indoor air quality, refrigeration and sustainability within the industry. Through research, standards writing, publishing and continuing education, ASHRAE shapes tomorrow's built environment today.
American Society of Mechanical Engineers (ASME) www.asme.org	ASME helps the global engineering community develop solutions to real-world challenges. As a non-profit professional organization, ASME enables collaboration, knowledge-sharing and skill development across all engineering disciplines, while promoting the vital role of the engineer in society. ASME codes and standards, publications, conferences, continuing education and professional development programs provide a foundation for advancing technical knowledge and a safer world.
American Society for Quality (ASQ) www.asq.org	ASQ is a global community of people dedicated to quality who share the ideas and tools that make the world work better. With individual and organizational members around the world, ASQ provides the quality community with training, professional certifications and knowledge to a vast network of members of the global quality community.
American Society of Safety Engineers (ASSE) www.asse.org	ASSE promotes the expertise, leadership and commitment of its members while providing them with professional development, advocacy and standards development. It also sets the occupational safety, health and environmental community's standards for excellence and ethics. ASSE is a visible advocate for safety, health and environmental professionals through proactive government affairs at the federal and state levels, and in member-led relationships with key federal safety and health agencies.

American Society for Testing and Materials International (ASTM) www.astm.org	ASTM International develops and delivers international voluntary consensus standards. ASTM standards are used to improve product quality, enhance safety, facilitate market access and trade, and build consumer confidence. Working in an open, transparent process and using advanced electronic infrastructure, ASTM members deliver the test methods, specifications, guides and practices that support industries and governments worldwide.
American Wind Energy Association (AWEA) www.awea.org	AWEA developed the standards covering the safety of wind turbines. They also are a member of the U.S. National Committee (USNC) of the International Electrotechnical Commission (IEC) that serves as the focal point for U.S. parties interested in the development, promulgation and use of globally relevant standards for the wind energy industry. As the U.S. representative to the IEC TC 88 (a subcommittee specific to energy from wind turbines), AWEA serves as a conduit to the global standards-setting community for technical and policy positions arising in the United States for the IEC TC 88 and brings issues from the global arena to the United States for review, consideration and response. The scope of the IEC TC 88 is to prepare international standards for wind turbines that convert wind energy into electrical energy. These standards address design requirements, engineering integrity, measurement techniques and test procedures. Their purpose is to provide a basis for design, quality assurance and certification.
Compressed Air & Gas Institute (CAGI) www.cagi.org	CAGI aims to be the united voice of the compressed air industry, serving as the unbiased authority on technical, educational, promotional and other matters that affect the industry.
Compressed Gas Association (CGA) www.cganet.com	CGA represents all facets of the industry: manufacturers, distributors, suppliers and transporters of gases, cryogenic liquids and related products. CGA is dedicated to the development and promotion of safety standards and safe practices in the industrial gas industry. The work of CGA is performed by committees of volunteers from member companies having expertise in the particular areas targeted. Each of these committees focuses on work item projects through its subcommittees and task forces.
Electrical Apparatus Service Association, Inc. (EASA) www.easa.org	EASA is a dynamic, professional trade organization that is recognized internationally as the leader in the electrical and mechanical apparatus sales, service and repair industry. They provide an ongoing flow of industry information and education that helps members worldwide serve as total solution providers for electrical and mechanical equipment and systems.
FM Global www.fmglobal.com	FM Global provides comprehensive global commercial and industrial property insurance, engineering-driven underwriting and risk management solutions, groundbreaking property loss prevention research and prompt, professional claims handling. FM Global’s products and services directly support its clients’ overall risk management objectives through understanding the nature and reality of their specific risks; establishing sound loss prevention solutions that safeguard against loss; developing cost-effective insurance and risk transfer solutions backed by large, stable capacity; and providing the claims and loss mitigation support to minimize business disruption.

International Association of Plumbing & Mechanical Officials (The IAPMO Group) www.iapmo.org	The IAPMO Group uses an open consensus process in the development of the Uniform Plumbing Code® and Uniform Mechanical Code®. These codes are established through scientific research, debate and analysis. The IAPMO Group provides code development assistance, education, plumbing and mechanical product testing and certification, building product evaluation and a manufacturer-preferred quality assurance program. Each component of the IAPMO Group works toward playing an integral part in protecting the health of people everywhere.
International Code Council (ICC) www.iccsafe.org	ICC is dedicated to developing model codes and standards used in the design, build and compliance process to construct safe, sustainable, affordable and resilient structures. Published by the ICC, the International Codes (I-Codes) provide minimum safeguards for people at home, at school and in the workplace. The I-Codes are a complete set of comprehensive, coordinated building safety and fire prevention codes.
Institute of Electrical and Electronics Engineers (IEEE) www.ieee.org	IEEE is dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through IEEE's publications, conferences, technology standards and professional and educational activities.
National Board of Boiler and Pressure Vessel Inspectors (NBBPVI) www.nationalboard.org	NBBPVI publishes the National Board Inspection Code (NBIC), which establishes rules for installation, inspection and repairs to boilers, pressure vessels and piping designed for internal or external pressure. NBBPVI's purpose is to install and maintain the integrity of pressure retaining items, thereby ensuring that these items continue to function safely, with the ultimate goal of public and personal safety. The NBIC Committee meets regularly to consider revisions to the rules based on advancements in technology and materials, the next edition of which will be published in July 2015.
National Electrical Contractors Association (NECA) www.necanet.org	NECA serves the management interests of the entire electrical contracting industry, which performs specialized construction work related to the design, installation and maintenance of electrical systems in a safe, effective and environmentally sound manner. NECA is dedicated to enhancing the industry through innovative research, performance standards, progressive labor relations and workforce recruiting and training.
National Electrical Manufacturers Association (NEMA) www.nema.org	NEMA is the association of electrical equipment and medical imaging manufacturers that provide a diverse set of products used in the generation, transmission, distribution and end use of electricity as well as medical diagnostic imaging. NEMA provides a forum for the development of technical standards that are in the best interests of the industry and users, advocacy of industry policies on legislative and regulatory matters and collection, analysis and dissemination of industry data.

North American Electric Reliability Corporation (NERC) www.nerc.com	NERC is a non-profit international regulatory authority whose mission is to ensure the reliability of the bulk power system in North America. NERC develops and enforces reliability standards; annually assesses seasonal and long-term reliability; monitors the bulk power system through system awareness; and educates, trains and certifies industry personnel. NERC is the electric reliability organization for North America subject to oversight by the Federal Energy Regulatory Commission and governmental authorities in Canada. NERC's jurisdiction includes users, owners and operators of the bulk power system, which serves more than 334 million people.
National Fire Protection Association (NFPA) www.nfpa.org	NFPA's mission is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training and education. NFPA develops, publishes and disseminates over 300 consensus codes and standards that are intended to minimize the possibility and effects of fire and other risks.
Professional Electrical Apparatus Recyclers League (PEARL) www.pearl1.org	PEARL is the professional organization of companies that supply quality surplus and remanufactured electrical equipment, apparatus and components. PEARL is an ANSI Accredited Standards Developer.
Portable Generator Manufacturers Association (PGMA) www.pgmaonline.com	PGMA seeks to develop and influence safety and performance standards for portable generators sold in North America.
Risk & Insurance Management Society (RIMS) www.rims.org	RIMS is dedicated to advancing the practice of risk management and brings networking, professional development and education opportunities to its membership.
UL Limited Liability Corporation (UL, LLC) www.ul.com	Formerly Underwriters Laboratories, Inc. (UL), UL, LLC is an independent safety science company innovating safety solutions from the public adoption of electricity to new breakthroughs in sustainability, renewable energy and nanotechnology. Dedicated to promoting safe living and working environments, UL, LLC helps safeguard people, products and places in important ways, facilitating trade and providing peace of mind.

While not listed as SDOs, the following organizations and alliances are currently addressing safety-related CSR relevant to ESS. Through the DOE Energy Storage Safety Strategy (DOE 2014), it is envisioned that ESS stakeholders individually and collectively through these organizations will collaborate in the development of CSR that foster the deployment of safe ESS.

The California Energy Storage Alliance (CESA)	CESA is a membership-based advocacy group committed to advancing the role of energy storage in the electric power sector through policy, education, outreach, and research. The mission of CESA is to make energy storage a mainstream energy resource that accelerates the adoption of renewable energy technology and promotes a more efficient, reliable, affordable, and secure electric power system. Members include technology manufacturers, project developers, systems integrators, consulting firms, and other clean tech industry leaders.
Electric Power Research Institute (EPRI) has formed an Energy Storage Integration Council (ESIC)	ESIC is a forum in which electric utilities guide a discussion with energy storage vendors, government organizations and other stakeholders to develop reliable, safe and cost-effective energy storage options for the utility industry. The ESIC was formed in 2013 by the energy storage program at EPRI, along with utilities, vendors, national laboratories and industry experts. The first general meeting was held in August 2013, and working groups have been assembled (applications, performance, system development and grid deployment) to develop common approaches to critical components supporting ESIC's mission. The initial focus is to find common solutions to definition and deployment for distribution system-connected ESS encompassing the utility scope from customer meter to 69kV.
Energy Storage Association (ESA)	ESA represents companies that develop and deploy energy storage technologies. ESA members research, manufacture, distribute, finance and build energy storage projects domestically and abroad. ESA is comprised of over 120 private companies, non-profit organizations and individual experts working together to educate the public and inform regulators and legislators about the importance of energy storage technologies.
National Alliance for Advanced Technology Batteries (NAATBatt)	NAATBatt is a non-profit trade association of foreign and domestic corporations, associations and research institutions focused on the manufacture of large format advanced batteries for use in transportation and large-scale energy storage applications in the United States. Members include advanced battery and electrode manufacturers, materials suppliers, vehicle makers, electric utilities, equipment vendors, service providers, universities and national laboratories. NAATBatt's core missions are to grow the North American market for products incorporating advanced energy storage technology and to reduce the cost of those products to U.S. consumers. NAATBatt supports the adoption of public policies and the development of new technologies and industrial standards that will reduce the price of large format advanced batteries to consumers and the products that use them. NAATBatt provides a platform for battery manufacturers, advanced materials suppliers, vehicle makers, recharging solution providers and electric utilities to work together across industry boundaries to address the challenges of large-scale electrochemical energy storage.

The New York Battery and Energy Storage Technology (NY-BEST™) Consortium	NY-BEST was created in 2010 to position New York State as a global leader in energy storage technology, including applications in transportation, grid storage, and power electronics. NY-BEST currently has more than 130 members that include manufacturers, academic institutions, utilities, technology and materials developers, start-ups, government entities, engineering firms, systems integrators, and end-users. The majority of its members are New York State based entities. NY-BEST serves as an expert resource to energy storage-related companies and organizations seeking assistance to grow their businesses in New York State. This includes access to financing, research capabilities, potential partners, technology developers, manufacturers, and other private sector and government resources. NY-BEST serves as an important connector in establishing a strong energy storage "ecosystem" encompassing all stages of energy storage product development and use. The vision of NY-BEST is that sustainable energy use requires transformative energy storage solutions and NY-BEST will lead the development and deployment of these solutions by linking energy markets with our world class industries and research institutions. The mission is to catalyze and grow the energy storage industry and establish New York State as a global leader.
SunSpec Alliance and MESA Standards Alliance	These organizations have a joint effort to advance common communication standards for energy storage devices to lower costs and increase customer adoption. An industry consortium of electric utilities and technology suppliers have developed the Modular Energy Storage Architecture (MESA) and created the MESA Standards Alliance. The MESA standards are an open, non-proprietary set of specifications and standards to accelerate interoperability, scalability, safety, quality, availability and affordability in energy storage components and systems. MESA Standards focus on three key aspects of ESS design: how ES components are physically packaged and arranged; how ES components are electrically connected and how they communicate internally; and how the ESS as a whole communicates with other devices and utility control systems. These standards are complementary to SunSpec communication standards for distributed energy components and applications. The intention of MESA and SunSpec is to enable seamless integration of storage and distributed energy. The SunSpec Alliance and MESA are both industry-led trade associations working to establish common standards for the different devices that comprise photovoltaic (PV) power systems and energy storage systems. Working together, the two associations are developing and extending smart grid standards that work for industry participants on both the utility and customer side of the meter.

3.0 Codes, Standards and Regulations

This section provides an inventory of current, standards, regulations and other criteria that apply or could possibly apply to a number of aspects of ESS or could be used as models in development of new codes, standards, regulations or other criteria. This inventory represents a "snapshot in time" associated with the very dynamic environment in which codes, standards, regulations and other criteria are revised, updated and newly developed. For that reason, it is recognized that such a snapshot in time is likely to be outdated in a very short period of time. In addition the complexity of CSR as to number of documents and developers is daunting. Additional detail on CSR can be found in *Overview of Development and Deployment of Codes, Standards and Regulations Affecting Energy Storage System Safety in the United States* (Conover 2014).

The CSR presented in this section are intended as a starting (not ending) point to help the industry and stakeholders initially identify those CSR that may apply to their activities as a component manufacturer, ESS manufacturer, installer or one involved in commissioning, O&M or even responding to an ESS related incident. From that identification actions can then be taken to review revisions that may be needed to existing or determine if new CSR need to be developed and the research and analysis that will be needed to support that work. Over time, this is intended to achieve a situation where the norm related to ESS is to readily and uniformly secure approval for and acceptance of the application and use of an ESS under applicable CSR related to safety, a track record of safe ESS operations, the ability for first responders to address an ESS related incident and no loss of life and minimal (if any) property damage if an ESS related incident occurs.

The CSR are presented in six sections covering, ESS components, entire ESS, the installation of ESS, commissioning and O&M, provisions related to incident response and transportation of ESS. In some cases a subject CSR could be relevant to multiple sections but to avoid duplication of CSR entries, it is located in the most applicable section and then as appropriate its relevance to other sections is addressed in the comments column. Note that the CSR listed are those primarily developed in the voluntary sector. The listing is not intended to cover individual state or local rules and regulations (e.g., a state or local building or fire code), although many of those regulations will be based on or adopt by reference the voluntary sector model codes and standards listed herein. The information in this section is static and represents a view at one point in time of a very dynamic CSR development and deployment process in the United States. This information is intended to be a starting point that is static in this publication but can be more dynamic in nature by locating this information in a robust and interactive online database that is available to support the DOE Energy Storage Safety Strategy (DOE 2014).

3.1 Standards for ESS Components

The fundamental basis for the evaluation of an ESS with respect to safety is the design and construction of the components of the ESS (e.g., battery, inverter, controls, etc.). Standards for ESS components are intended to provide criteria for the design and construction of the component and safety-related metrics that are considered important to evaluate. The designer of the component would then simply design and construct the component to the standard and subject it to testing required by the standard. If the component satisfied the provisions of the standard and related testing criteria and metrics, then the component would be considered in compliance with the standard. Through third-party certification programs, ongoing production of the component would be inspected to ensure that subsequent production is identical to that of the component that was tested and found to comply with the standard. In addition, those certification programs would also review and assess the administrative and quality control aspects associated with the manufacturer of the component. Standards covering ESS components and the associated conformity assessment activities to document and validate compliance would be of primary relevance to component manufacturers in deploying the component. Manufacturers of complete ESS "products" or those that assembled an ESS on site from various components would benefit when using components that complied with relevant standards because they will be easier to accept and deploy. Utilities, building regulatory agency staff and others engaged in validating compliance have an easier time approving ESS installations when the components are validated as complying with applicable standards. Note that the standards covered in Section 3.2 for an entire ESS "product" could concurrently address the acceptability of the components to the degree that such standards addressed the safety of the individual components in the ESS.

Table 3.1 is a listing of standards applicable to components of ESS. Included are standards that clearly apply, may apply or while not directly applicable to ESS components may offer some insight or examples that could be applied in the future to ESS. The title and designation of the standard and summary of the scope are provided along with initial comments relating to further consideration of the standard in addressing ESS safety. Although the focus of this document is U.S. CSR some international standards are included because they are covered in Section 4.0 on ESS approval experiences or were presented in presentations during the DOE Safety Workshop in February 2014 (Sandia and PNNL 2014; Appendix B).

Table 3.1. Standards Applicable to ESS Components

Standard	Scope Summary	Comments
ATIS 06000330:2008 Valve Regulated Lead Acid (VRLA) Batteries Used in the Telecommunications Environment	Covers VRLA batteries, used as a reserve energy source that supports DC-powered telecommunications load equipment. Defines the proper operational use, storage conditions and test criteria initial and lifetime for VRLA cells (modules). Intended to be used to establish initial physical and performance characteristics of VRLA cells or modules, performance expectations throughout their lifetime and operations conditions for appropriate use and guidance for designers of these cells or modules.	Addresses requirements for monobloc VRLA batteries (not system-level requirements) – where VRLA Batteries are used as a component of an ESS then this standard should be considered for review and use where applicable.
CENELEC Workshop Agreement (CWA) 50611 Flow batteries – Guidance on the specification, installation and operation, April 2013	The CWA provides guidance on the specification, installation and operation of flow batteries. It facilitates the pre-commercial phase when flow batteries need to be compared with other flow batteries or other electrical storage devices. It provides guidance to conformity assessment bodes to benchmark flow battery conformity with existing directives and other regulations.	Consider review to determine applicability and then any needed revisions and possible research and analysis to support those revisions.
EN 50272-2 Safety Requirements for Secondary batteries and battery installations – Part 2 stationary batteries	The standard applies to a 1500 VDC limit, protection against electricity, gas emission and electrolyte. It is limited to lead-acid and nickel technologies in applications for telecom, PV, uninterruptable power supply (UPS), emergency lighting, power station, stationary engine starting.	Where the application of the ESS is for telecom, PV, UPS, emergency lighting, power station, stationary engine starting the standard would appear to apply. Might be considered for revision to address other ESS applications based on further review and assessment.
FM Global Property Loss Prevention Data Sheet 5-31 CABLES AND BUS BARS, December 2004	This data sheet covers electrical protection and fire protection for cables and bus bars and discusses aluminum conductors, describing methods of connecting, splicing and terminating to prevent excessive heating that could result in arcing and fire.	
IEC 60622 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Sealed nickel-cadmium prismatic rechargeable single cells	The standard specifies marking, tests and requirements for sealed nickel cadmium prismatic secondary single cells.	

Standard	Scope Summary	Comments
IEC 60623 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Vented nickel-cadmium prismatic rechargeable single cells	The standard specifies marking, designation, dimensions, tests and requirements for vented nickel-cadmium prismatic secondary single cells.	A new edition is under development.
IEC 60896-11 Stationary lead-acid batteries, Part 11: Vented types – General requirements and methods of tests	This part of IEC 60896 is applicable to lead-acid cells and batteries which are designed for service in fixed locations and which are permanently connected to the load and to the DC power supply. Part 11 of the standard is applicable to vented types only. The object of this standard is to specify general requirements and main characteristics with corresponding test methods associated with all types and construction modes of lead-acid stationary batteries, excluding valve-regulated types.	
IEC 60896-21 Stationary lead-acid batteries, Part 21: Valve regulated types – Methods of test	Applies to all stationary lead-acid cells and monobloc batteries of the valve regulated type for float charge applications (i.e., permanently connected to a load and to a DC power supply), in a static location and incorporated into stationary equipment or installed in battery rooms for use in telecom, UPS, utility switching, emergency power or similar applications. The objective is to specify test methods for all types and construction of valve regulated stationary lead-acid cells and monobloc batteries used in standby power applications. This part of IEC 60896 does not apply to lead-acid cells and monobloc batteries used for vehicle engine starting applications (IEC 60095 series), solar PV energy systems (IEC 61427) or general purpose applications (IEC 61056 series).	
IEC 60896-22 Stationary lead-acid batteries, Part 22: Valve regulated types – Requirements	Applies to all stationary lead-acid cells and monobloc batteries of valve regulated type for float charge applications, (i.e., permanently connected to load and DC power supply), in a static location and incorporated into stationary equipment or installed in battery rooms for use in telecom, UPS, utility switching, emergency power or similar applications. The objective of this part of IEC 60896 is to assist in understanding the purpose of each test contained within IEC 60896-21 and provide guidance on a suitable requirement in the battery meeting the needs of a particular industry application and operational condition. This standard is used in conjunction with common test methods described in IEC 60896-21 and is associated with all types and construction of valve regulated stationary lead-acid cells	

Standard	Scope Summary	Comments
	and monoblocs used in standby power applications. This part of IEC 60896 does not apply to lead-acid cells and batteries used for vehicle engine starting applications (IEC 60095 series), solar PV applications (IEC 61427), or general purpose applications (IEC 61056 series).	
IEC 61427-1 Secondary cells and batteries for photovoltaic energy systems (PVES) – General requirements and methods of test	This international standard provides general information about secondary batteries used in PVES and the typical methods of test used for the verification of battery performance. This standard does not include specific information relating to battery sizing, method of charge or PVES design. NOTE: This standard is applicable to lead-acid and nickel-cadmium cells and batteries. This standard will be amended to include other electrochemical systems when they become available.	The indication that the standard will be amended to include other electrochemical systems suggests it be reviewed for possible revision and identification of needed research or analysis to support any needed revisions.
IEC 61951-1 Ed 4 Portable sealed rechargeable single cells – Part 1: Nickel-cadmium	Specifies marking, designation, dimensions, tests and performance requirements for portable sealed nickel-cadmium small prismatic, cylindrical and button rechargeable single cells, suitable for use in any orientation.	While not likely applicable to ESS, it may provide a basis for criteria that could fill gaps in other ESS-related standards.
IEC 61951-2 Ed 3 Portable sealed rechargeable single cells - Part 2: Nickel-metal hydride	Specifies marking, designation, dimensions, tests and performance requirements for portable sealed nickel-metal hydride, small prismatic, cylindrical and button rechargeable single cells, suitable for use in any orientation. This third edition cancels and replaces the second edition published in 2003 of which it constitutes a technical revision.	While not likely applicable to ESS it may provide a basis for criteria that could fill gaps in other ESS-related standards.
IEC 61960 Ed 3 Secondary lithium cells and batteries for portable applications	Specifies performance tests, designations, markings, dimensions and other requirements for secondary lithium single cells and batteries for portable applications. The objective of this standard is to provide the purchasers and users of secondary lithium cells and batteries with a set of criteria with which they can judge the performance of secondary lithium cells and batteries offered by various manufacturers.	While not likely applicable to ESS it may provide a basis for criteria that could fill gaps in other ESS-related standards.
IEC 62133-1 Ed 2 Secondary cells and batteries containing alkaline and other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications – Part 1: Nickel systems	This standard and standard 62133-2 below are in development and are categorized in: Aerospace electric equipment and systems, Electrical and electronic equipment. These standards address safety of the respective battery chemistries for portable applications.	While not likely applicable to ESS, it may provide a basis for criteria that could fill gaps in other ESS-related standards.

Standard	Scope Summary	Comments
IEC 62133-2 Ed 2 2 Secondary cells and batteries containing alkaline and other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications – Part 2: Lithium systems	See above entry for Standard 62133-1.	While not likely applicable to ESS it may provide a basis for criteria that could fill gaps in other ESS-related standards.
IEC 62259 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Nickel-cadmium prismatic secondary single cells with partial gas recombination	The standard specifies marking, designation, dimensions, tests and requirements for vented nickel-cadmium prismatic secondary single cells where special provisions have been made in order to have partial or, under very specific conditions, full gas recombination.	
IEC 62485-2 Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries	This part of the IEC 62485 applies to stationary secondary batteries and battery installations with a maximum voltage of DC 1 500 V (nominal) and describes the principal measures for protections against hazards generated from electricity, gas emission, and electrolyte.	Appears to be same as EN 50272-2 covered above
IEC CD 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.	The standard provides requirements on safety aspects associated with the erection, use, inspection, maintenance and disposal of cells and batteries for stationary applications and motive (other than on-road vehicle). Under development moving toward the committee draft voting stage. Includes safety requirements for lithium-ion cells for stationary and off-road motive applications and some battery requirements (evaluation of battery and battery management system [BMS] combination). Not a system standard, as it covers only battery and BMS interaction. Regional regulations such as EU directives (LV, electromagnetic compatibility [EMC]) Japan S Mark (SBA S1101).	The standard is current available but revisions are underway (CD – committee draft)
IEC CDV 62620 Secondary cells and batteries containing alkaline or other non-acid electrolytes –	The standard specifies marking, designation, dimensions, tests and requirements for large format lithium-ion secondary single cells and batteries used in Industrial Applications including Stationary applications.	Under development. Next stage is a draft standard. Generic performance requirements for lithium-ion cells and batteries for

Standard	Scope Summary	Comments
Secondary lithium cells and batteries for use in industrial applications		stationary and off road motive applications. Tests based upon cell and battery specifications.
IEC 62620 Ed 1 Large format secondary lithium cells and batteries for use in industrial applications	The standard covers product and test specifications for all secondary cells and batteries of sealed and vented designs containing alkaline or other non-acid electrolytes.	Current standard being revised as discussed above.
IEC 62675 Ed 1 Sealed Ni-MH prismatic rechargeable single cells for industrial applications	The standard covers secondary cells and batteries containing alkaline or other non-acid electrolytes - Sealed nickel-metal hydride prismatic rechargeable single cells for industrial applications.	
IEC/TR 62914 Ed 1 Experimental procedure for the forced internal short-circuit test (Supplemental information to IEC 62133 Ed 2.0)	This technical report is in development is categorized in: Acid secondary, Alkaline secondary, Cells & batteries, Copper products.	
IEEE C37.90.1-2002 Standard Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus	The standard covers two types of design tests for relays and relay systems that relate to the immunity of this equipment to repetitive electrical transients are specified. Test generator characteristics, test waveforms, selection of equipment terminals on which tests are to be conducted, test procedures, criteria for acceptance, and documentation of test results are described. This standard has been harmonized with IEC standards where consensus could be reached.	Could apply to relays and relay systems associated with an ESS. A review of possible application and use of this standard for relays and relay systems applied to ESS should be considered.
IEEE C57.12.00-2010 Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers	The standard provides electrical and mechanical requirements for liquid-immersed distribution and power transformers, and autotransformers and regulating transformers; single- and polyphase, with voltages of 601 V or higher in the highest voltage winding, are set forth. It is basis for the establishment of performance, and limited electrical and mechanical interchangeability requirements of equipment are described, and for assistance in the proper selection of such equipment. The requirements in the standard apply to all liquid-immersed distribution, power, and regulating transformers except the following: instrument transformers, step voltage and induction voltage regulators, arc furnace transformers, rectifier transformers, specialty transformers, grounding transformers, mobile transformers, and mine transformers.	Could apply to transformers associated with an ESS that are within the scope of the standard. Further review of transformers used in conjunction with ESS would be needed to determine the degree to which, if at all, this standard would be applicable to ESS.

Standard	Scope Summary	Comments
IEEE C57.13-1993 Standard Requirements for Instrument Transformers	The standard covers electrical, dimensional, and mechanical characteristics, taking into consideration certain safety features, for current and inductively coupled voltage transformers of types generally used in the measurement of electricity and the control of equipment associated with the generation, transmission, and distribution of alternating current. The aim is to provide a basis for performance, interchangeability, and safety of equipment covered and to assist in the proper selection of such equipment. Accuracy classes for metering service are provided. The test code covers measurement and calculation of radio and phase angle, demagnetization, impedance and excitation measurements, polarity determination, resistance measurements, short-time characteristics, temperature rise tests, dielectric tests, and measurement of open-circuit voltage of current transformers.	Could apply to transformers associated with an ESS that are within the scope of the standard. Further review of transformers used in conjunction with ESS would be needed to determine the degree to which, if at all, this standard would be applicable to ESS. A review of the scope indicates that it covers generation, transmission and distribution but does not currently cover storage. A review of increasing the scope to include storage may be appropriate.
IEEE C62.22-2009 Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems	The guide covers the application of metal-oxide surge arresters to safeguard electric power equipment, with a nominal operating voltage 1000 V and above, against the hazards of abnormally high-voltage surges of various origins. It also provides information on the characteristics of metal-oxide surge arresters and the protection of substation equipment, distribution systems, overhead lines, and large electrical machines.	This standard could apply to surge arrestors associated with ESS that are connected to the grid or sources with a nominal operating voltage in the scope of the standard. A review of the standard might be warranted to verify whether it could or should be applied to ESS.
IEEE 484 Recommended Practice for Installation Design and Installation of VLA Batteries for Stationary Applications	The recommended practice document provides recommended design practices and procedures for storage, location, mounting, ventilation, instrumentation, preassembly, assembly, and charging of VLA batteries. Required safety practices are also included. This document is applicable to full-float stationary applications where a battery charger normally maintains the battery fully charged and provides DC loads.	
IEEE 1361 Guide for Election, Charging, Test, and Evaluation of Lead-Acid Batteries Used in Stand-Alone PV Systems	The guide was written to provide a relevant PV battery test procedure that can be used to evaluate battery performance and identify appropriate PV battery charging requirements. The document contains a tutorial on lead-acid battery technology, battery charging characteristics, and a laboratory test procedure to evaluate charge parameters and battery performance.	

Standard	Scope Summary	Comments
IEEE 1660 Guide for Application and Management of Stationary Batteries Used in Cycling Service	The guide is intended to provide assistance to users of stationary battery systems in determining appropriate battery management strategies that may be applied by addressing the primary similarities and differences in battery design and operation for standby versus cycling applications.	General information on batteries for stationary applications may be applicable if a review finds it is or could be relevant to safety considerations.
IEEE 1661 Guide for Test and Evaluation of Lead-Acid Batteries Used in PV Hybrid Power Systems	The guide was written to provide a PV hybrid power system battery test procedure that can be used to assist in evaluating battery capacity, and appropriate PV battery charging requirements.	
Telcordia GR-3020-CORE Nickel cadmium batteries in the outside plant (OSP)	The document addresses the safety and performance issues of NiCd batteries intended for use as backup power systems in telecommunications OSP. NiCd batteries have a longer service and shelf life than lead-acid batteries and an inherent ruggedness to withstand harsh environments. The document includes electrical, chemical, environmental, physical design and quality and reliability requirements as well as a section on documentation and testing requirements and auxiliary charging devices.	
Telcordia GR-3150-CORE Generic requirements for secondary non-aqueous lithium batteries	The document presents general requirements that Telcordia and participating industry representatives view as applicable to large format non-aqueous rechargeable lithium batteries to replace or interoperate with conventional batteries (i.e., lead-acid, nickel-based); function seamlessly with DC power plants; and provide reliable backup power to load equipment in a network environment of a typical telecommunications service provider. Lithium batteries compliant with criteria in this document are recommended for deployment in the OSP at locations such as controlled environmental vaults (CEVs), electronic equipment enclosures (EEEs), huts and in uncontrolled structures such as cabinets. This standard addresses lithium batteries comprised of non-aqueous liquid or polymerized electrolytes that provide ionic conductivity between lithiated positive active material electrically separated from metallic lithium or lithiated negative active material. This document covers lithium batteries shipped disassembled (full assembly requires the series or parallel connections of cells or modules and a connection to an external BMS) or fully assembled (as 48 V systems with an integrated electronic management system).	Requirements are for telecom applications. Covers performance, safety and construction, including formatting to serve as replacements for current lead-acid technologies.

Standard	Scope Summary	Comments
Telcordia GR-4228-CORE VRLA battery string certification levels based on requirements for safety and performance	The document provides a 3-level system of VRLA String Safety and Performance Criteria based on Telcordia generic requirements documents. The VRLA string criteria levels are defined as follows: • Level 1, Safety and Minimal Operability – minimum acceptable level of compliance needed to preclude hazards and degradation of the network facility and hazards to personnel, and needed to ensure battery operability at the installation time in controlled environments. • Level 2, Limited Operability – minimum acceptable level of compliance needed to provide limited assurance of battery operability under controlled environment conditions. • Level 3, Full Operability – minimum acceptable level of compliance needed to ensure battery operability throughout its expected life under the range of acceptable environmental conditions.	The requirements are for telecom applications and include safety, performance, construction criteria and quality.
UL 489 Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures	1.1 This standard covers molded-case circuit breakers, circuit-breaker and ground-fault circuit interrupters, fused circuit breakers and accessory high-fault protectors. These circuit breakers are specifically intended to provide service entrance, feeder and branch circuit protection in accordance with the National Installation Codes in Annex B, Ref. 1. This standard covers instantaneous-trip circuit breakers (circuit interrupters) specifically intended as part of a combination motor controller in accordance with the National Installation Codes in Annex B, Ref. 1. 1.2 This standard covers molded-case and fused molded-case switches. 1.3 This standard covers devices rated at 600 V or less and 6000 amps or less. 1.4 The devices referenced in 1.1 and 1.2 are intended for installation in an overall enclosure or as parts of other devices such as panelboards. The acceptability of the combination will be determined when the complete product is investigated. 1.5 This standard covers circuit-breaker enclosures and accessory devices intended for use with the devices described in 1.1 and 1.2. 1.6 This standard does not cover low-voltage power circuit breakers covered in Annex B, Ref. 3 and Ref. 4 or supplementary protectors covered in Annex B, Ref. 5.	Where circuit breakers are used in conjunction with an ESS and within the scope of this standard, they could be validated for safety per this standard. It is not likely that these components would perform differently when supporting an ESS compared to more traditional technologies.

Standard	Scope Summary	Comments
	1.7 This standard contains supplements covering the requirements for molded-case circuit breakers for: a) Marine Use; b) Naval Use; c) Uninterruptible Power Supply Use; d) Classified Circuit Breakers; and e) Software in Programmable Components.	
UL 810A Electrochemical Capacitors	1.1 These requirements cover electrochemical capacitors for use in equipment such as electronic products, uninterruptible power supplies, emergency lighting, engine starting, and power equipment. These energy storage capacitors, also known as electric double-layer capacitors, ultracapacitors, double-layer capacitors or supercapacitors, consist of either individual capacitors or multiple series and/or parallel connected capacitors with or without associated circuitry. 1.2 These requirements do not cover electrochemical capacitors for use in hazardous (Classified) locations.	Where electrochemical capacitors are used in conjunction with an ESS and within the scope of this standard, they could be validated for safety per this standard. It is not likely that these components would perform differently when supporting an ESS compared to more traditional technologies.
UL 1642 Lithium Batteries	1.1 These requirements cover primary (nonrechargeable) and secondary (rechargeable) lithium batteries for use as power sources in products. These batteries contain metallic lithium, lithium alloy or lithium-ion and may consist of a single electrochemical cell or two or more cells connected in series, parallel, or both that convert chemical energy into electrical energy by an irreversible or reversible chemical reaction. 1.2 These requirements cover lithium batteries intended for use in technician-replaceable or user-replaceable applications. 1.3 These requirements are intended to reduce the risk of fire or explosion when lithium batteries are used in a product. The final acceptability of these batteries is dependent on their use in a complete product that complies with the requirements applicable to such product. 1.4 These requirements are also intended to reduce the risk of injury to persons due to fire or explosion when user-replaceable lithium batteries are removed from a product and discarded. 1.5 These requirements cover technician-replaceable lithium batteries that contain 5.0 g (0.18 oz) or less of metallic lithium. A battery containing more than 5.0 g (0.18 oz) of lithium is judged on the basis of compliance with the requirements in this standard as applicable, and further test to determine whether the battery is acceptable for its intended uses.	

Standard	Scope Summary	Comments
	1.6 These requirements cover user-replaceable lithium batteries that contain 4.0 g (0.13 oz) or less of metallic lithium with not more than 1.0 g (0.04 oz) of metallic lithium in each electrochemical cell. A battery containing more than 4.0 g (0.13 oz) or a cell containing more than 1.0 g (0.04 oz) lithium may require further examination and test to determine whether the cells or batteries are acceptable for their intended uses. 1.7 These requirements do not cover the toxicity risk that may result from the ingestion of a lithium battery or its contents, nor the risk of injury to persons that may occur if a battery is cut open to provide access to the metallic lithium.	
UL 1973 Batteries for Use in Light Electric Rail (LER) and Stationary Applications	Safety standard for stationary batteries for energy storage applications, non-chemistry specific and includes electrochemical capacitor systems or hybrid electrochemical capacitor and battery systems. Includes requirements for unique technologies such as flow batteries and sodium beta (i.e., sodium sulfur and sodium nickel chloride). Includes construction requirements, tests and production tests. Also includes requirements for cells used in these systems such as lithium-ion, nickel, lead-acid and includes sodium beta and flow battery requirements.	
UL 2580-ULC S8250 Batteries for use in Electric Vehicles	1.1 These requirements cover electrical energy storage assemblies such as battery packs and combination electrochemical capacitor assemblies and modules that make up these assemblies for use in electric-powered vehicles as defined in this standard. 1.2 This standard evaluates electrical energy storage assembly’s ability to safely withstand simulated abuse conditions and prevents any exposure of persons to hazards from the abuse. This standard evaluates electric energy storage assembly and modules based on manufacturer’s specified charge and discharge parameters at specified temperatures. It does not evaluate assembly’s interaction with other control systems within the vehicle. 1.3 This standard does not evaluate performance or reliability of devices. 1.4 This standard does not include requirements for the evaluation of batteries for light electric vehicles such as electrical assist bicycles, wheel chairs, electric scooters and similar devices as defined in the Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications, UL 2271/ULC-S2271.	While not relevant to stationary ESS, the provisions of this standard may provide guidance in establishing any standards that may be needed for batteries used in ESS.

3.2 Standards for the Entire ESS

As presented in Section 3.1, the fundamental basis for the evaluation of an ESS technology with respect to safety is the design and construction of the components of the ESS (e.g., battery, inverter, controls, etc.). Standards for ESS components are intended to provide criteria for the design and construction of the component and safety-related metrics that are considered important to evaluate. The designer of the component would then simply design and construct the component to the standard and subject it to testing required by the standard.

Considering ESS as an assembly of components, a standard for a complete ESS "product" is likely to refer to various components and component standards within the ESS standard and then simply tie them together. One approach to assessing the safety of the ESS "product" is to confirm that the components meet relevant component standards and assess the acceptability of their combination as an ESS. Another is to consider the ESS "product" as a black box and cover how the entire ESS as an assembly of components and evaluate the ESS "product" against an appropriate standard covering that assembly. If the ESS "product" satisfied the provisions of the standard and related testing criteria and metrics, then the components of the ESS would be considered in compliance with the standard. Through third-party certification programs, ongoing production of the ESS "product" would be inspected to ensure that subsequent production is identical to the ESS that was tested and found to comply with the standard. In addition, those certification programs would also review and assess the administrative and quality control aspects associated with the manufacturer of the component. The degree to which such an ESS standard addressed the performance of one or more components within the requirements in the standard the need to test and list components can be reduced (e.g. testing the entire ESS to the standard validates the safety of the ESS without having to conduct a separate assessment of each component of the system).

Standards covering an ESS as a complete product and the associated conformity assessment activities to document and validate compliance would be of primary relevance to manufacturers deploying the entire ESS "product," although ESS component manufacturers would want to be familiar with those standards and know that if used in the ESS, which would comply with those standards. Those that assemble a complete ESS "product" on site from various components would likely have to document compliance with the standard and, as such, would benefit when using components that complied with relevant component safety standards. Utilities, building regulatory agency staff and others engaged in validating compliance would have an easier time approving ESS installations when the ESS "product" is validated as complying with applicable standards. In the absence of such standards and until they are developed, it is more likely that approval of an ESS "product," whether pre-packaged or assembled on site from various components, would have to be pursued as outlined in Section 5.0.

Table 3.2 is a listing of standards applicable to entire ESS. Included are any and all standards that clearly apply, may apply or while not directly applicable to ESS may offer some insight or examples that could be applied in the future to ESS. The title and designation of the standard and summary of the scope are provided along with initial comments relating to further consideration of the standard in addressing ESS safety. Although the focus of this document is U.S. CSR, some international standards are included because they are covered in Section 4.0 on ESS approval experiences or were used in presentations during the DOE Safety Workshop in February 2014 (Sandia and PNNL 2014; Appendix B).

Table 3.2. Standards for the Entire ESS

Standard	Scope Summary	Comments
ANSI C84.1 Electric Power Systems and Equipment— Voltage Ratings (60 Hertz)	1.1 Scope This standard establishes nominal voltage ratings and operating tolerances for 60-hertz electric power systems above 100 volts. It also makes recommendations to other standardizing groups with respect to voltage ratings for equipment used on power systems and for utilization devices connected to such systems. This standard includes preferred voltage ratings up to and including 1200 kV maximum system voltage, as defined in the standard. In defining maximum system voltage, voltage transients and temporary overvoltages caused by abnormal system conditions such as faults, load rejection, and the like are excluded. However, voltage transients and temporary overvoltages may affect equipment operating performance and are considered in equipment application. 1.2 Purpose The purposes of this standard are to: 1) Promote a better understanding of the voltages associated with power systems and utilization equipment to achieve overall practical and economical design and operation; 2) Establish uniform nomenclature in the field of voltages; 3) Promote standardization of nominal system voltages and ranges of voltage variations for operating systems; 4) Promote standardization of equipment voltage ratings and tolerances; 5) Promote coordination of relationships between system and equipment voltage ratings and tolerances; 6) Provide a guide for future development and design of equipment to achieve the best possible conformance with the needs of the users; and 7) Provide a guide, with respect to choice of voltages, for new power system undertakings and for changes in older ones.	This standard applies to equipment uses on power systems and utilization devices connected to such systems. This would appear to include ESS and as such the standard would be a logical reference where measuring and expressing the voltage of ESS.
AWEA 9.1-2009 Small Wind Turbine Performance and Safety Standard	This standard was created by the small wind turbine industry, scientists, state officials, and consumers to provide consumers with realistic and comparable performance ratings and assurance the small wind turbine products certified to this standard are engineered to meet standards for safety and operation. The goal is to provide consumers with confidence in the quality of small wind turbine products meeting this standard and an improved basis for comparing competing product performance.	While not applicable to ESS, AWEA is a source of information for standards having the same general purpose but covering ESS. Potentially relevant to situations where an ESS may be connected to a wind turbine and used to store its output.

Standard	Scope Summary	Comments
	This performance and safety standard provides a method for evaluation of wind turbine systems in terms of safety, reliability, power performance, and acoustic characteristics. This standard for small wind turbines is derived largely from existing international wind turbine standards developed under the auspices of the International Electrotechnical Commission (IEC). Specific departures from the IEC standards are provided to account for technical differences between large and small wind turbines, to streamline their use, and to present their results in a more consumer-friendly manner.	
CA PUC Tariff Rule 21	Third parties must use certified equipment (both behind the meter and on the distribution grid) when attempting to interconnect new components to the grid. Certified equipment is equipment that has passed through rigorous certification testing procedures done by Nationally Recognized Testing Laboratories (NRTLs); UL is one such example. NRTLs create testing procedures for equipment that verify equipment functionality and safety to pre-set testing standards created by nationally recognized engineering groups such as IEEE. Certified equipment is tested against set standards so that the performance of the component under various conditions is predictable and certain. Predictability and certainty in relation to grid component reactions to various grid events enables responses to these events, by first responders and other interested parties, routinized, predictable and safe. Therefore, by requiring certified equipment in the interconnection process, new equipment will be expected to perform in certain, predictable ways under various grid conditions and events. Predictability also enables safety measures and routines to be created and executed.	This is included as information but technically is not a standard but instead represents the adoption mechanisms by which standards developed in the voluntary sector are adopted and third parties are accredited and recognized. Further work on the inventory will need to go beyond voluntary sector standards and model codes or model regulations and address what has been actually adopted and is being applied by AHJs (utilities, PUCs, federal, state and local regulatory agencies, insurance carriers, etc.).
CA PUC Tariff Rule 21, Section L	Testing procedures and criteria for "certifying" generators or inverters is provided. The testing procedures listed in the rule rely heavily on those described in UL, IEEE, and International Electrotechnical Commission (IEC) documents – most notably, UL 1741 testing procedures and IEEE 1547 Standard for Interconnecting Distribution Resources with Electric Power Systems. Section L describes the test procedures and requirements for equipment used for the Interconnection of Generating Facilities to Distribution Provider's Distribution or Transmission System. Included are Type Testing, Production Testing, Commissioning	

Standard	Scope Summary	Comments
	Testing, and Periodic Testing. Equipment tested and approved (i.e., "Listed") by an accredited NRTL meets both Type Testing and Production Testing requirements described in Rule 21 and is considered to be certified equipment for the purposes of interconnecting with the distribution or transmission system. Non-certified equipment will be required to provide information on some or all of the tests described in the rule and even then there is no guarantee that a utility will approve the non-certified equipment for use on the grid.	
IEC 60812 Analysis Techniques for System Reliability - Procedure for Failure Mode and Effects Analysis (FE/ULMA)	The standard describes FMEA and Failure Mode, Effects and Criticality Analysis (FMECA), and gives guidance as to how they may be applied to achieve various objectives by providing the procedural steps necessary to perform an analysis; identifying appropriate terms, assumptions, criticality measures, failure modes; defining basic principles; and providing examples of necessary worksheets or other tabular forms. All the general qualitative considerations presented for FMEA will apply to FMECA, as latter is an extension of the other.	This standard should be reviewed for its possible application and use to assessing ESS and installations and revised or enhanced as appropriate. Potential use is in documenting the safety of an ESS or ESS installation in the absence of specific standards covering component, entire ESS or ESS installation safety.
IEC 60950-1 (2013) Information technology equipment - Safety - Part 1: General requirements	The standard is applicable to mains- or battery-powered information technology equipment, including electrical business equipment and associated equipment, with a RATED VOLTAGE not exceeding 600 V. Also applicable are components and subassemblies intended for incorporation in information technology equipment. It is not expected that such components and subassemblies comply with every aspect of the standard, provided that the complete information technology equipment, incorporating such components and subassemblies, does comply.	While not applicable, standard may provide relevant criteria for ESS-related standards. If ESS are intended for use in conjunction with IT equipment, a review to determine if any revisions to address interconnection is warranted.
IEC 61025 Fault Tree Analysis (FTA)	The standard describes fault tree analysis and provides guidance on its application as follows: • definition of basic principles: describing and explaining associated mathematical modeling AND explaining FTA relationships to other reliability modeling techniques; • description of the steps involved in performing the FTA; • identification of appropriate assumptions, events and failure modes; • identification and description of commonly used symbols.	This standard should be reviewed for its possible application and use to assessing ESS and ESS installations and revised or enhanced as deemed appropriate. Potential use is in documenting the safety of an ESS or an ESS installation in the absence of specific standards covering component, entire ESS or ESS installation safety.

Standard	Scope Summary	Comments
IEC 61508 Functional Safety of Electrical/Electronic/ Programmable Electronic Safety-related	The standard is intended to be a basic functional safety standard applicable to all kinds of industry. It defines functional safety as: "part of the overall safety relating to the equipment under control (EUC) and the EUC control system which depends on the correct functioning of the E/E/PE safety-related systems, other technology safety-related systems and external risk reduction facilities."	
IEC 62040-1 Ed1 Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS used in operator access areas	This standard specifically applies to UPS with an electrical energy storage device in the DC link. It is used with IEC 60950-1, referred to in this standard as reference document (RD). It is applicable to UPS that are movable, stationary, fixed or for building-in, for use in low-voltage distribution systems and intended to be installed in any operator accessible area or in restricted access locations as applicable. It specifies requirements to ensure safety for the operator and layman who may come into contact with the equipment and, where specifically stated, for the service person.	
IEC 62040-1 Ed2 Uninterruptible power systems (UPS) – Part 2: General and safety requirements for UPS installed in restricted access locations	The standard addresses the EMC conformity assessment of categories C1, C2 and C3 products as defined in this part of IEC 62040, before placing them on the market. The requirements have been selected to ensure an adequate level of EMC for UPS at public and industrial locations.	
IEC 62257-9-5 Recommendations for Small Renewable Energy and Hybrid Systems for Rural Electrification – Protection Against Electrical Hazards	The document applies to stand-alone rechargeable electric lighting appliances or kits that can be installed by a typical user without employing a technician. This technical specification presents a quality assurance framework that includes product specifications a framework for interpreting test results test methods and standardized specifications sheets templates for communicating test results.	May provide some information for consideration to the degree that small ESS may be deployed in an environment similar to that covered by this standard.
IEC 62257-9-1 Recommendations for small renewable energy and hybrid systems for rural electrification – Micropower systems	The standard applies to a micropower plant which is the electric energy generation subsystem associated with a decentralized rural electrification system. It provides general requirements for the design, erection and operation of micropower plants and general requirements to ensure the safety of persons and property. The plants covered by this specification are low-voltage AC, three- or single-phase, with rated capacity less than or equal to 100 kVA.	To the degree that ESS may be used with such systems, a review of the standard may be warranted to determine if any revisions are needed to address ESS. May provide ideas for use in development of standards covering an entire ESS.

Standard	Scope Summary	Comments
IEC 62257-9-2 Recommendations for small renewable energy and hybrid systems for rural electrification – Microgrids	The standard specifies the general requirements for the design and the implementation of microgrids used in decentralized rural electrification to ensure the safety of persons and property and their satisfactory operation according to the scheduled use.	To the degree that ESS may be used with such systems a review of the standard may be warranted to determine if any revisions are needed to address ESS. It may also provide some ideas for use in development of any standards covering an entire ESS.
IEC 62897 Stationary Energy Storage Systems with Lithium Batteries – Safety Requirements (under development)	This part of the standard specifies general safety requirements for stationary energy storages with lithium batteries. The purpose of the requirements of this standard is to ensure that HAZARDS to the operator/user and the surrounding area are reduced to a tolerable level. Requirements for protection against particular types of HAZARDS: electric shock or burn, mechanical hazards, spread of fire from the equipment, excessive temperature, effects of fluids and fluid pressure, liberated gases, explosion, chemical hazards (e.g., electrolyte).	This is a new work proposal. It covers small battery systems for residential or similar use that can be connected to a main source of supply, and would appear very relevant to ESS.
IEC 62932-2-1 Flow Battery Systems For Stationary Applications – Part 2-1: Performance, general requirements and methods of test	This part of the IEC 62932 series specifies general information relating to the requirements and typical methods of test for flow battery system.	IEC 62932-2-1, Flow Battery Systems For Stationary Applications – Part 2-1: Performance, general requirements and methods of test
IEC 62932-2-2 Flow Battery Systems For Stationary Applications – Part 2-2: Safety requirements	This part of IEC 62932-2-2 applies to Flow Battery Systems for stationary use and its installations with a maximum voltage of DC 1 500 V (nominal) in compliance with IEC 62932-1.	IEC 62932-2-2, Flow Battery Systems For Stationary Applications – Part 2-2: Safety requirements
IEC 62933 EES systems – Terminology	This regulation will define terms applicable to the electrical energy storage systems	Under development
IEC 62934 Unit parameters and testing methods of EES systems	The scope is to define Unit parameters and Testing methods to assure the system capability and performance of electrical ESS.	Under development
IEC 62936 Environmental issues of EES systems	This new work item proposal deals with general environmental requirements, specific environmental requirements of EES systems. The general environmental requirements include the normative documents for the harmful material of system, recycling of system and greenhouse effects. The specific environmental requirements of EES systems only	Under development

Standard	Scope Summary	Comments
	need the normative documents from several aspects such as electrical, mechanical, surrounding conditions, etc.	
IEC NP 62937 Safety considerations related to the installation of grid integrated EES Systems	The scope of this NWIP is to prepare normative documents on safety dealing with: 1) main risks related to couples of use cases and associated technologies; 2) technical contents and results to be included in the safety report and auditing framework; 3) list of main features to be validated by testing; 4) scale at which the storage system must be tested; and 5) recommendations to prevent or mitigate accidental effect.	Under development
IEEE 485 Lead-Acid Batteries for Stationary Applications	This standard details methods for defining the DC loads and for sizing a lead-acid battery to supply those loads in full-float operation.	
IEEE 1375 Guide for the Protection of Stationary Battery Systems	This guidance provides for the protection of stationary battery systems, which include the battery and DC components to and including the first protective device downstream of battery terminals. Recommendations are not intended to set requirements; rather, they present options to the battery system designer concerning the types of protection available.	Although not a test the guide may have some useful information on battery protection for stationary applications.
IEEE 1491 Guide for Selection and Use of BMS in Stationary Applications	The document discusses operational parameters that may be observed by battery monitoring equipment used in stationary applications and the relative value of such observations. Although a list of commercially available systems is not given, a means for establishing specifications for the desired parameters to be monitored is provided.	
IEEE 1679 Recommended Practice for the Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications	Standard covers recommended information for an objective evaluation of emerging energy storage technology by a potential user of any stationary application. Storage technologies are those that provide a means for the reversible storage of electrical energy (i.e., device receives electrical energy and can discharge electrical energy later). The storage medium may be electrochemical (e.g., batteries), kinetic (e.g., flywheels), electrostatic (e.g., electric double-layer capacitors [EDLCs]), thermal or other medium. Devices recharged by non-electrical means such as fuel cells are beyond the scope of this document.	The document provides general guidance on performance and safety.
ISO 9000 Series Quality Management	The ISO 9000 family addresses various aspects of quality management and contains some of ISO's best known standards. The standards provide guidance and tools for companies and organizations who want to ensure that their products and services consistently meet customer's requirements, and that quality is consistently improved.	While not generally adopted as part of safety related CSR, quality management is a relevant topic in ensuring technology safety. Those engaged in the development and

Standard	Scope Summary	Comments
	Standards in the ISO 9000 family include: • ISO 9001:2008 - sets out the requirements of a quality management system • ISO 9000:2005 - covers basic concepts and language • ISO 9004:2009 - focuses on how to make a quality management system more efficient and effective • ISO 19011:2011 - sets out guidance on internal and external audits of quality management systems.	production of ESS may need to consider ISO 9000 compliance where those who purchase and operate ESS are also AHJs such as utilities or federal, state or local government for government-owned ESS.
NFPA 111-2013 Standard on Stored Electrical Energy Emergency and Standby Power Systems	Readiness of emergency power is a key consideration in safeguarding building occupants in the event of a disruption of the normal utility supply. NFPA 111 covers performance requirements for stored electric energy systems providing an alternate source of electrical power in buildings and facilities during interruption of the normal power source. Requirements in NFPA 111 address: • Power sources • Transfer equipment • Controls • Supervisory equipment • Accessory equipment that are needed to supply electrical power to selected circuits • Installation, maintenance, operation, and testing requirements as they pertain to the performance of the stored emergency power supply system (SEPSS).	The degree to which ESS deployment is to be pursued on the basis of being an emergency power source this standard would apply. Beyond that, the standard could provide additional guidance in addressing ESS safety even if not being used as a power source during utility service disruptions.
NFPA 791-2014 Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation	NFPA 791 covers recommended procedures for evaluating unlabeled electrical equipment for compliance with nationally recognized standards. Criteria provide guidance to third-party field evaluation bodies (FEBs) on how to perform evaluations of unlabeled electrical equipment in a consistent and reliable manner, thus assisting regulating authorities who make product and related installation approval decisions and facilitating acceptance of the results. Specific areas covered include pre-site preparation, construction inspection, electrical testing, and reporting, and documentation.	See discussion under Section 6.2. This standard should be reviewed to determine any revisions needed to facilitate its use with ESS so it can be used as a basis for determining and documenting the safety of an ESS that may not have been tested and listed to an ESS safety standard, assuming one applicable to ESS is available.

Standard	Scope Summary	Comments
PGMA Safety Standard for Portable Generators (under development)	Scope – Clear definition of what is/is not covered by the standard (e.g., power, voltage, other criteria). Includes criteria for the following: • Guarding of moving parts (i.e., mechanical hazards) • Enclosing "live" parts (electrical shock hazard) • Sharp edges • Corrosion resistance • Endurance (after a defined period of operation, ensure that product still conforms to standard) • Environmental tests (e.g., temperature, humidity, rain, etc.) • Mechanical strength (e.g., drop test or impact test) • Grounding and bonding • Spacings (typically, creepage and clearance distances) • Abnormal operation (operation outside the scope of specifications (e.g., high/low voltage or overload) – Product does not need to operate properly but must not create a hazard • Temperature test – Product operated and temperatures taken at various points for safety to personnel (accessible points) and within limits for insulation use • Electrical strength (dielectric test) • Labeling requirements • Operator manual requirements	While not applicable to ESS, this document provides a listing of system related issues that would possibly be relevant to ESS and any standards covering ESS (at least of the size and intended use similar to that of a portable generator).
UL 924 Emergency Lighting and Power Equipment	1 Scope 1.1 This Standard applies to emergency lighting and power equipment for use in unclassified locations and intended for connection to branch circuits 600 V or less. Intended to supply illumination, power or both automatically to critical areas and equipment in the event of failure of normal supply in accordance with NEC Article 700 or 701, NFPA 70, Life Safety Code, NFPA 101, Fire Code, NFPA 1, International Building Code (IBC) and International Fire Code (IFC). 1.2 Examples of equipment from 1.1 include Exit Signs, Emergency Luminaires, Unit Equipment, Central Station Battery Banks, Inverters, Automatic Battery Charging and Control Equipment, Automatic Load Control Relays and Derangement Signal Equipment.	The scope of the standard appears to include ESS used to supply these loads and should be reviewed to determine if revisions may be needed and how they can be pursued.

Standard	Scope Summary	Comments
	1.3 This Standard also applies to auxiliary lighting and power equipment for use in unclassified locations. Auxiliary equipment has not been investigated to determine compliance with the performance requirements of Article 700 or 701 of the NEC, NFPA 70, the Life Safety Code, NFPA 101, or the IBC. Such equipment includes luminaires with an integral battery backup power supply, illuminated directional signs, battery assemblies, and related devices. 1.4 This Standard does not include requirements for equipment covered by other Standards, such as Luminaires, UL 1598; Uninterruptible Power Systems, UL 1778; Luminous Egress Path Marking Systems, UL 1994; Transfer Switch Equipment, UL 1008; Electric Signs, UL 48	
UL 1741 Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources	1.1 These requirements cover inverters, converters, charge controllers, and interconnection system equipment (ISE) intended for use in stand-alone (not grid-connected) or utility-interactive (grid-connected) power systems. Utility-interactive inverters, converters, and ISE are intended to be operated in parallel with an electric power system (EPS) to supply power to common loads. 1.2 For utility-interactive equipment, these requirements are intended to supplement and be used in conjunction with the Standard for Interconnecting Distributed Resources With Electric Power Systems, IEEE 1547, and the Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems, IEEE 1547.1. 1.3 These requirements cover AC modules that combine flat-plate PV modules and inverters to provide AC output power for stand-alone use or utility-interaction, and power systems that combine other alternative energy sources with inverters, converters, charge controllers and ISE in system-specific combinations. 1.4 These requirements also cover power systems that combine independent power sources with inverters, converters, charge controllers, and interconnection system equipment (ISE) in system specific combinations. 1.5 The products covered by these requirements are intended to be installed in accordance with the NEC, NFPA 70.	The scope of the standard might be interpreted to include ESS used to supply these loads and should be reviewed to determine if revisions may be needed and how they can be pursued.

Standard	Scope Summary	Comments
UL 1778 Uninterruptable Power Sources	1.1 Scope Replace this clause of the RD with the following: 1.1.1 Equipment covered by this standard This Standard applies to UPS, whose primary function for this Standard is to ensure continuity of an alternating power source. The UPS may also serve to improve the quality of the power source by keeping it within specified characteristics. This Standard is applicable to movable, stationary, fixed, and built-in UPS for distribution systems up to 600 V AC. This equipment is designed to be installed in accordance with the Canadian Electrical Code, Part I, Canadian Standards Association (CSA) C22.1, or the National Electrical Code, ANSI/NFPA 70, and, unless otherwise identified, the Standard for the Protection of Electronic Computer Data-Processing Equipment, ANSI/NFPA 75. This Standard specifies requirements intended to ensure safety for the OPERATOR and where specifically stated for SERVICE PERSONNEL. This Standard is intended to reduce the risk of fire, electric shock, or injury to persons from installed equipment, both as a single unit or as a system of interconnected units, subject to installing, operating, and maintaining equipment in the manner prescribed by the manufacturer. 1.1.2 Additional requirements In addition to the requirements in this Standard, a UPS is to comply with the UPS-relevant requirements of Information Technology Equipment Safety - Part 1: General Requirements, CAN/CSA-C22.2 No. 60950-1/ UL 60950-1, first edition, (RD), as applicable for the country where the product will be used. Wherever there is a conflict between requirements of this document and the RD, requirements of this Standard will prevail. Engine-driven DC power generators intended to provide backup power for the battery supply circuit of UPS units are investigated for compliance with the requirements of the Standard for Stationary Engine-Generator Assemblies, UL 2200, and the CSA Standard for Motors and Generators, C22.2 No. 100.UPS that employ hospital grade components	The scope of the standard might be interpreted to include ESS used to supply these loads and should be reviewed to determine if revisions may be needed and how they can be pursued.

Standard	Scope Summary	Comments
	identified by the markings “Hospital Only,” “Hospital Grade,” or a green dot on the body of the component, or otherwise implying suitability for medical use are evaluated to the requirements of this Standard and Medical Electrical Equipment, Part 1: General Requirements for Safety, CAN/CSA-C22.2 No. 601.1/UL 60601-1. 1.1.3 Exclusions These requirements do not cover UPS units for use as emergency systems or as legally required standby systems, described in Articles 700 and 701, respectively, of the National Electrical Code, ANSI/NFPA 70, and Section 46 of the Canadian Electrical Code, Part I, CSA C22.1.Where considered appropriate, revision of requirements will be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this Standard. NOTE 1: For equipment subject to transient overvoltages exceeding those for Category II according to IEC 60664, additional protection might be necessary. Such additional protection may be located in the mains supply to the equipment or in the equipment as an integral design feature. NOTE 2: Where the additional protection is an integral part of the equipment insulation requirements, CREEPAGE DISTANCES and CLEARANCE distances from the mains through to the load side of the additional protection may be judged as Category III or IV as required. All insulation requirements, CREEPAGE DISTANCES, and CLEARANCE distances on the load side of the additional protection may be judged as Category I or II as required. This Standard does not cover all types of UPS but may be a guide for such equipment. Requirements additional to those specified in this Standard are in some cases necessary for specific applications; e.g., equipment intended for operation exposed to extremes of temperature; excessive dust, moisture or vibration; flammable gases; corrosive or explosive atmospheres; and UPS equipment based on rotary machinery.	
UL 2021 Fixed and Location-Dedicated Electric Room Heaters	1.1 These requirements cover fixed and location-dedicated electric room heating equipment rated 600 V or less to be employed in ordinary locations in accordance with the NEC, ANSI/NFPA 70.	If the ESS employs fixed space heaters for thermal control, this standard may be applicable to cover that component of the ESS. Also may

Standard	Scope Summary	Comments
	1.2 These requirements do not cover movable heaters, wall- or ceiling-hung heaters, baseboard heaters, duct heaters, central-heating furnaces, fan-coil units, panel- or cable-type radiant-heating equipment, electric boilers, or any other electric heating equipment or appliances covered in or as a part of separate, individual requirements.	be relevant to thermal storage systems.
UL 6141 Wind Turbine Converters and Interconnection Systems Equipment	1 Scope 1.1 These requirements cover Wind Turbine Converter (WTC) products and assemblies. Some of the features and functions of these products include but are not limited to, generation of real and reactive power in parallel with the electric power system, EPS (electric utility grid), supplying power in a standalone operational mode, multiple mode operation, and bidirectional power flow operation with the EPS. 1.2 These requirements address WTC products and assemblies intended for installation in accordance with their ratings, installation instructions, the NEC, ANSI/NFPA 70, and applicable utility and model building codes. 1.3 These requirements also address wind turbine utility interconnection systems equipment (WTUISE) that performs utility interconnection protection functions for paralleling wind turbines with the EPS.	While not directly applicable to an ESS this standard could provide some guidance for standards for an ESS as well as its interconnection to the grid and to wind turbines.
UL 6142 Small Wind Turbines	1 Scope 1.1 These requirements cover small wind turbine systems (WT) and electrical subassemblies. With respect to this standard, small WT are considered to be wind turbines where a user or service person cannot or is not intended to enter the turbine to operate it or perform maintenance. These units are intended for use in stand-alone (not grid-connected) or utility interactive applications. Utility-interactive, grid-tied WT are operated in parallel with an electric power system (EPS) to supply power to common loads. 1.2 The WT power, control and protection systems are evaluated only to the extent that they function within the manufacturer’s specified limits and response times. These control and protection functions are evaluated with respect to risk of electric shock and fire. It is intended that the electrical subassemblies that address power transfer control and protection functions evaluated per this document are to be coordinated	While not directly applicable to an ESS this standard could provide some guidance for standards for an ESS as well as its interconnection to the grid and to wind turbines.

Standard	Scope Summary	Comments
	with the mechanical and structural limitations specified in AWEA 9.1, Small Wind Turbine Performance and Safety Standard, the IEC 61400 series documents, or Germanischer Lloyd: Guideline for the Certification of Wind Turbines documents. 1.3 These requirements do not cover: a) WT generating systems intended for off-shore installation; b) WT generating systems intended for hazardous locations; c) Mechanical or structural integrity of the WT system or subassemblies; d) Verification that manufacturer-defined controls and protection limits maintain the WT system within its safe mechanical and structural limits; e) Mechanical loading of ladders, hoist supports, elevator mounting means, scaffolding, personnel tie offs, or other personnel load-bearing functional parts. 1.4 The wind turbine products covered by these requirements are intended to be installed according to the NEC, ANSI/NFPA 70. 1.5 The evaluation of products to this standard includes evaluation of all features and functions incorporated in or available for the turbine, or referred to in the documentation provided with the turbine, if these features or functions can affect compliance of the product with this standard. 1.6 Turbines where a user or service person is intended or required to enter the turbine to operate or perform maintenance on the turbine are considered to be large wind turbine systems and are covered in the Outline of Investigation for Wind Turbine Generating Systems, UL 6140. 1.7 These requirements cover WT rated 1500 Vac or less.	
UL 9540 Outline for Investigation for Safety for Energy Storage Systems and Equipment	These requirements cover ESS that are intended to store energy from power or other sources and provide electrical or other types of energy to loads or power conversion equipment. The ESS may include equipment for charging, discharging, control, protection, communication, controlling the system environment, fuel or other fluid movement and containment, etc. The system may contain other ancillary equipment related to the functioning of the energy storage system. These are intended for use in utility-interactive applications in compliance with	Applies to ESS and should be reviewed and finalized for use as a basis for testing and listing ESS.

Standard	Scope Summary	Comments
	IEEE 1547 and IEEE 1547.1 or other applications intended to provide grid support functionality. These systems may be stand-alone to provide energy for local loads, or in parallel with an EPS, electric utility grid or applications that perform multiple operational modes.	
UL 9741, Outline of Investigation for Bidirectional Electric Vehicle (EV) Charging System Equipment	These requirements cover bidirectional electric vehicle charging equipment that charge electric vehicles from an electric power system and also include functionality to export power from the electric vehicle to an electric power system. When commanded, the bidirectional charging equipment exports electric power from the electric vehicle stored energy supply to the electric power system (EPS) to supply power to common loads. For utility-interactive equipment, these requirements are intended to supplement and be used in conjunction with the Standard for Interconnecting Distributed Resources With EPS, IEEE 1547, and the Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems, IEEE 1547.1.	May be of interest if considering EV batteries to be used as an EES with grid interactive capabilities.

3.3 Codes, Standards and Regulations for the Installation of an ESS

Table 3.3 is a listing of CSR applicable to the installation of an ESS or which may provide some guidance in addressing the installation of an ESS due to their addressing similar technologies or issues likely to be relevant in assessing ESS safety. Included are any and all CSR that clearly apply, may apply or while not directly applicable to ESS may offer some insight or examples that could be applied in the future to ESS installations. The title and designation of the standard and summary of the scope are provided along with initial comments relating to further consideration of the standard in addressing ESS safety. Although the focus of this document is U.S. CSR, some international standards are included because they are covered in Section 4.0 on ESS approval experiences or were presented in presentations during the DOE Safety Workshop in February 2014 (Sandia and PNNL 2014; Appendix B).

The CSR in this section are relevant to the installation of an ESS “product” that has been approved as outlined in Section 3.2. They simply cover where and how that “product” interacts with its environment to ensure the surrounding environment is not adversely affected by an incident associated with the ESS and, in turn, that the ESS is not adversely affected by a natural or manmade incident associated with the surrounding environment. Where the ESS is not a “product” and has not been approved as covered in Section 3.2 and instead is an assembly of ESS components on site, then the provisions of Section 3.3 will have a greater impact on the ESS because they will address the acceptability of how those components are aggregated as an ESS on site. In other words, the CSR in Section 3.3 will assume much of what would be covered in Section 3.2 had the ESS been a completed “product” that arrived at the site compliant with standards applicable to the ESS “product.”

Table 3.3. Standards for ESS Installation

Standard	Scope Summary	Comments
AS 2676-1983 Installation and Maintenance of Batteries in Buildings	The standard sets out the requirements for the installation and maintenance in buildings of stationary batteries having a stored capacity exceeding 1 kWh, or a floating voltage of 115 V but not exceeding 650 V. Applies to both battery rooms and battery cabinets. Safety requirements are included particularly in relation to the ventilation requirements to ensure an explosive atmosphere does not arise. Commissioning, inspection and maintenance of stationary batteries are also covered.	Should be reviewed for applicability to ESS and then revisions considered as deemed appropriate. An Australian standard that could provide guidance for development of U.S. or international standards.
AS/NZS 3000-2007 Electrical Installations	The standard sets out requirements for the design, construction and verification of electrical installations, including the selection and installation of electrical equipment forming part of such electrical installations. These requirements are intended to protect persons, livestock, and property from electric shock, fire and physical injury hazards that may arise from an electrical installation that is used with reasonable care and with due regard to the intended purpose of the electrical installation. In addition, guidance is provided so that the electrical installation will function correctly for the purpose intended.	Should be reviewed for applicability to ESS and then revisions considered as deemed appropriate. An Australian standard that would appear to parallel in scope the National Electrical Code (NFPA 70).
AS 3011.2-1992 Electrical installations - Secondary batteries installed in buildings - Sealed cells	Specifies requirements for the installation of sealed secondary batteries permanently installed in buildings.	Should be reviewed for applicability to ESS and then revisions considered as deemed appropriate. An Australian standard that could provide guidance for development of U.S. or international standards.
AS 4777.1-2005 Grid connection of energy systems via inverters	This Standard specifies the electrical installation requirements for inverter energy systems and grid protection devices with ratings up to 10 kVA for single-phase units, or up to 30 kVA for three-phase units, for the injection of electric power through an electrical installation to the electricity distribution network. NOTES: 1 Although this Standard does not apply to larger systems, similar principles can be used for the installation of such systems. 2 This Standard does not cover detailed installation requirements for the energy source(s) and its associated wiring.	Should be reviewed for applicability to ESS and then revisions considered as deemed appropriate. An Australian standard that could provide guidance for development of U.S. or international standards.

Standard	Scope Summary	Comments
EN 61000-6 Electromagnetic Compatibility (EMC)	There are various sub standards (6-1, 6.-2, etc.) that apply to EMC. Information from IEC 61000-6-1 covers EMC immunity requirements for electrical and electronic apparatus intended for use in residential, commercial and light-industrial environments. Immunity requirements in the frequency range 0 Hz to 400 GHz are covered. No tests need to be performed at frequencies where no requirements are specified. This generic EMC immunity standard is applicable if no relevant dedicated product or product-family EMC immunity standard exists. This standard applies to apparatus intended to be directly connected to a low-voltage public mains network or connected to a dedicated DC source which is intended to interface between the apparatus and the low-voltage public mains network. This standard also applies to apparatus which is battery operated or is powered by a non-public, but non-industrial, low voltage power distribution system if this apparatus is intended to be used in the locations described below. The environments encompassed by this standard are residential, commercial and light industrial locations, both indoor and outdoor. Though not comprehensive, the following list gives an indication of locations included: – residential properties, e.g., houses, apartments; – retail outlets, e.g., shops, supermarkets; – business premises, e.g., offices, banks; – areas of public entertainment, e.g., cinemas, public bars, dance halls; – outdoor locations, e.g., gas stations, amusement and car parks, sports centers; – light-industrial locations, e.g., workshops, laboratories, service centers. Locations characterized by being supplied directly at low voltage from the public mains network are considered to be residential, commercial or light-industrial. The object of this standard is to define the immunity test requirements for apparatus specified in the scope in relation to continuous and transient, conducted and radiated disturbances including electrostatic discharges. The immunity requirements have been selected to ensure an adequate level of immunity for apparatus at residential, commercial and light-industrial locations. The levels do not, however,	To the degree that EMC associated with ESS could be an issue, these standards should be reviewed for possible application to ESS and revised if warranted.

Standard	Scope Summary	Comments
	cover extreme cases, which may occur at any location but with a very low probability of occurrence. Not all disturbance phenomena have been included for testing purposes in this standard; only those considered as relevant for the equipment covered. These test requirements represent essential electromagnetic compatibility immunity requirements.	
EPA Emergency Planning and Community Right-to-Know Act (EPCRA)	The Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986 was created to help communities plan for emergencies involving hazardous substances. EPCRA requires hazardous chemical emergency planning by federal, state and local governments, Indian tribes, and industry. It also requires industry to report on the storage, use and releases of hazardous chemicals to federal, state, and local governments.	The Act should be reviewed to confirm (or not) its applicability to ESS installations. If applicable, then guidelines for ESS manufacturers and users would be helpful and relevant in ensuring compliance with the Act.
TITLE 47 USC TELECOMMUNICATION CHAPTER I--FEDERAL COMMUNICATIONS COMMISSION PART 15_RADIO FREQUENCY DEVICES Subpart B Unintentional Radiators Sec. 15.109 Radiated emission limits.	Sets radiated emissions limits.	May need to be reviewed for applicability to ESS and, if found to apply, revised if warranted and then satisfied by ESS. This is not a voluntary sector standard but a regulation. As noted previously, the focus of this document is currently standards and model codes. Future work will have to address the adoption and application of those standards and model codes as well as specific regulations that may apply to ESS but are not derived from standards and model codes.
FM Global Property Loss Prevention Data Sheet 5-10 Protective Grounding for Electric Power Systems and Equipment, January 2011	The document describes the various methods used for grounding electrical systems and the non-current carrying metal parts of electrical wiring systems and equipment and also discusses the advantages and disadvantages of the different grounding methods, and the means employed to safeguard property from arc damage and fire.	
FM Global Property Loss Prevention Data Sheet 5-1 Lightening and Surge Protection for Electrical Systems, April 2012	The document describes modern procedures and practices for protecting industrial power distribution systems and associated equipment from damage caused by overvoltages due to lightning, switching, or a system abnormality.	

Standard	Scope Summary	Comments
FM Global Property Loss Prevention Data Sheet 5-19 Switchgear and Circuit Breakers, January 2006	The document describes switchgear as a general term covering switching, interrupting, control, metering, protective, and regulating devices and assemblies of these devices with their associated interconnections, accessories, and supporting structures and provides for the basic operation, protection, inspection, maintenance, and testing of various types of switchgear used in applications of at least 600V.	
FM Global Property Loss Prevention Data Sheet 5-23 Emergency and Standby Power Systems, October 2012	The document describes describe the types, operation, and protection of emergency and standby power systems, and provides guidelines for their application. Recommendations are included for the arrangement and protection of fuel supplies feeding emergency and standby power systems.	
IAPMO Uniform Mechanical Code (UMC)	The UMC established minimum requirements and standards for the protection of the public health, safety and welfare. 101.3 Scope. The provisions of this code shall apply to the addition to or erection, installation, alteration, repair, relocation, replacement, use, or maintenance of heating, ventilating, cooling, refrigeration systems; incinerators; or other miscellaneous heat-producing appliances within this jurisdiction. The UMC addresses the design, construction, installation, quality of materials, location, operation, and maintenance or use of heating, ventilating, cooling, and refrigeration systems; heat-producing appliances, fuel-gas piping systems, and fuel-gas appliances to maintain the desired environmental conditions in a space.	Where an ESS is installed indoors provisions in the UMC related to ventilation and exhaust and separation of the room where the ESS is located from other portions of the building could apply and should be reviewed.
IAPMO Uniform Plumbing Code (UPC)	The UPC establishes minimum requirements and standards for the protection of the public health, safety and welfare. 101.2 Scope. The provisions of this code shall apply to the erection, installation, alteration, repair, relocation, replacement, addition to, use, or maintenance of plumbing systems within this jurisdiction. The UPC covers potable water, building supply, and distribution pipes; all plumbing fixtures and traps; all drainage and vent pipes; and all building drains, and building sewers, including their respective joints and connections, devices, receptors, and appurtenances within the property lines of the premises and shall include potable water piping, potable water treating or using equipment, medical gas and medical vacuum systems, liquid and fuel-gas piping, and water heaters and vents for same.	Where an ESS involves fluids and fluid piping the provisions of the UPC could apply to the piping, floor drains and based on the fluids conveyed how leaks and discharges are to be captured and removed.

Standard	Scope Summary	Comments
IAPMO Uniform Solar and Hydronics Code	The USEHC established minimum requirements and standards for the protection of public health, safety and welfare for application to the erection, installation, alteration, repair, relocation, replacement, addition to, use or maintenance of solar energy systems, including but not limited to equipment and appliances intended to utilize solar energy for space heating or cooling; water heating; swimming pool heating or process heating; and solar PV systems. The code includes systems where equipment and components collect, convey, store and convert the sun's energy for a purpose, including but not limited to service water, pool water and space heating and cooling as well as electrical service.	A review is suggested to determine if any provisions in the code could be applicable to ESS installed in conjunction with renewable systems.
IEC 62935 Planning and Installation of Electrical Energy Storage Systems	This work item proposal deals with the planning and installation of EES systems and should be elaborated in close cooperation with unit parameter and testing aspects. The intention is to give guidance for planning and installation of EES systems and to provide standards and other deliverables which can be used by power system planers, system integrators and commissioning staff. This activity was initiated by IEC TC 120 under PNW 120-33. The rationale for the proposed activity in this areas was that the introduction of the ESS as components of the grid (utility grid, commercial or industrial grid, residential grid) may require implementing safety measures regarding the urbanization levels of areas in which they are installed. The potential risks for these systems must be studied in relation to the technologies used and their locations. The scope of this NWIP is to prepare normative documents on safety dealing with main risks related to the couples of use cases and associated technologies, technical contents and results to be included in the safety report and auditing framework, list of main features to be validated by testing, scale at which the storage system must be tested, recommendations to prevent or mitigate accidental effect.	This is a new work item that provides an opportunity to address ESS installations including among others safety considerations associated with those installations.
IEC New Work Item Proposal (NWIP) 21/823/NP – Flow Battery Technologies – Safety	This activity is in the working stage to become an IEC standard and will complement the existing CWA: Flow batteries - Guidance on the specification, installation and operation.	
ICES-003 Issue 5 August 2012	1. Scope – This Interference-Causing Equipment Standard–003 (ICES-003) sets out the technical requirements relative to radio noise generated by Information Technology Equipment (ITE).	Canadian requirements that may not be relevant to ESS but the issue of EMC has been suggested as possibly

Standard	Scope Summary	Comments
Spectrum Management and Telecommunications Interference-Causing Equipment Standard	2. Purpose and Applications – 2.1 ITE is defined as devices or systems that use digital techniques for purposes such as data processing and computation. ITE is any unintentional radiator (device or system) that generates and/or uses timing signals or pulses having a rate of at least 9 kHz and employs digital techniques for purposes such as computation, display, data processing and storage, and control. ITE is designated Category II Equipment, meaning that a Technical Acceptability Certificate (TAC) or equipment certification is not required. ITE that is subject to ICES-003 is approved through Self-Declaration of Compliance (SDoC) by the manufacturer, importer or distributor of ITE, which will ensure compliance with all technical requirements prescribed by ICES-003 and the results compiled into a test report. That report shall clearly state which test method was used to determine compliance. The methods of measurement are set out in the standards incorporated by reference in ICES-003 specified in section 3.	affecting ESS or other systems connected to ESS and is being included here for consideration.
IEEE 519-1992 Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems	The guide applies to all types of static power converters used in industrial and commercial power systems. The problems involved in the harmonic control and reactive power compensation of such converters are addressed, and an application guide is provided. Limits of disturbances to the AC power distribution system that affect other equipment and communications are recommended.	Should be reviewed for relevance to ESS.
IEEE 1145-1999 Recommended Practice for Installation and Maintenance of Nickel-Cadmium Batteries for Photovoltaic (PV) Systems	The document provides safety precautions, installation design considerations, and procedures for receiving, storing, commissioning, and maintaining pocket- and fiber-plate nickel-cadmium storage batteries for PV power systems. Disposal and recycling recommendations are also discussed. This recommended practice applies to all PV power systems, regardless of size or application that contain nickel-cadmium battery storage subsystems.	Note applicability to commissioning and O&M.
IEEE 1187-2013 Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Batteries for Stationary Applications	The document provides guidance for the installation and installation design of VRLA batteries. This recommended practice is intended for all standby stationary installations. However, specific applications, such as emergency lighting units and semi-portable equipment, may have other appropriate practices and are beyond the scope of this recommended practice. Alternative energy applications are not covered.	

Standard	Scope Summary	Comments
IEEE P2030.2.1 Working Group (WG), Guide for Design, Operation, Maintenance of Battery Energy Storage Systems, both Stationary and Mobile, and Applications Integrated with Electric Power Systems (SASB/SCC21/WGBESS)	The document provides alternative approaches and practices for design, operation, maintenance, integration and interoperability, including distributed resources interconnection, of stationary or mobile battery energy storage systems (BESS) with the EPS at customer facilities, electricity distribution facilities or bulk transmission electricity facilities. This document addresses BESS and applications conformance to the IEEE 1547 series requirements for distributed resources interconnection, implementing IEEE 2030 smart grid interoperability reference model (SGIRM) guidance, and builds upon the IEEE 1547, IEEE 2030, and relevant IEEE PV standards and IEEE standards for batteries. This standard is intended to be used by BESS designers, operators, system integrators, and equipment manufacturers. It provides an introduction of engineering concerns of BESS, identifies key technical parameters, engineering approaches and application practices requirements of BESS, and its operation and maintenance (O&M). It addresses not only electric power concerns but also the directly related communications and information technology concerns for BESS and applications integrated with EPSes. Implementation of this guide will assist in the standardization of BESS applications.	
ICC International Building Code (IBC)	The provisions of this code shall apply to the construction, alteration, relocation, enlargement, replacement, repair, equipment, use and occupancy, location, maintenance, removal and demolition of every building or structure or any appurtenances connected or attached to such buildings or structures. Exception: Detached one- and two-family dwellings and multiple single-family dwellings (townhouses) not more than three stories above grade plane in height with a separate means of egress and their accessory structures shall comply with the International Residential Code.	The IBC should be reviewed as it relates to the installation in, on or around buildings and safety issues addressed in the code, including but not limited to chemical storage, designation of ESS related areas as hazardous, limitations on ESS locations, fire separation, egress, fire suppression and smoke control.
ICC International Fire Code (IFC)	This code establishes regulations affecting or relating to structures, processes, premises and safeguards regarding: 1. The hazard of fire and explosion arising from the storage, handling or use of structures, materials or devices; 2. Conditions hazardous to life, property or public welfare in the occupancy of structures or premises;	The IFC should be reviewed as it relates to the installation in, on or around buildings and safety issues addressed in the code including but not limited to fire department and first responder access, egress, fire suppression and smoke control.

Standard	Scope Summary	Comments
	3. Fire hazards in the structure or on the premises from occupancy or operation; 4. Matters related to the construction, extension, repair, alteration or removal of fire suppression or alarm systems; and 5. Conditions affecting the safety of fire fighters and emergency responders during emergency operations.	
ICC International Mechanical Code (IMC)	The IMC regulates the design, installation, maintenance, *alteration* and inspection of mechanical systems that are permanently installed and utilized to provide control of environmental conditions and related processes within buildings. It also regulates those mechanical systems, system components, *equipment* and appliances specifically addressed herein. The installation of fuel-gas distribution piping and *equipment*, fuel gas-fired appliances and fuel gas-fired *appliance* venting systems shall be regulated by the *International Fuel Gas Code*. Exception: Detached one- and two-family dwellings and multiple single-family dwellings (townhouses) not more than three stories high with separate means of egress and their accessory structures shall comply with the *International Residential Code*.	Where an ESS is installed indoors provisions in the IMC related to ventilation and exhaust and separation of the room where the ESS is located from other portions of the building could apply and should be reviewed.
ICC International Plumbing Code (IPC)	The IPC applies to the erection, installation, alteration, repairs, relocation, replacement, addition to, use or maintenance of plumbing systems within this jurisdiction. This code shall also regulate nonflammable medical gas, inhalation anesthetic, vacuum piping, nonmedical oxygen systems and sanitary and condensate vacuum collection systems. The installation of fuel-gas distribution piping and equipment, fuel-gas-fired water heaters and water heater venting systems shall be regulated by the *International Fuel Gas Code*. Exception: Detached one- and two-family dwellings and multiple single-family dwellings (townhouses) not more than three stories high with separate means of egress and their accessory structures shall comply with the *International Residential Code*.	Where an ESS involves fluids and fluid piping the provisions of the IPC could apply to the piping, floor drains and based on the fluids conveyed how leaks and discharges are to be captured and removed.
ICC International Wildland Urban-Interface Code	The provisions of the IWUCl apply to the construction, alteration, movement, repair, maintenance and use of any building, structure or premises within the *wildland urban-interface areas* in this jurisdiction.	Where an ESS is to be installed in an area that is subject to wildfires, it may be appropriate to consider how such installations should be protected or

Standard	Scope Summary	Comments
	Buildings or conditions in existence at the time of the adoption of this code are allowed to have their use or occupancy continued, if such condition, use or occupancy was legal at the time of the adoption of this code, provided such continued use does not constitute a distinct danger to life or property. Buildings or structures moved into or within the jurisdiction shall comply with the provisions of this code for new buildings or structures.	located to minimize damage to them from wild fires.
IEEE 80 Guide for Safety in AC Substation Grounding	The guide covers outdoor ac substations, either conventional or gas-insulated. Distribution, transmission, and generating plant substations are also included. With proper caution, the methods described herein are also applicable to indoor portions of such substations, or to sub-stations that are wholly indoors. No attempt is made to cover the grounding problems peculiar to DC substations. A quantitative analysis of the effects of lightning surges is also beyond the scope of this guide.	While not applicable directly to an ESS the document might be applicable if an ESS were a component of a substation and in that case might benefit from a review for possibly addressing ESS in the future. This guide could serve to develop ESS grounding, although if such a decision were made and considering other similar situations such as IEEE 979 on fire protection, instead of separate issue-focused standards, it would be appropriate to consider a singular standard for ESS installations (grounding) and other relevant issues such as fire protection.
IEEE 100 The Authoritative Dictionary of IEEE Standards Terms Seventh Edition		While not just applicable to ESS installations but also components and entire systems, a review of this document should be undertaken to determine any needed revisions or additions to address ESS technology.
IEEE 693 Recommended Practice for Seismic Design of Substations	The document provides seismic design recommendations for substations, including qualification of each equipment type. Design recommendations consist of seismic criteria, qualification methods and levels, structural capacities, performance requirements for equipment operation, installation methods, and documentation.	Note this would apply to systems as well as installations but while not applicable to ESS it could apply to situations where the ESS is a component of a substation. See

Standard	Scope Summary	Comments
		additional discussion under IEEE 80, 100 and 979 regarding applicability of substation standards to an ESS or use of these standards to craft a standard covering all issues, such as seismic, for ESS.
IEEE 937 Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for PV Systems	The standard covers design considerations and procedures for storage, location, mounting, ventilation, assembly, and maintenance of lead-acid secondary batteries for PV power systems are provided. Safety precautions and instrumentation considerations are also included. Even though general recommended practices are covered, battery manufacturers may provide specific instructions for battery installation and maintenance.	
IEEE 979 Guide for Substation Fire Protection	The original guide (1994) was developed to identify substation fire protection practices that generally have been accepted by industry. The new edition includes changes in industry practices for substation fire protection. New clauses on fire hazard assessment and pre-fire planning have been added. The purpose of the original guide (1994) was to give design guidance, fire hazard assessment, and pre-fire planning in the area of fire protection to substation engineers. Existing fire protection standards, guides, and so on that may aid in the design of specific substations or substation components are listed in Annex F. the new edition revision updates that guidance.	While not applicable directly to an ESS the document might be applicable if an ESS were a component of a substation and in that case might benefit from a review for possibly addressing ESS in the future. This guide might serve as a model for the development of a similar guide for ESS fire protection.
IEEE 1184 Guide for Batteries for Uninterruptible Power Supply Systems	The guide discusses various battery systems so that the user can make informed decisions on selection, installation design, installation, maintenance, and testing of stationary standby batteries used in UPS systems.	This guide divides the available technologies into the following three main categories: VLA, VRLA and NiCd batteries.
IEEE/ASHRAE 1635-2012 Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications	The document discusses VLA, VRLA, and NiCd stationary battery installations and is intended to serve as a bridge between the electrical designer and the heating, ventilation, and air-conditioning (HVAC) designer. Ventilation of stationary battery installations is critical to maximize battery life while minimizing the hazards associated with hydrogen production. This guide describes battery operating modes and the hazards associated with each. It provides the HVAC designer with the information to provide a cost-effective ventilation solution.	The document should be reviewed for its applicability to all possible ESS and where criteria are found in need of revision or development research and analysis should be undertaken as warranted to support revisions. Note that the identification and conduct of research and analysis to support

Standard	Scope Summary	Comments
		changing existing standards or development of new criteria for existing or new standards apply to every possible standards development response to address deployment of safe ESS.
IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems	The standard establishes criteria and requirements for interconnection of distributed resources (DR) with electric power systems (EPS). It provides a uniform standard for interconnection of distributed resources with electric power systems. It also provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. The U.S. Federal Energy Policy Act of 2005 calls for state commissions to consider certain standards for electric utilities. Under Section 1254 of the Act: "Interconnection services shall be offered based upon the standards developed by the Institute of Electrical and Electronics Engineers: IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems, as they may be amended from time to time." IEEE 1547 was first published in 2003, reaffirmed in 2008, and Amendment 1 published in 2014 as an outgrowth of the IEEE-hosted SCC21 May 2012 Workshop. More than 80 industry participants collaborated in the IEEE-hosted SCC21 December 2013 workshop, and recommended a revised title, scope, and purpose to launch an IEEE SCC21 project and working group to complete a full revision of the IEEE 1547 standard before 2018, but preferably sooner.	Would apply to ESS that are interconnected with EPS and as a result may need to be reviewed to determine if any changes are needed to more appropriately address interconnection with ESS.
IEEE C2-2012 - 2012 National Electrical Safety Code (NESC)	This Code covers basic provisions for safeguarding of persons from hazards arising from the installation, operation, or maintenance of conductors and equipment in electric supply stations and 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. The standard is applicable to the systems and equipment operated by utilities, or similar systems and equipment, of an industrial establishment or complex under	As with the NEC (NFPA 70) below this document should be reviewed to identify any areas where it should be revised to address ESS safety. That may also include a reference to standards applicable to ESS components or entire ESS. Note the NESC also addresses operation and

Standard	Scope Summary	Comments
	the control of qualified persons. This standard consists of the introduction, definitions, grounding rules, list of referenced and bibliographic documents, and Parts 1, 2, 3, and 4 of the 2012 Edition of the NESC.	maintenance, a topic covered in Section 3.4 below but for simplicity the NESC is included here.
NFPA 15-2012 Standard for Water Spray Fixed Systems for Fire Protection	The standard helps ensure effective fire control, extinguishment, prevention, or exposure protection through requirements for the design, installation, and system acceptance testing of water spray fixed systems for fire protection. It also contains requirements for the periodic testing and maintenance of ultra high-speed water spray fixed systems.	The standard should be reviewed for possible application to ESS. If not applicable or in need of revision, changes should be pursued. Based on further analysis and research, development of additional criteria for ESS fire protection may be warranted where application of this standard might be inappropriate based on ESS technology.
NFPA 70-2014 National Electrical Code (NEC)	Adopted in all 50 states, NEC is the benchmark for safe electrical design, installation and inspection to protect people and property from electrical hazards. The NEC addresses the installation of electrical conductors, equipment and raceways; signaling and communications conductors, equipment and raceways; and optical fiber cables and raceways in commercial, residential and industrial occupancies. Article 480 provides electrical installation requirements for all stationary installations of electrical storage batteries (photo). For batteries in PV systems, additional requirements of Art 690, Part VIII apply. But covering a battery system from square one to end of life requires far more knowledge than what is in Art 480 (see SIDEBAR: Beyond Article 480). 2014 NEC includes a subsection on battery and cell terminations.	A meeting was held on June 3, 2014 of interested parties to initiate work on possible changes to the NEC that are due November 7, 2014 (see Section 6.2 below.)
NFPA 70E-2012 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 Occupational Safety and Health Administration (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 400-2013 Hazardous Materials Code	NFPA 400 consolidates fundamental safeguards for the storage, use, and handling of hazardous materials in all occupancies and facilities. The Code does not apply to storage or use of hazardous materials for	This document would appear to apply to energy storage systems to the degree that those systems contained

Standard	Scope Summary	Comments
	individual use on the premises of one- and two-family dwellings. The Code's fire and life safety requirements are applicable to a wide range of substances including but not limited to ammonium nitrate solids and liquids, corrosive solids and liquids, flammable solids, organic peroxide formulations, oxidizers, pyrophoric solids and liquids, toxic and highly toxic solids and liquids, unstable (reactive) solids and liquids, water-reactive solids and liquids. Compressed gases and cryogenic fluids are included within the context of NFPA 55.	hazardous materials. As such, the document could limit where ESS are located in, on or around buildings and if so located how they are to be protected. A review of this document in that regard is advised and based on that review revisions to the document considered, research conducted in support of those revisions or ESS installations adjusted accordingly in conformance with the document.
NFPA 550-2012 Guide to the Fire Safety Concepts Tree	The guide describes the structure, application and limitations of the Fire Safety Concepts Tree, which provides an overall structure with which to analyze the potential impact of fire safety strategies. NFPA 550 examines the interrelation of fire safety features and their effect on achieving specific fire safety goals and objectives. It identifies tools to help fire safety practitioners communicate fire safety and protection concepts and can be used to assist with the analysis of codes or standards, facilitate the development of performance-based designs, provide an overall structure with which to analyze potential fire safety strategy impacts and identify gaps and redundancies in the strategies.	See Section 6.2, below.
NFPA 704-2012 Standard System for the Identification of the Hazards of Materials for Emergency Response	The standard provides criteria for assessing the health, flammability instability and related hazards presented by short-term, acute exposure to a material under conditions of fire, spill or similar emergencies. A number rating system of 0-4 is provided to rate each of the four hazards on a placard and provides emergency responders with information to determine immediate actions in an emergency. Tables in the standard provide criteria for the ratings and placard specifications such as letter size and arrangement of numbers and colors.	See Section 6.2, below.
NFPA 790-2012 Standard for Competency of Third-Party Field Evaluation Bodies	Installed electrical equipment that has not been previously certified, listed, recognized, or classified undergo a "field evaluation" to ensure compliance. The standard provides qualifications and competencies for third parties performing field evaluations and specifies how they are to be completed. Provisions cover FEB application for recognition; FEB organization; FEB personnel; appeals, complaints, and disputes;	The standard should be reviewed and considered for use in addressing the acceptability of third party agencies that may undertake a review of ESS installations for safety.

Standard	Scope Summary	Comments
	application for evaluation; preparation for evaluation; evaluation; evaluation report; decision to issue an FEB statement of conformity; use of FEB statement of conformity; and test and measuring equipment.	
NFPA 850-2010 Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage DC Converter Stations	The document outlines fire safety recommendations for gas, oil, coal, and alternative fuel electric generating plants, including high voltage DC converter stations and combustion turbine units used for electric generation. Fire prevention and fire protection recommendations advance the safety of construction and operating personnel, physical integrity of plant components, and the continuity of plant operations. Specific criteria provided include combustion turbines and internal combustion engines, alternative fuels, wind turbine generating facilities, solar thermal power generation, and geothermal power plants.	NFPA has formed a task group of NFPA 850, 851 and 853 to look into how to address ESS.
NFPA 851-2010 Recommended Practice for Fire Protection for Hydroelectric Generating Plants	The document provides fire prevention and fire protection recommendations for hydroelectric generating plants to safeguard personnel, protect physical property, ensure continuity of power production, and control the impact of fire and firefighting activities on the environment. NFPA 851 offers guidance for the design, construction, and operation of hydroelectric facilities. In addition, general plant design, fire protection systems, identification and protection of hazards, and development of a fire risk control program are also covered.	Should be reviewed for possible guidance in addressing fire protection of ESS installations.
NFPA 853-2010 Standard for the Installation of Stationary Fuel Cell Power Systems	The standard provides fire prevention and protection requirements for safeguarding life and physical property for buildings or facilities that employ stationary fuel cell systems of all sizes. Criteria cover design, construction and installation requirements, including general equipment configuration, siting and interconnections, fuel supplies and storage arrangements, ventilation, exhaust and fire protection. Specific provisions for fuel cell power systems 50 kW or less are also included.	See Section 6.4, below.
The NFPA Foundation (CSR related activity)	The NFPA Foundation is conducting a multi-phase research program to develop guidance for the protection of lithium-ion batteries in storage (it is not clear if this is applicable to those used in energy storage applications or simply the storage of those batteries while awaiting sale or distribution or both). The first two phases of this project, a hazard assessment and a large-scale flammability characterization, were completed in 2013. The latter program provided good information on the performance of cartoned small format batteries in storage and	Related to installation CSR, the following research announcement indicates there is interest in addressing ESS fire protection (conducting research may signal a void in CSR or need to update current CSR to address new technology).

Standard	Scope Summary	Comments
	indications are that a practical sprinkler protection solution, similar to that used for other common stored commodities will be effective. To confirm this finding, a third and final phase of the test program – a validation phase is required. This will consist of large-scale testing (between 8 and 24 pallet loads) to ensure that the sprinkler system proposed will be effective in controlling the fire hazard.	
IEC TC 120 PNW 120-31 Planning and Installation of Electrical Energy Storage Systems – Standard Technical Specification (proposed work item)	The intention of this activity is to give guidance for planning and installation of EES systems and to provide standards and other deliverables which can be used by power system planers, system integrators and commissioning staff.	
IEC 60529 Degrees of protection provided by enclosures	The standard applies to the classification of degrees of protection provided by enclosures for electrical equipment with a rated voltage not exceeding 72,5 kV. The object of the standard is to give a) Definitions for degrees of protection provided by enclosures of electrical equipment as regards: 1) protection of persons against access to hazardous parts inside the enclosure; 2) protection of the equipment inside the enclosure against ingress of solid foreign objects; 3) protection of the equipment inside the enclosure against harmful effects due to the ingress of water. b) Designations for these degrees of protection. c) Requirements for each designation. d) Tests to be performed to verify that the enclosure meets the requirements of this standard. It will remain the responsibility of individual technical committees to decide on the extent and manner in which, the classification is used in their standards and to define “enclosure” as it applies to their equipment. However, it is recommended that for a given classification the tests do not differ from those specified in this standard. If necessary, complementary requirements may be included in the relevant product	Appears relevant to ESS installations and should be reviewed and revised as warranted.

Standard	Scope Summary	Comments
	standard. A guide for the details to be specified in relevant product standards is given in annex B. For a particular type of equipment, a technical committee may specify different requirements provided that at least the same level of safety is ensured. This standard deals only with enclosures that are in all other respects suitable for their intended use as specified in the relevant product standard and which from the point of view of materials and workmanship ensure that the claimed degrees of protection are maintained under the normal conditions of use. This standard is also applicable to empty enclosures provided that the general test requirements are met and that the selected degree of protection is suitable for the type of equipment to be protected. Measures to protect both the enclosure and the equipment inside the enclosure against external influences or conditions such as mechanical impacts, corrosion, corrosive solvents (e.g., cutting liquids), fungus, vermin, solar radiation, icing, moisture (e.g., produced by condensation), explosive atmospheres and the protection against contact with hazardous moving parts external to the enclosure (such as fans), are matters for the relevant product standard to be protected.	
IEC 62485-1 Ed 1 Safety requirements for secondary batteries and battery installations – Part 1 General safety information		Should be reviewed for possible application to ESS and revised as warranted.
IEC 62485-2 Safety requirements for secondary batteries and battery installations. Part 2: Stationary batteries.	This part of the IEC 62485 applies to stationary secondary batteries and battery installations with a maximum voltage of DC 1 500 V (nominal) and describes the principal measures for protections against hazards generated from: electricity, gas emission, and electrolyte. This international standard provides requirements on safety aspects associated with the erection, use, inspection, maintenance and disposal.	Appears identical to IEC 50272-2
IEC 62485-3 Ed 1 Safety requirements for secondary batteries and battery installations – Part 3 traction	This part of IEC 62485 applies to secondary batteries and battery installations used for electric vehicles (e.g., in electric industrial trucks, including lift trucks, tow trucks, cleaning machines, automatic guided vehicles), battery powered locomotives, electric vehicles (e.g., goods	While not applicable to ESS, the standard may prove to be a resource in determining provisions needed to address ESS installation safety.

Standard	Scope Summary	Comments
batteries	vehicles, golf carts, bicycles, wheelchairs) and does not cover the design of such vehicles. The standard covers lead dioxide-lead (lead-acid), nickel oxide-cadmium, nickel-oxide-metal hydride and other alkaline secondary batteries. Safety aspects of secondary lithium batteries in such applications will be covered in their own appropriate standards. The nominal voltages are limited to 1 000 V AC and 1 500 V DC, respectively, and describe the principal measures for protection against hazards generally from electricity, gas emission and electrolyte. It provides requirements on safety aspects associated with the installation, use, inspection, maintenance and disposal of batteries.	
IEC 62485-4 Ed 1 Safety requirements for secondary batteries and battery installations – Part 4: VRLA batteries for use in portable appliances		While not applicable to ESS, the standard may prove to be a resource in determining provisions needed to address the safety of ESS installations.
IEC 61434:1996-10-03 Edition 1.0 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Guide to designation of current in alkaline secondary cell and battery standards	Applies to secondary cells and batteries containing alkaline or other non-acid electrolytes. It proposes a mathematically correct method of current designation which shall be used in future secondary cell and battery standards.	
IEC/TS 61438:1996-11-28 Edition 1.0 Possible safety and health hazards in the use of alkaline secondary cells and batteries – Guide to equipment manufacturers and users	The document outlines the fundamental conditions necessary for the creation of each hazard. It includes identification and characterization of the possible hazards inherent in the application, use, and abuse of nickel-cadmium cells and batteries. It also includes examples for appliance design which minimizes these hazards. Additionally it presents some typical but non-exhaustive examples of misuse that may precipitate or actions which mitigate the hazard.	
UL 96A, Installation Requirements for Lightning Protection Systems	The document is intended to assist code authorities, designers, and installers to develop, and install a complete lightning protection system that can withstand the tremendous power of a lightning strike. Depending on the type, a strike can exceed 300,000 Amperes, over one	Should be reviewed and considered as related to protection of ESS installations from the effects of lightning.

Standard	Scope Summary	Comments
	gigavolt (one billion volts) and with temperatures as high as 36,000 Deg. F., or about three times as hot as the surface of the sun. This guide does not include information on protection of equipment inside a building. The dissipation of a lightning strike requires correct system design, installation in accordance with UL 96A, NFPA 780 and all listed components correctly installed and connected to earth. And common bonded to the building electrical system in accordance with Article 230, 250, 280, 800 and 810, of the NEC. This installation guide covers definitions and installations used on virtually all types of structures designed and built today. The installation must be designed to protect the entire structure not just a small portion or section of the structure.	

3.4 Codes, Standards and Regulations for Commissioning, Operation or Maintenance of an ESS

Table 3.4 is a listing of CSR applicable to the commissioning, operation or maintenance of an ESS or which may provide some guidance in addressing the installation of an ESS due to their addressing similar technologies or issues likely to be relevant in assessing ESS safety. Included are any and all CSR that clearly apply, may apply or while not directly applicable to ESS may offer some insight or examples that could be applied in the future to ESS installations. The title and designation of the standard and summary of the scope are provided along with initial comments relating to further consideration of the standard in addressing ESS safety. Although the focus of this document is U.S. CSR, some international standards are included because they are covered in Section 4.0 on ESS approval experiences or were presented in presentations during the DOE Safety Workshop in February 2014 (Sandia and PNNL 2014; Appendix B).

Table 3.4. Standards for ESS Commissioning, Operation or Maintenance

Standard	Scope Summary	Comments
ANSI Z535 Safety Alerting Standards	ANSI Z535.1 sets forth the technical definitions, color standards, and color tolerances for the ANSI Z535 uniform safety color ANSI Z535.2 regulates requirements for the design, application, and use of safety signs in facilities and in the environment through consistent visual layout. Reorganized to best describe the five types of safety signs used in facilities, the 2011 edition of this standard is revised to better harmonize with ANSI Z535.4, ANSI Z535.5, and ANSI Z535.6 ANSI Z535.3 provides general criteria for the design, evaluation, and use of safety symbols to identify and warn against specific hazards and information to avoid personal injury ANSI Z535.4 delivers specifications for design, application, use, and placement of safety signs and labels on a wide variety of products. A new type of product safety sign, the “safety instruction sign,” was added to join the existing types of signs, hazard alerting signs, and safety notice signs, which were also more clearly defined and named in this edition. The definitions for “accident,” “harm,” and “incident” were refined to more clearly delineate a separation between physical injury and other safety-related issues (e.g., property damage). It was revised to correspond with ANSI Z535.2, ANSI Z535.5, and ANSI Z535.6 ANSI Z535.5 discusses tag and tapes, which are used only until the identified hazard is eliminated or the hazardous operation is completed. The Z535.5-2011 edition was revised to link with ANSI Z535.2, ANSI Z545.4, and ANSI Z535.6. The Safety Instructions Tag was in addition to existing types of signs, hazard alerting tags as well as safety notice tags and barricade tapes, which were more clearly defined and named in this edition. Industries (typically manufacturing and construction) that employ lockout/tagout procedures or have a need to mark an area affected by a temporary hazard will find this standard beneficial. ANSI Z535.6 provides updated information for manufacturers to promote efficient development of safety messages.	ESS installations will need signage and safety alert messaging and directions. Compliance with these standards, as applicable to ESS, should be considered. If there is something uniquely different about ESS when compared to other items covered by these standards then revision to one or more of the standards may be warranted to ensure anything uniquely needed to address ESS is covered and the standards can be referenced and applied to ESS to foster uniformity in safety altering messaging.

Standard	Scope Summary	Comments
Health Safety Executive (UK) HSG 85 Electricity at work: Safe working practices	The guidance covers the key elements to consider when devising safe working practices and is for people who carry out work on or near electrical equipment. It includes advice for managers and supervisors who control or influence the design, specification, selection, installation, commissioning, maintenance or operation of electrical equipment.	While not applicable in the United States, this measure should be reviewed to determine if it could be used as a basis for U.S. requirements where further work determines there is a need for additional requirements to protect worker safety.
ICC Standard 1000 Commissioning (draft)	The standard establishes minimum requirements for the application of the process of commissioning buildings and systems, and criteria for code officials (authority having jurisdiction [AHJ]), owners, and agencies to implement the commissioning requirements.	The effort intends to provide a complete set of requirements for current practices of the overall commissioning process described in relevant commissioning process standards, including procedures for commissioning process application and acceptance criteria for adoption by local jurisdictions to facilitate implementation and enforcement of commissioning provisions established in codes. Logically, if ESS are part of or associated with a building, this standard provides an opportunity to establish commissioning requirements for ESS.
IEC 61850 Communication networks and systems in substations	Applicable to substation automation systems: defines communication between intelligent electronic devices in substation and system requirements; provides overview of standard series; refers to text and figures from other parts of IEC 61850 series. IEC 61850-1 Communication networks and systems in substations - Part 1: Introduction and overview IEC 61850-2 Communication networks and systems in substations - Part 2: Glossary IEC 61850-3 Communication networks and systems in substations - Part 3: General requirements IEC 61850-4 Communication networks and systems in substations - Part 4: System and project management IEC 61850-5 Communication networks and systems in substations - Part 5: Communication requirements for functions and device models	Applies to substation automation systems. The degree to which an ESS could be connected to a substation and as such need to communicate with the substation or related system requirements should be evaluated. Based on that evaluation, a recommendation to apply the standard could be considered and, if so, any needed revisions identified.

Standard	Scope Summary	Comments
	IEC 61850-6 Communication networks and systems for power utility automation - Part 6: Configuration description language for communication in electrical substations related to IEDs IEC 61850-7 Communication networks and systems in substations - Basic communication structure for substation and feeder equipment IEC 61850-7-1: Principles and models IEC 61850-7-2: Abstract communication service interface (ACSI) IEC 61850-7-3: Common Data Classes IEC 61850-7-4: Compatible logical node classes, data classes IEC 61850-8 Communication networks and systems in substations - Specific Communication Service Mapping (SCSM) IEC 61850-8-1: Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3 IEC 61850-9 Communication networks and systems in substations - Specific Communication Service Mapping (SCSM) IEC 61850-9-1: Sampled values over serial unidirectional multidrop point to point link IEC 61850-9-2: Sampled values over ISO/IEC 8802-3 IEC 61850-10 Communication networks and systems in substations - Part 10: Conformance testing	
IEEE 450 Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid (VLA) Batteries for Stationary Applications	The document provides recommended maintenance, test schedules and procedures to optimize the life and performance of permanently installed VLA storage batteries for standby power applications. It provides guidance to determine when batteries should be replaced. This practice is applicable to full-float stationary applications where a charger maintains the battery and provides DC loads. However, specific applications such as emergency lighting units and semi-portable equipment may have other appropriate practices beyond the scope of this recommended practice.	Applies to VLA but could serve as a resource for standards addressing the same subject by for different ESS technologies.
IEEE 1106 Recommended Practice for Installation, Maintenance, Testing and Replacement of Vented NiCd Batteries for Stationary Applications	The document provides recommendations for installation design and for installation, maintenance, and testing procedures to optimize life and performance of vented NiCd batteries in stationary standby applications. Also provides guidance for determining when these batteries should be replaced.	Applies to Ni-Cad batteries but could serve as a resource for standards addressing the same subject by for different ESS technologies.

Standard	Scope Summary	Comments
IEEE 1188 Recommended Practice for Maintenance, Testing, and Replacement of VRLA Batteries for Stationary Applications	The recommended practice is limited to maintenance, test schedules, and testing procedures that can be used to optimize the life and performance of VRLA batteries for stationary applications. Also provides guidance to determine when batteries should be replaced. The maintenance and testing programs described represent "the best program" based on the information reviewed at the time this document was developed. Stationary cycling applications such as those found in alternative energy applications are beyond the scope of this recommended practice.	Applies to VRLA but could serve as a resource for standards addressing the same subject by for different ESS technologies.
IEEE 1578-2007 Recommended Practice for Stationary Battery Electrolyte Spill Containment and Management	The document covers descriptions of products, methods, and procedures relating to stationary batteries, battery electrolyte spill mechanisms, electrolyte containment and control methodologies, and firefighting considerations are provided.	Would be applicable to ESS and should be reviewed to determine if any changes are needed to address other ESS technologies that may not be currently addressed.
IEEE 1657 Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries	The document defines the areas of recommended knowledge for installers and maintainers of stationary batteries and related systems to the extent that they affect the battery. Design of the dc system and sizing of the dc battery charger(s) are beyond the scope of this recommended practice. This document covers lead-acid and nickel-cadmium battery technologies.	Would apply to LA and NC batteries and should be reviewed with the intent of revising it to include other relevant ESS technologies. As there are professional credentialing standards for many other technologies this may be something that will enhance the safety of ESS installations.
IEEE P2030.3 – Standard for Test Procedures for Electric Energy Storage Equipment and Systems for Electric Power Systems Applications (proposed)	Storage equipment and systems connected to an EPS need to meet requirements specified in related IEEE standards. Standardized test procedures are necessary to establish and verify requirement compliance. These test procedures need to provide repeatable results at independent test locations and have flexibility to accommodate the variety of storage technologies and applications. This standard establishes test procedures for electric energy storage equipment and systems for EPS applications. It is recognized that electric energy storage equipment or systems can be single devices providing all required functions or an assembly of components, each having limited functions, which in turn shall be tested for those functions in accordance with this standard. Conformance may be	See IEEE P2030.2.1 as this is the new designation for the IECC P2030.3 effort.

Standard	Scope Summary	Comments
	established through combination of type, production, and commissioning tests. Additionally, requirements on installation evaluation and periodic tests are included in this standard.	
NFPA 921-2014 Guide for Fire and Explosion Investigations	NFPA 921 sets the bar for scientific-based investigation and analysis of fire and explosion incidents. Referenced in the field, training, and court, it is the foremost guide for rendering accurate opinions as to incident origin, cause, responsibility and prevention and is intended for use by public sector employees responsible for fire investigation and private sector professionals who conduct investigations for insurance companies or litigation purposes. All aspects of fire and explosion investigation are covered from basic methodology to collecting evidence to failure analysis. Guidelines apply to all types of incidents from residential fires and motor vehicle fires to management of complex investigations such as high-rise fires and industrial plant explosions.	See section 6.2.
IEC/TR 62060:2001-09-27 Edition 1.0 Secondary cells and batteries - Monitoring of lead-acid stationary batteries – User guide	The document applies to lead-acid vented and valve regulated batteries, for use in stationary battery applications. The objectives of this technical report are to assist users in the selection of methods to obtain sufficient information to indicate the state of health of an operating stationary lead-acid battery; to achieve this by describing characteristics that can be electrically measured and remotely interrogated on a regular basis; to indicate the sensitivity and reliability of the measured data and to provide the user with methods of interpretation; and to provide users with good operating characteristics and general guidelines.	Applies to LA batteries but could serve as a resource for standards addressing the same subject by for different ESS technologies.

3.5 Codes, Standards and Regulations Relevant to Incident Response Associated with an ESS Installation

Table 3.5 is a listing of CSR applicable to the responding to a safety-related incident associated with an ESS or which may provide some guidance in addressing an ESS due to their addressing similar technologies or issues likely to be relevant in assessing ESS safety. Included are any and all CSR that clearly apply, may apply or while not directly applicable to ESS may offer some insight or examples that could be applied in the future to ESS installations. The title and designation of the standard and summary of the scope are provided along with initial comments relating to further consideration of the standard in addressing ESS safety. Although the focus of this document is U.S. CSR, some international standards are included because they are covered in Section 4.0 on ESS approval experiences or were presented in presentations during the DOE Safety Workshop in February 2014 (Sandia and PNNL 2014; Appendix B).

Table 3.5. Standards Relevant to Incident Response Associated with an ESS Installation

Standard	Scope Summary	Comments
NFPA 472 Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction (WMD) Incidents	The standard identifies the minimum levels of competence required by responders to emergencies involving hazardous materials/WMD. This standard applies to any individual or member of any organization who responds to hazardous materials/WMD incidents. This standard shall cover competencies for awareness level personnel, operations level responders, hazardous materials technicians, incident commanders, hazardous materials safety officers and other specialist employees. Outside the United States, hazardous materials might be called dangerous goods (see Annex H). WMD are known by many different abbreviations and acronyms, including chemical, biological, radiological, nuclear, explosive (CBRNE), biological, nuclear, incendiary, chemical, explosive (B-NICE), chemical, ordinance, biological, radiological agents (COBRA), and nuclear, biological, chemical (NBC).	While not specifically addressing ESS the standard may provide some guidance in development of similar criteria to cover ESS.
NFPA 921 Guide for Fire and Explosion Investigations	All aspects of fire and explosion investigation are covered from basic methodology to collecting evidence to failure analysis. Guidelines apply to all types of incidents from residential fires and motor vehicle fires to management of complex investigations such as high-rise fires and industrial plant explosions.	See Section 6.2.
NFPA 1001 Standard for Fire Fighter Professional Qualifications	The standard identifies the minimum job performance requirements (JPRs) for career and volunteer fire fighters whose duties are primarily structural in nature.	Consider review with respect to applicability to ESS and, if warranted, develop appropriate revisions.
NFPA 1500 Standard for Fire Department Occupational Safety	The standard contains minimum requirements for a fire service-related occupational safety and health program.	Consider review with respect to its applicability to ESS and, if warranted, develop appropriate revisions.
NFPA 1600 Standard on Disaster/Emergency Management and Business Continuity Programs	The standard establishes a common set of criteria for all hazards disaster/emergency management and business continuity programs, hereinafter referred to as “the program.” The emergency management and business continuity community comprises many different entities, including the government at distinct levels (e.g., federal, state/provincial, territorial, tribal, indigenous, and local levels); business and industry; nongovernmental organizations; and	Consider review with respect to its applicability to ESS and, if warranted, develop appropriate revisions.

Standard	Scope Summary	Comments
	individual citizens. Each of these entities has its own focus, unique missions and responsibilities, varied resources and capabilities, and operating principles and procedures.	
NFPA 1670 Standard on Operations and Training for Technical Search and Rescue Incidents	The standard identifies and establish levels of functional capability for conducting operations at technical search and rescue incidents while minimizing threats to rescuers. This standard was developed to define levels of preparation and operational capability that should be achieved by any AHJ that has responsibility for technical rescue operations. These defined levels provide an outline of a system used to manage an incident efficiently and effectively to maximize personnel safety and bring about the successful rescue of victims and eventual termination of the event. The system should be followed to increase the capabilities of the AHJ to deal successfully with even the most complex incident. The system progresses from the simple basic awareness level to the operations level and finally to the technician level. It should be understood that, as the system expands, the requirements for training, operational skills, management ability, and types and amounts of equipment also expand. The requirements of this standard shall apply to organizations that provide response to technical search and rescue incidents, including those not regulated by governmental mandates.	Consider review with respect to its applicability to ESS and if warranted develop appropriate revisions.
NFPA EV Safety Training Program "Hybrid and Electric Vehicle Emergency Field Guide" 2013	A resource for facts on safe response to electric and hybrid vehicle incidents involving damaged high voltage batteries, battery fires, extrication challenges, submersion, and charging stations. This document covers the vital aspects of EV/hybrid hazard awareness and procedures, including information from related NFPA codes and new consistent Moditech Rescue Solutions® vehicle diagrams.	While not a standard, it could serve as a basis for supporting incident response in stationary ESS.
NHTSA DOT HS 811 574 Interim Guidance for Electric and Hybrid-Electric Vehicles Equipped with High Voltage Batteries, January 2012	The document provides interim guidance for electric and hybrid-electric vehicles and identifies appropriate post-crash safety measures for vehicle owners and the general public, emergency responders, and for towing/recovery operators and vehicle storage facilities.	While not a standard, it could serve as a basis for supporting future standards associated with ESS safety.

3.6 Codes, Standards and Regulations for ESS Transportation

Table 3.6 is a listing of CSR applicable to the transport of an ESS or which may provide some guidance in addressing an ESS due to their addressing similar technologies or issues likely to be relevant in assessing ESS safety. Included are any and all CSR that clearly apply, may apply or while not directly applicable to ESS may offer some insight or examples that could be applied in the future to ESS installations. The title and designation of the standard and summary of the scope are provided along with initial comments relating to further consideration of the standard in addressing ESS safety. Although the focus of this document is U.S. CSR, some international standards are included because they are covered in Section 4.0 on ESS approval experiences or were presented in presentations during the DOE Safety Workshop in February 2014 (Sandia and PNNL 2014; Appendix B).

Table 3.6. Standards for ESS Transportation

Standard	Scope Summary	Comments
IEC 62281:2012-12-05 Edition 2.0 Safety of primary and secondary lithium cells and batteries during transport.	Specifies test methods and requirements for primary and secondary (rechargeable) lithium cells and batteries to ensure their safety during transport other than for recycling or disposal. Requirements specified in this standard do not apply in those cases where special provisions given in the relevant regulations, listed in 7.3, provide exemptions. This second edition cancels and replaces the first edition, published in 2004, and constitutes a technical revision. This edition includes the following significant technical changes with respect to the previous edition: • distinction between small and large cell or battery by gross mass rather than by lithium content or watt-hour rating ("nominal" energy); • combination of the no mass loss and no leakage criteria into one criteria; • extension of an acceptable mass loss of 0.2% from 5 g to 75 g mass of a cell or battery; • reduction of large batteries to be tested under tests T 1 to T 5 and T 8 from 4 to 2 samples; • reduction of test samples required for small battery assemblies (5.2.2); • reduction of the vibration amplitude to 2 g for large batteries in T-3 vibration test method; • replacement of the impact test by the crush test for prismatic, pouch, button, and coin cells as well as cylindrical cells with no more than 20 mm in diameter.	Should be reviewed as applicable to lithium cells and a determination made if revisions are needed to better address that type of cell or other types of cells.
IEC 62540:2009-11-25 Edition 1.0 Radio frequency identification (RFID) for stationary lead-acid cells and monoblocs – Tentative requirements	The standard applies to all stationary lead-acid cells and monobloc batteries for float charge applications (i.e., permanently connected to a load and to a DC power supply), in a static location	Should be reviewed as applicable to lithium cells and a determination made if revisions are needed to better address that type of cell or other types of cells.

Standard	Scope Summary	Comments
	(i.e., not generally intended to be moved) and incorporated into stationary equipment or installed in battery rooms for use in telecom, UPS, utility switching, emergency power or similar applications. These batteries are covered by IEC 60896-11, IEC 60896-21 and IEC 60896-22.	
UN 38.3 UN Manual for Tests and Criteria for Transportation of Dangerous Goods, Lithium Battery Testing Requirements	The document presents the procedures to be followed for the classification of lithium metal and lithium ion cells and batteries (see UN Nos. 3090, 3091, 3480 and 3481, and the applicable special provisions of Chapter 3.3 of the Model Regulations). 38.3.2 Scope 38.3.2.1 All cell types shall be subjected to tests T.1 to T.6 and T.8. All non-rechargeable battery types, including those composed of previously tested cells, shall be subjected to tests T.1 to T.5. All rechargeable battery types, including those composed of previously tested cells, shall be subjected to tests T.1 to T.5 and T.7. In addition, rechargeable single cell batteries with overcharge protection shall be subjected to test T.7. A component cell that is not transported separately from the battery it is part of needs only to be tested according to tests T.6 and T.8. A component cell that is transported separately from the battery shall be tested as a cell.	Should be reviewed as applicable to lithium cells and a determination made if revisions are needed to better address that type of cell or other types of cells.

4.0 Experiences with Energy Storage System Installation Approvals

Specific experiences with CSR and ESS installation approvals, as provided by those involved in actual ESS installations, are provided in Section 4.0. The purpose of this information is to provide some insight into the CSR that have been applied in approving ESS installations and the processes associated with requesting and securing those approvals. The following summarizes the experiences detailed in Sections 4.1 to 4.12.

The ESS technology (thermal storage for space heating) is tested and certified by an accredited third party and installed in accordance with the NEC.
The primary focus of battery technologies has been testing and listing (certification) by an accredited third party with the installation having to comply with the NEC (electrical) and the IBC (structural, fire, location in relation to the building served).
Where systems are assembled from components, the basis for approval of the system as an assembly of its component parts is an engineered solution composed of tested and listed “parts,” which is also applied as a basis for approval if the ESS is integrated with other systems such as PV systems.
Regulatory authorities generally accept certification of the ESS by an accredited third party, and they generally review and approve the installation on that basis, although additional discussion with those authorities may be necessary.
Regulatory authorities will inspect the ESS installation to verify proper installation in relation to applicable CSR and ESS specifications and the terms of any listings and the functionality of associated systems (fire detection, heat and smoke detectors, pull stations, etc.).
Lacking specific standards for an ESS technology other standards are used as a basis for assessing the ESS (e.g., compilation of existing provisions that are related to key issues and then application and use of them as needed in the absence of ESS-specific standards).
Where the utility is the approving authority (e.g., grid side of the meter), the criteria for and process associated with ESS approval can be less cumbersome because the utility is also the owner/customer as long as the utility has a department that can develop and/or adopt applicable criteria and consider such approvals based on those criteria (e.g., if there is no such department the application can be passed throughout the utility and not approved in a timely manner or at all).
Some installations are designed and installed by the ESS manufacturer; in other cases, installation is completed by a contractor hired by the customer; noting the installer is generally responsible for documenting compliance with adopted CSR.

Details provided by those involved with specific installations, and upon which the above summary observations are based, are provided in Sections 4.1 to 4.12.

4.1 Electric Thermal Storage Systems

The ESS technology (thermal storage for space heating) is safety tested and certified by UL and must be installed in accordance with national, state and local electric codes. There are two UL standards under which thermal storage systems are listed: UL 1995, Heating and Cooling Equipment, which are centrally ducted or supply heat to hydronic systems; and UL 2021, Fixed and Location-Dedicated Electric Room Heaters, which are direct-connected room heaters. In addition to being tested and listed to these UL standards, there are requirements covering clearances to combustibles for the installation of the thermal ESS (the product). Depending on system type, this can range from 2 to 6 inches from surroundings and combustibles. The NEC also requires at least 36 inches from the electric service panels, which is the front side of most of the equipment. The dead load of the ESS must also be considered in relation to building codes, although standard floor surfaces and structures are usually suitable to support the weight of the systems; however, this is something the contractor should give attention to when applying these thermal storage systems. [8]

4.2 PV Solar and Storage System Combination

The ESS technology involves a solar interconnection where the inverter is shared by the PV system and ESS (common DC bus with one PV port and one battery port) in a 20-foot shipping container. There are four projects in NJ/PA/MD, and the main code compliance item has been testing and listing by a third party (UL). UL 1741 has been used as a basis for testing and certification with IEEE 1547 subsumed (considered a part of) in that certification. In addition, the installation must follow the NEC (NFPA 70) as well as the ICC IBC for structural, fire rating and setback from (clearances to) the building. The solar installations follow an approach used by those enforcing adopted CSR that essentially requires a standard "engineered solution composed of listed parts." That approach was used in securing the approval for the storage system (cells meeting UL 1642, breakers, contactors, fuses, etc.). There is also a professional engineer review process allowed in some states (e.g., review by an acceptable third party of the proposed ESS installation), but that review process has not been required in securing approval for these four projects. All of the component UL certifications are provided to the enforcement authority, which generally reviews and approves the proposed installation based on those certifications, but occasionally a 30-minute conference with them may be needed at the outset before the on-site inspection at final permit approval. The enforcement authority also inspects the functionality of the fire detection system installed with the system (e.g., heat and smoke detectors, pull station and external beacon/siren). [9]

4.3 Flow Batteries

There is ambiguity around requirements for energy storage in Australia (AU). Details associated with four installations in AU are provided below.

- A battery system was installed in mid-2013 at the Global Change Institute (GCI), commissioned in late 2013 and consists of 120kW/288kWh of zinc bromide flow (ZBM) batteries installed in the basement of the GCI building at University of Queensland. Currently, there are no standards in Australia for flow batteries. As guidelines, the following Australian Standards were followed: AS 4777 covering grid connection of energy systems, where inverters were installed (installation and

[8] Steffes Corporation
[9] Solar Grid Storage

inverter requirements and grid protection) and AS 3000 covering electrical installations (wiring rules). In terms of grid connection, there is no set or approved process for applying for energy storage to be connected to the grid, apart from having to gain the utility's permission. However, it is completely up to the utility if the system installation received final approval, although there are no set criteria associated with that review and approval. In this installation, the University of Queensland is a large utility customer, so they probably would have had some sway, although on the customer side of the meter, the customer took the responsibility for securing needed approvals. Because there are no standards for flow batteries in Australia and to protect the company (manufacturer of the system) and follow good practice, the system manufacturer followed Australian Standards listed below. However, they had to choose which parts of the standards that applied to them and used the rest as guidelines for their storage technology. This kind of thinking has influenced a few of their other installations.

  - AS2676 – Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings (related to vented and sealed lead-acid batteries)
  - AS3011 – Electrical installations – Secondary batteries installed in buildings (related to vented and sealed lead-acid batteries)

- The Smart Grid, Smart City trial was installed late 2011 to early 2012, commissioned by mid-2012 and is comprised of 60 × 5kW/10kWh ZBM-based ESS installed on the grid side of the meter at individual residential homes in suburban and rural areas of Newcastle and Scone, Australia. Currently, there are no standards in Australia for flow batteries. AS 4777 and AS 3000 were used in this installation as reported above. In terms of grid connection, the utility was involved, and their criteria and process were the same as reported above. The utility (Ausgrid) was also the customer and main driver of the entire trial (which covered more than energy storage, as they were testing a number of other Smart Grid technologies). As such, utility approval was not an issue.
- The Advanced Energy Storage trial (AEST) was installed in 2008−2010 and comprised of 29 × 5kW/20kWh hybrid lead-acid/ZBM ESS installed on the customer side of the meter at individual residential homes in rural Queensland. The standards and approval situation was identical to the Smart City trial, although in this case, the utility was Ergon Energy.
- One small private customer wanted to connect a residential-scale ZBM-based energy storage system to the grid in Brisbane, AU. The customer has been trying with little success to get approval from the local utility for the installation, but each department in the utility noted that it was not their responsibility. This is most likely because private residential energy storage on-grid is not common, and other similar applications have not been likely submitted to the utility.
- The ESS manufacturer is always approached by the end customer (who is often also the utility), and gaining approval did not concern the ESS manufacturer but was end customer/utility's responsibility.
- In terms of any alternative methods or materials (performance-based CSR compliance), because the ESS manufacturer was not largely involved in the approval process, the manufacturer did not have much experience with the approval process. Most end customers realize that there is a lack of standards for new battery technologies and understand that the ESS manufacturer cannot always follow strict guidelines, so they are comfortable with the approach outlined above, wherein what standards are available that directly or indirectly apply to the ESS are used. In most cases, customers are not greatly familiar with battery technologies, especially ZBM.[10]

[10] Redflow

4.4 Hybrid Energy Storage Technology

The Eagle Picher Demonstration Project located in Joplin, MO focused on-peak energy and a UPS for emergency use (Figure 4.1). The project was commissioned on June 29, 2012 and is a 2 Mwh storage system, with a 1 Mw rate capability. This system is operating a 480 VDC battery buss voltage, and the project has three unique battery electro chemistries for energy storage. This demonstration project is housed in a total of four 40 foot long containers. The demonstration termed the Power Pyramid™ uses multiple energy inputs and multiple storage tiers within the pyramid to optimize the final solution. Tier 1 can provide a rapid response to short duration load changes while allowing for high cycle count. Tier 2 can provide medium-duration load support for longer duration load fluctuations while being limited to medium cycle count. Tier 3 can provide long-duration load support for extended load fluctuations while being limited to low cycle count.

Figure 4.1. Eaglepicher's Demo Powerpyramid™ Installation

The ATK BESS Project in Promontory, UT (Figure 4.2) is a modular 300 kW/1.2 MWh arrangement that includes equipment racks, bussing, environmental controls (heating and cooling), fire suppression and safety components. The system components are portable to the extent that each module can be moved and replaced with common hand tools and processes. Segregation of controls, power electronics and battery storage are designed with an emphasis on safety. The project is configured with three battery sub-units connected to a bi-directional 100 kW inverter. Inverters are 100kW bi-directional that accept 440 VAC, 60Hz, three-phase input. Input conditioning consists of AC/DC rectification and regulation using these high efficiency inverters. The inverter output contains an inversion and switching section to convert battery DC outputs to a single/useable AC output. Governed by interfaces between the battery outputs and the inverter input, switching is necessary to allow battery modeling/selection based on load needs.

Figure 4.2. ATK BESS System

The Carthage Water & Electric Plant in Carthage, MO is under development (Figure 4.3) and consists of a Renewable Energy Storage System (RESS) to demonstrate various grid utility applications to include renewable integration and peak shaving. The RESS operating system will be rated at 100 kW/216 kWh and will include 20 kW of PV solar and approximately 10 kW of wind turbines. The project will be competed in spring 2014.

Figure 4.3. CWEP RESS Installation

An ESS installation in New York City is under development (Figure 4.4) that incorporates EaglePicher Technologies (EPT)'s PowerPyramid™ into Arista Power's (OTCBB: ASPW) Power on Demand (PoD) system for a large multi-story building. This project will provide 200 kW/900 kWh of energy storage. The system utilizes energy storage to reduce utility costs, specifically demand charges, and allow seamless enrollment to demand response programs. The system is due to be commissioned in spring 2014.

Figure 4.4. Arista Multi-Story Building, NYC

The National Renewable Energy Laboratory's (NREL) clean energy user test facility (under development), consists of a three tiered, 300 kW/386 kWh PowerPyramid™ grid-tied energy storage system for grid stabilization, microgrid support and on-command power response that will be moved to a U.S. Department of Defense facility in the future. The tiers of batteries included will be Li-Ion/$FePO_4$, lead-acid and nickel-iron. The system is designed to be modular so any number of additional tiers could be added to the system at a later date. This system is will be commissioned in August 2014.

The following are the codes and standards used for the projects described above:

- NEC (NFPA 70)
- OSHA regulations
- UL 1741 (for the inverter)
- IEEE 1547 (for the inverter)
- New York City building code and fire code (for the Arista building in NYC).

4.5 Large System AC Uninterruptable Power Systems (UPS) and Small System DC UPS

The ESS installed range from 10kVA up to 2000kVA in capacity. This represents the energy that would be stored internal to the ESS for about 10-20 minutes of backup time. Some large network providers have battery rooms that would house 10 times the amount of batteries that are stored internal to the ESS described herein to provide for longer hold up times. The input and output conditions are most typically 480VAC-480 VAC, but ESS are available for 600VAC I/P down to 208VAC I/P with many different O/P voltages from 115/208/220/230/240/480/600. The CSR that have been applied to the ESS are as follows:

- UL1778 “UPS”
- UL924 “Emergency Lighting and Power Equipment”
- IEC62040 “UPS”
- UL 1973 “Batteries for Use in Light Electric Rail (LER) and Stationary Applications”
- UL/IEC 60950 “ITE”
- IEC62040-5-3 “DC UPS” 380VDC up to 1500VDC
- NEC (NFPA 70).

The large system ESS is installed on the customer side of the meter. Figure 4.5 shows the five UPS ESS on the left side of the photo, with the switch gear for the customer on the right. The ESS manufacturer leaves the responsibility for the permitting to the customer. These large systems are installed in every state in the United States. In particular, Phoenix, AZ was noted as having rigorous short circuit arc flash protection requirements for ESS.[11]

Figure 4.5. ESS Installation

4.6 Grid Storage Battery

A 1.0 MWHr battery (Kokham battery with S&C invertor) was interconnected on 13.2kv distribution feeder in a fenced utility enclosure. The only permitting required was from the city for the utility site and fence construction. As this is a utility asset, only the National Electrical Safety Code (NESC) applies. The

[11] Emerson Network Power

only materials required by those approving the project were to secure approval for the ESS installation for the physical size of the enclosure around the ESS as part of the construction permit process.[12]

4.7 Grid-Connected Premise Battery

A 6.0 kWHr battery (Sunverge unit) was installed outdoors in conjunction with utility owned rooftop solar and interconnected on utility side of the customer meter. There was no permitting, review and approval process, as this is a utility asset, and only the NESC applies. No materials were required to secure approval for the ESS installation.

4.8 Customer Connected Premise Battery

A 6.0 kWHr battery (Sunverge unit) was installed indoors in conjunction with rooftop solar and interconnected on customer side of the utility net meter. The permitting, review and approval process involved securing an electrical permit from the city in which the ESS was being installed. The basis for the review and approval of the ESS and electrical permit was the 2011 NEC. There were no other materials required by those approving the ESS installation (e.g., information, documentation, analysis, reports, third-party certification, etc.).[13]

4.9 Tehachapi Storage Project

The Tehachapi Storage Project (TSP) is a 32MWh/8 MW Li-Ion battery with an 8 MW/4 MVAR/9 MVA bi-directional power conversion system (PCS), along with system level controls/communications necessary to run eight core tests used to evaluate the capabilities of the Battery Energy Storage System (BESS) relative to 13 identified operational uses. The TSP system is designed to be capable of a C/4 charge and discharge rate and dynamic reactive power support with a short-term overload of 15 MVAR (minimum) peak for 4 seconds. The BESS is installed at the monolith substation near Tehachapi, CA. The BESS output is at 12kV and is connected to the Southern California Edison (SCE) 66kV sub-transmission system through a 12k/66kV transformer provided by SCE. TSP was installed as an R&D project to demonstrate grid reliability functions as well as the capability to participate in the energy market and can be controlled by their respective energy/generation management systems.

SCE specified the following list of codes and standards for the BESS vendor.

- IEEE 979, IEEE Guide for Substation Fire Protection
- IEEE 100, The New IEEE Standard Dictionary of Electrical and Electronics Terms
- IEEE 80, IEEE Guide for Safety in AC Substation Grounding
- NEC-2008, NFPA-70 National Electrical Code
- ANSI Z535–1994, Product Safety Signs and Labels
- IEEE 693-2005, IEEE Recommended Practices for Seismic Design of Substations
- ANSI C63.16, American National Standard Guide for Electrostatic Discharge Tests Methodologies and Criteria for Electronic Equipment

[12] Kansas City Power and Light
[13] Kansas City Power and Light

- IEEE 139, IEEE Recommended Practice for the Measurement of Radio Frequency Emission from Industrial, Scientific, and Medical (ISM) Equipment Installed on User's Premises
- IEEE 519, IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems
- IEEE 1547, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
- IEEE 1547.1, 2005 Standard for Conformance Tests Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems (see more ancillary references in IEEE 1547.1 "Normative References" section)
- 8ANSI C84.1, Electric Power Systems and Equipment—Voltage Ratings (60 Hz)
- UL 1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources
- NEC Article 480, Storage Batteries
- IEEE C2-2007, National Electrical Safety Code 2007 Edition
- OSHA 1926.441, Batteries and Battery Charging
- IEEE C57.12, IEEE Standard Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
- IEEE 987, IEEE Guide for Application of Composite Insulators
- IEEE C57.13, IEEE Standard Requirements for Instrument Transformers
- IEEE C62.22, IEEE Guide for the Application of Metal-Oxide Surge Arrestors for AC Systems
- IEEE C37.90.1, IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems
- IEC 61850, Communication Networks and Systems in Substations
- ISO 9000, Quality Management – Parts 1 to 4
- ISO 9001, Quality Systems – Model for Quality Assurance in Design, Development, Production, Installation and Servicing
- ISO 9002, Quality Systems – Model for Quality Assurance in Production and Installation
- ISO 9003, Quality Systems – Model for Quality Final Inspection and Test
- ISO 1459, 1461, Hot-dip Galvanizing
- SGIP, Small Generator Interconnection Procedure, FERC Order 2006-B
- FERC Order 661, Low voltage ride through (LVRT) – Appendix G.

The ESS vendor was responsible for demonstrating that the BESS met the prescribed standards. SCE provided quality control oversight. SCE also required the manufacture of a TSP "mini-system" (30kW/116kWh) to help validate the compliance of the BESS design with relevant standards from the above list. This mini-system is composed of inverter and battery building-blocks that are used to compile the full BESS. SCE oversaw factory acceptance testing (FAT) of the mini-system in the supplier's factory. After completing the mini-system FAT successfully, the mini-system was delivered to SCE's laboratory. Over approximately 6 months of testing, SCE has used the mini-system to thoroughly validate ESS safety, functionality and performance. Several significant issues (and many minor ones) have already been identified and resolved due to this mini-system testing. Each of the resolutions implemented have also been applied to the BESS; using this scaled-down testing has mitigated safety concerns and will hopefully reduce down-time for the full BESS.

The BESS is located adjacent to the SCE Monolith 66kV substation. A 6,300 square foot metal building on a concrete slab was constructed to house the BESS and associated system hardware. The BESS receives auxiliary power through step-down transformers connected to the monolith 12kV bus. The BESS performs real and reactive power exchange on the 66kV bus via a series of transformers, and the output is metered using a CAISO power meter at the 66kV bus interface. The BESS is designed to be an unmanned facility that will perform specific control algorithms as directed remotely via energy/generation management systems. Fire alarms are detected both via direct connection to a Remote Terminal Unit (RTU) and to the system controller. Further, an e-stop (emergency stop) feature has been developed, whereby the local operation immediately halts bi-directional inverter operation and opens all contactors on the battery side. Attention has been given in the design to ensure that the e-stop functionality does not require specific processor based logic or communication requirements.

The TSP Project initiated a CAISO Small Generator Interconnection Agreement (SGIA) and was included in Queue Cluster 4, along with other new generation within the CAISO-controlled system. Standard requirements for the CAISO Interconnection Process were followed to allow for market participation. The facility was constructed within the boundaries of the existing monolith substation, which alleviated the need for other typical construction related permitting. As noted above, the ESS vendor was responsible for demonstrating that the BESS met the prescribed standards.

The following list contains some of the materials required to demonstrate compliance with prescribed standards. The list is not comprehensive but provides many of the significant compliance-related materials.

- Report detailing seismic (earthquake) evaluation
- Thermal analyses for BESS heat generation and HVAC capacity
- Battery Rack Structural Design drawings
- Third-Party Evaluation of Fire Suppression System adequacy
- Vendor Report demonstrating effectiveness of FM-200 Fire Suppression System (destructive demonstration of battery system with application of fire suppression agent)
- Heavy Lifting Plan for component installation
- Power System Load Flow modeling (for evaluation of Battery impact on the grid). This was used internally to evaluate the system, and was provided to CAISO as part of the interconnection process
- Transformer short-circuit duty requirements (CAISO SGIA submission).

As this was an R&D effort, the SCE project team specification also included additional hardware for evaluation of the installed system. This hardware included a scaled-down mini-system and an additional controller for performing Real Time Digital Simulation (RTDS) Hardware In The Loop (HWIL) testing. The mini-system provided all the main components of the full system to allow lab testing of control features and verification of operations prior to energizing the full 8 MW BESS. This has proven an invaluable tool for identifying issues in a controlled setting in advance of commissioning the full system. Similarly, the HWIL controller in the RTDS environment allowed for placing the controller in a virtual grid model to evaluate the impact of the BESS on the grid before placing the full system online.

Additional insight on the installation included extensive safety testing imposed on the vendor of the battery system to demonstrate the overall safety of the installation and the effectiveness of the fire suppression system.

4.10 Energy Storage Installations at San Diego Gas & Electric

The following systems have been installed at SDG&E.

Note that all SDG&E installations to date have been outside of buildings. For installations inside buildings, it is anticipated that the energy storage unit would have to meet UL standards and be tested by a Nationally Recognized Test Lab. In addition, the installation would have to be approved by the AHJ following a formal approval process requiring a Plan Check process and electrical inspection.

- 25 kW/50 kWh, 240V, 1-ph, Lithium-Ion Chem
- 50 kW/82 kWh , 120/208V, 3-ph, Lithium-Ion
- 500 kW/1500 kWh, 120/208V, 3-ph, Lithium-Ion
- 500 kW/1500 kWh, 277/480V, 3-ph, Lithium-Ion.

The following standards were applied to these installations:

- ANSI/IEEE C2, National Electrical Safety Code, whenever applicable
- IEEE 519, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
- NFPA 704, Standard System for the Identification of the Hazards of Materials for Emergency Response
- ANSI Z535, Product Safety Signs and Labels
- ANSI C57/IEEE transformer standards, latest editions, whenever applicable
- ANSI C37/IEEE surge withstand capabilities, latest editions, whenever applicable
- IEEE P1547-2003, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
- IEEE P1547.1, Standard Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
- UL 1642 and IEC 62133, applicable sections related to battery cell safety, where applicable.

The following environmental requirements were placed on these installations.

- The equipment will be installed on the Pacific coast at an elevation below 3300 feet. The environment may contain salt air, ocean fog, and seismic activity. Extra insulation, material and finishes of above average durability are required for the equipment to withstand the described environmental effects
- The system shall be designed for proper operation without de-rating for an ambient temperature range of 10F–120F, zero gas/vapor emissions (describe, if exception) and less than 58 decibels (dbA) measured at the unit (for other noise frequencies provide db specification of unit)

- Systems must be designed to minimize the risk to the environment including land contamination or disturbance (footprint), water contamination or diversion and air emissions
- The seller must provide sufficient information specific to their particular product to facilitate utility personnel training and communications with emergency response and environmental agencies
- Material Safety Data Sheets (MSDS) shall be provided, as applicable.

The following safety-related requirements were placed on the energy storage units and installation.

- Units must be compliant with IEEE1547 and UL1642. Systems must be able to protect themselves from internal failures and utility grid disturbances. As such, systems must be self-protecting for AC or DC component system failures. In addition, systems must be able to protect themselves from various types of grid faults and other abnormal conditions on the grid.
- Systems must be designed in compliance with applicable safety standards for battery cell construction, potential exposure to chemicals and cell module or enclosure resistance to hazards such as ruptures and exposure to fire.
- For all systems equipment, the bidder shall provide information on specific safety issues related to the equipment, including appropriate responses on how to handle batteries in case of an emergency, such as fires or cell module ruptures.
- Systems must be designed such as to minimize risk of injury to the workforce and public during installation, maintenance and operation.
- Systems shall be equipped with meaningful status lights and LED panels to operate the system, and at minimum provide easy access to mode and AC power (charging or discharging) information. Audible alarms should be included as necessary to ensure safety, such as chemical leaks.

The following seismic considerations are to be addressed in the installation.

- The utility system is located in an active seismic area. The equipment and accessories (including mounting) shall be designed in accordance with Seismic Zone 4 classification withstand ability.
- Container anchoring provisions to the foundations shall be the responsibility of the utility. However, the seller shall provide physical data (weights, dimensions, centers of gravity, etc.) as required for foundation and anchoring design.

Compliance with the adopted CSR and specifications is through a review by utility personnel in four separate departments:

- Technology Innovation & Development, Electric Distribution Engineering (Standards), Safety Compliance and Environmental Operations
- Electric Distribution Engineering (Standards)
- Safety Compliance
- Environmental Operations.

All ESS installations are done in accordance with the following utility developed manuals.

- Overhead Construction Standards Manual
- Underground Construction Standards Manual
- Electric Standard Practice Manual.

4.11 Southern California Edison

There are four ESS applications as follows:

- LG Residential Energy Storage Units (RESU) consisting of LG automotive grade lithium-ion batteries, 4kW, 10kWh (AC) system operating at 240/120VAC split phase that incorporate up to 4kW (DC) PV through a single inverter and also provide backup power, and numerous control strategies
- S&C PureWave Community Energy Storage (CES) Unit consisting of Kokam lithium-ion batteries, 25kVA, 50kWh (AC) system operating at 240/120VAC split phase with no PV inputs but also providing islanding, remote control, and aggregation capabilities
- A Princeton Power Systems BESS consisting of Samsung lithium-ion batteries, 100kW, 100kWh (AC) system operating at 480VAC three-phase that incorporates up to 100kW (DC) PV through single inverter (48kW installed) and also provides backup (not used), and several control strategies
- An A123 distribution battery energy storage system (DBESS) consisting of A123 lithium-ion "nanophosphate" batteries with Parker bi-directional power inverters, 2MVA, 500kWh, 480V, 53 ft shipping container, plus 40 ft auxiliary skid with two 1MVA isolation transformers and 30 ft 480/12kV interconnection skid provides real/reactive power dispatch, ramping, and profiles.

A listing of all safety-related CSR that the ESS technology (and its subsystems if available) was designed to satisfy is shown below for each ESS.

- LG RESU: UL 1741, UL 1642, FCC Code of Federal Regulations Sections 15.109 and 15.209, IEEE Std. C37.90.2-1995, IEEE Std. 1547-2003, IEEE Std. 519-1992, ANSI C84.1, SCE Tariff Rule 21, ITIC CBEMA Curve, IEEE Std. 802.3 and 802.15.4, NEMA 250-2008
- S&C Community Energy Storage Unit: All standards were referenced in American Electric Power's *Functional Specification for CES Unit* Revision 2.2
- Princeton Power Systems BESS: Same as RESU in section above.
- A123 DBESS: UL 1741, IEEE 519, IEEE 1547, NFPA 70 (2008), NFPA 72 (2007), NFPA 101 (2009), FCC Part 15 Class A, EN55022 Class A

SCE performed in-depth laboratory testing on each of the deployed energy storage units. Laboratory testing included basic (non-destructive) safety, functional and performance testing.

- The RESUs were tested and evaluated for several years prior to deployment while the BESS and CES each underwent over 6 months of testing. Laboratory testing by SCE identified several safety issues that were not discovered through the UL testing. As an example, each subsystem must be capable of fully protecting itself in the event of loss of communication. In addition, available standards did not address how to control properly the charging and discharging of battery systems (largely vendor specific) so laboratory testing along with close manufacturer interaction was the only method to verify fully the correct operation of redundant safety mechanisms.

- Two DBESS units were installed, operated and evaluated for more than 3 years at the Large Energy Storage Test Apparatus (LESTA), a purpose-built test facility with a dedicated 12 kV circuit and load banks. LESTA allowed SCE personnel to operate the DBESS units in a controlled environment without affecting actual customers or loaded distribution circuits. Through this testing, SCE gained valuable installation, operation, maintenance, repair, troubleshooting and performance information.
- Nationally recognized laboratories were used to complete the UL Listing of the RESU and BESS (the two devices that were installed behind customer meters). DBESS subsystem/component manufacturers used third-party testing to verify compliance with applicable safety standards.

A description of each ESS installation is as follows:

- Fourteen of the LG RESU were installed in customer homes behind their meters. The RESUs were installed in the garage near the main panel. The systems were protected from vehicle impact by a large steel brace. Flexible conduit was used to connect the RESU to two new electrical panels: one feeding the RESU and through the second, the RESU provided power to selected circuits for backup. Backed-up circuits were removed from the main electrical panel and fed ONLY from the RESU to allow the RESU to isolate them in the event of a grid outage. The self-contained Smart Meter was employed as the means to satisfy utility requirements for visible disconnection. PV power from the rooftop system was brought and combined in the garage near the RESU. This combined voltage connected directly to the RESU. The RESU communicates via LAN (to a 4G radio) to a RESU server where all devices are remotely controlled. In addition, the RESU utilizes ZigBee communication to get site demand and energy information from the Smart Meter. This information is used to actively control the RESU’s charging and discharging powers to modify the load profile of the home.
- One S&C Purewave CES was installed next to the street near a residential transformer on the utility side of meters. Two batteries were installed in a fiberglass enclosure underground with the PCS installed above them. The CES was installed (electrically) between the transformer and the homes served. This allows the CES to island the homes in the event of a grid outage. Bollards were required to protect the CES from vehicle impact. To provide easy isolation in the event of a grid event, a 240VAC bypass switch was also installed near the CES. This switch allows trouble-men to safely and quickly isolate the CES or otherwise change the electrical configuration of the installation. The CES is controlled remotely and operates according to specific commands. It is used to shift load on the street from on-peak to off-peak relieving the circuit. Another operation involves charging the CES using excess PV generation by the homes and discharging in the evening when the load is highest.
- One Princeton Power Systems BESS was installed near a parking structure behind a customer meter. The entire system was contained within an ISO shipping container. A PV array was installed on the roof of the parking structure and the DC cables connected the PV array to the BESS. The installation includes visible AC and DC disconnects. The BESS is used to shift electric vehicle charging load from on to off-peak. In addition, it actively monitors power usage and generation to modify the load profile of a solar car shade and charging system.
- One A123 DBESS container and auxiliary skid was removed from LESTA using heavy forklifts (cranes could not be used due to the site’s location beneath 220kV transmission lines), transported to

Irvine via flatbed trailers and temporarily installed at a greenfield site on the University of California Irvine's (UCI) campus. Unlike LESTA, which has a purpose-built concrete slab with built-in trenches, 12kV vault and electrical switchgear, the greenfield site had no existing infrastructure. The SGSS container and auxiliary skid were placed and anchored directly on grade, with temporary precast concrete trenches installed between structures. A new 30-ft interconnection skid was also installed on grade. The interconnection skid is fed by a PME, which is fed from another switch across the street. The local PME allows the entire site, including interconnected skid, to be disconnected from the circuit for installation and removal. The site is concealed, and access is controlled by a 10-ft chain link fence with cloth mesh siding. Because the location is temporary, the DBESS is controlled manually on site, though remote control options exist. The system is operated in conjunction with UCI graduate student experiments to examine the circuit-level effect of on/off/inter-peak charging and discharging with different power levels, durations, and profiles.

A description of the approval process associated with each ESS installation is as follows:

- The LG RESUs each required approval from the City of Irvine and SCE. The city reviewed the electrical connections to and from the system including the installation of the new electrical panels, the PV array and the reconfiguration of backed-up circuits. Because the RESU was UL Listed, the city focused on factors outside of the system and did not investigate the internal safety mechanisms.

  SCE's review was also simplified due to the UL Listing. SCE reviewed the capability for export and the single line to verify anti-islanding compliance. Because the batteries were coupled with the PV power through one inverter, the home was not eligible for NEM. SCE produced a new Uncompensated Export Addendum to the Customer Generating Facility Non-Export Agreement to allow the RESUs to discharge power to the grid but not receive any credit. SCE inspected the installation and verified anti-islanding at each location.
- The S&C CES was installed as a utility asset; thus, no City of Irvine electrical inspection was conducted. However, the city and the local Irvine Campus Housing Authority were involved with easement, aesthetic and vehicle protection concerns. Within SCE, pilot standards for the CES and CES Bypass switch were produced to ensure trouble-men are appropriately trained. SCE performed electrical analysis of the installation including flicker and voltage sag for all customers served by the CES. SCE also performed structural analysis of the underground enclosure containing the batteries.
- The Princeton Power Systems BESS was installed on the University of California at Irvine's campus; thus, the University performed all electrical, structural and aesthetic review and approval. The BESS inverter is also UL listed; thus, the review process focused on the external components. The BESS incorporates a stand-alone fire suppression system. This was disclosed to the University, but no external communication was provided. The University inspected the system after installation.
- The A123 DBESS was installed as a utility asset, so no municipal electrical inspection was necessary. However, the site and construction were permitted through the City of Irvine and UCI. The site is subject to a 1-year license from UCI, after which the system will be removed and the site restored to its previous state.

The following CSR and approval documentation were employed in the review and approval of the ESS installations:

- The LG RESU was supported by the UL 1741 Listing (not compliance, but full third-party certified listing) for the entire RESU system (including batteries, charger, inverter and controls) and was crucial to obtain approval from both the city and SCE. SCE also required verification that the anti-islanding performance compiled with Rule 21. However, UL 1741 (based on IEEE 1547) is significantly stricter than Rule 21. An electrical diagram, plot plan, UL letter of certification for the RESU unit, RESU single line (internal components), operational ranges for each of the inputs and outputs (AC and DC), nominal power of the system (battery and PV separately) and expected annual energy production of the PV were provided.
- As a utility device, compliance with IEEE 1547 was required for the S&C CES Unit. Anti-islanding was verified. SCE performed significant laboratory testing to verify safety of the system in a variety of grid events, loss of communication and other situations. An electrical diagram, physical layout, rated power (real and reactive), rated energy, islanding power quality and capabilities, operational ranges for the inputs and outputs, the SCE laboratory test report, installation documentation, operational procedures and emergency procedures were provided.
- The Princeton Power Systems BESS was supported by the UL 1741 Listing for the BESS inverter and UL 1642 listing for the BESS battery cells were required for installation and interconnection of the BESS. These certifications were necessary for University approval. An electrical diagram, plot plan, UL letter of certification for the inverter, UL certification for batteries, BESS single line (internal components), operational ranges for each of the inputs and outputs (AC and DC), nominal power of the system (battery and PV separately) and annual PV energy production were provided.

4.12 Portland General Electric

A project of the scope of the Salem Smart Power Center involves engineering of literally every discipline. One of the primary concerns with the installation was fire safety. They designed their own fire suppression system that loops a specially designed polymer tubing throughout the battery stacks. A point source of heat in contact with the tubing causes the tubing to burst at that point and releases fire suppressant at the location of the heat source.

Some engineers are internal and some are outside consultants; each being responsible for compliance with those codes and safety standards that fall within their discipline. The project was subject to design criteria as required in the NEC and NESC. Also, there were required documented inspections by authoritative regulators and third parties during construction, installation and start up. The project has been in compliance with all requirements and in several instances, especially as it relates to fire detection and suppression as noted above have exceeded conventional methods. They also engaged the local fire department in training to prepare the first responders to respond to any fire at the facility. In addition, the project was subjected to an internal audit program.

They also had to deal with standard construction concerns not directly related to the battery facility, which resulted in some re-grading of the property. They also applied the state building code.

5.0 Performance-based Review and Approval

Generally, CSR tend to be prescriptive in nature, although there can be performance-related provisions contained within them. Prescriptive criteria direct exactly the acceptable means and methods to be used in achieving some objective. Examples of prescriptive criteria include the following:

- Install 2 by 4 in. framing at 16 in. on center
- The surface of the vent shall be at least 18 in. from combustible materials
- The floor shall be 12 in. above the base flood elevation
- The room shall be provided with at least 15 cfm of ventilation per person
- The means of egress shall be at least 36 in. in clear width

Performance criteria establish an objective but do not prescribe the means and methods to achieve that objective. Examples of performance criteria based on the above examples are:

- The wall shall be designed to withstand the anticipated design loads
- The temperature on materials surrounding the vent shall be limited to 120°F
- The floor shall be elevated so it will not be covered by flood water
- The occupants of the room shall have sufficient ventilation to provide for acceptable indoor air quality
- The corridor width shall be sufficient to allow all occupants to get out of the building in an emergency.

The above examples are from codes covering building construction. Similar examples exist in standards for equipment and products where prescriptions for how to construct something and desired performance outcomes are established. Testing confirms that the outcomes desired for specific metrics are realized without regard for the means employed to secure those outcomes. A review of plans and specifications and the actual installation validates compliance with any prescriptive criteria. Most equipment and product standards contain both prescriptive criteria focused on the construction of the subject and then performance criteria to assess the performance of the subject against specific objectives. This would be the case for CSR covering ESS components and an ESS "product." Most CSR that would cover the installation, commissioning and other aspects associated with installation of an ESS also tend to be prescriptive in nature, but also generally provide a performance path to document and validate compliance with the CSR. If CSR that contain criteria that specifically address how to determine the acceptability of an ESS installation are not available, then as discussed in Section 1.0, there may be no way to document readily and uniformly that what is proposed is safe or secure the necessary approvals for and acceptance of the ESS.

Where a technology is mature, CSR will exist that cover the design and construction of the technology and its component parts if any as well as its installation, commissioning, operation, repair and even demolition. When satisfied, CSR serve as a basis to document and validate the acceptability of the technology with respect to topics such as safety covered in CSR. With respect to ESS components or an ESS "product," an accredited and approved third-party agency need only evaluate and test them against applicable standards, assess the results and based on that assessment indicate whether the criteria were satisfied or desired metrics achieved. A component or system so assessed and meeting the applicable standards is then considered listed and labeled. With respect to ESS installation, that assessment is done by the AHJ or designee using the CSR adopted as the basis for approval. Those CSR will generally include a reference to and reliance on standards covering the ESS components and the entire ESS.

As covered in Section 3.0:

- For ESS components (e.g., batteries, inverters, relays, wire, etc.) covered in Section 3.1, some standards may exist and others may be under development or simply not available yet (e.g., new standards are needed).
- In the case of standards applicable to an ESS "produce" covered in Section 3.2, appropriate standards would be comprised of a combination of the component standards by reference and then additional criteria for how to assemble the components and what performance criteria the ESS was expected to satisfy would be provided. An alternative in treating the entire ESS as an assembly the acceptability of the components could be addressed if standards to test and evaluate the resultant assembly of the components as an ESS "product" were available.
- With respect to an ESS installation and its interconnection to other systems as well as the interrelationship with the built environment (its surroundings) as covered in Section 3.3, CSR may exist, may be under development or not available yet. Where relevant and ESS-specific CSR do not exist, existing criteria in CSR can be applied as the basis for an assessment of an ESS by the entity seeking approval of the ESS. That information combined with how the AHJ views the CSR they have adopted and the ESS proposed may be a sufficient basis for considering and approving what is proposed. In other instances, authorities responsible for approval of an ESS installation may not be inclined to approve the installation until their CSR "catch up" with the technology and provide specifics upon which they can validate the safety of an ESS installation.

It is important to note that the above items are additive. That is standards are needed to assess the safety and acceptability of components of an ESS and the ESS "product." Then CSR are needed to address the safe installation, application, commissioning, operation, repair/renovation and even de-commissioning of the ESS.

Until standards are available for use in validating (e.g., testing, listing and certification) the safety of ESS components and their assembly as an ESS "product" and CSR are available that specifically address how an ESS is to be installed, commissioned, operated and interconnected with other systems and interact with its surroundings, there will be challenges associated with securing approval to install and use ESS. In addition as repairs and renovations or alterations to an existing ESS installation are undertaken the issue of safety and compliance with CSR will have to be revisited. The challenges in securing the necessary approvals to deploy safe ESS can be due to the lack of specific criteria in CSR upon which to evaluate an ESS for safety and approve the installation of the ESS. To ensure that new technologies can be considered, CSR have an alternative approval path that can be used as a basis for documenting and validating safe ESS until CSR can be updated and enhanced to provide specific criteria for all ESS technologies and possible applications. That path provides a basis for documenting and validating compliance with CSR as long as what is proposed is shown to be no more hazardous nor less safe than what is currently allowed in or provided for by existing CSR. One challenge is determining the basis for assessing equivalent performance, especially for new technologies, where there are few similar technologies and criteria may not be available upon which to base that assessment. Another is securing the involvement of an accredited third party testing and certification agency that can conduct the needed activities and document the safety of the ESS and its intended installation to the relevant AHJs. A more formidable challenge is that each AHJ may apply this path differently. Even if ESS safety is validated by an accredited third party on the basis of performance equivalency, the lack of a uniform application by AHJs of the current CSR in determining that basis can result in each ESS installation being validated as safe on a different basis. This in turn can necessitate the development of different safety documentation for each installation.

With the information above as a foundation, the following cover three available methods to document the safety of an ESS and on that basis seek approval for the ESS under current CSR that may not specifically address the safety of a proposed ESS installation. While AHJs ultimately retain the authority to perform the activities described in each method they generally rely on information provided by accredited third parties. Note that utilities are more likely to conduct this work themselves for ESS installations they will own and operate than are federal, state or local agencies who are the AHJs associated with the permitting and approval of ESS installations on the customer side of the meter.

5.1 Unlisted ESS Components or Entire Systems

The acceptability of the ESS "product" or components of an ESS, where there are no applicable or available standards, can be secured through the application and use of NFPA 791 covered in Section 3.2. This standard provides a methodology for evaluating and accepting unlabeled electrical equipment (e.g., untested and labeled as meeting available and applicable standards) for compliance with the intended safety associated with nationally recognized standards and other requirements imposed by the AHJ. Where an ESS component or ESS "product" is tested and labeled as meeting applicable nationally recognized standards, which are generally adopted by reference as part of CSR that would apply to an ESS installation, then that associated labeling speaks to the acceptability of the ESS or ESS component. Where not labeled, because of a choice by the manufacturer or because standards do not yet exist upon which to assess the safety of the ESS component of ESS "product," the provisions of NFPA 791 provide guidance to technology proponents in documenting the acceptability of what is proposed and to AHJs in evaluating what is proposed and considering if and how it should be approved. It is important to note that the application of NFPA 791 would likely be different for each ESS manufacturer and for those seeking to install the ESS as well as each AHJ. As such, while providing a basis for approval, the application and use of NFPA 791 is more likely to be unique for each ESS and each ESS installation. While providing a short term means to foster deployment of ESS the availability of specific CSR covering the ESS and ESS installation would eliminate the need to apply NFPA 791.

5.2 Alternative Methods and Materials

Until the provisions in CSR "catch up" to specifically address ESS installations there is little concrete guidance for ESS manufacturers or users seeking approval of an ESS installation or for AHJs to use in assessing the safety of the installation. Alternative methods and materials provisions in CSR provide a path to documenting or verifying compliance with existing CSR on the basis that what is proposed, while not specifically addressed in the CSR, is no more hazardous nor less safe than something that is specifically covered in the CSR. Where an ESS component or entire ESS is unlisted the application of NFPA 791 as discussed above should be considered and will be helpful in documenting the safety of the ESS components and ESS "product." The provisions associated with alternative methods and materials, while applicable to an ESS component or entire ESS, are more apt to be applied in securing approval for the intended installation of the ESS, even if it is listed. This is because, whether listed or unlisted, CSR also cover how the installation of an ESS in relation to its surroundings is deemed to be safe.

The specifics from the ICC International Green Construction Code (IgCC) are provided below and are representative of similar language in other CSR covering alternative methods and materials.

SECTION 105

APPROVAL

105.1 General. This code is not intended to prevent the use of any material, method of construction, design, system, or innovative approach not specifically prescribed herein, provided that such construction, design, system or innovative approach has been approved by the code official as meeting the intent of this code and all other applicable laws, codes and ordinances.

105.2 Approved materials and equipment. Materials, equipment, devices and innovative approaches approved by the code official shall be constructed, installed and maintained in accordance with such approval.

105.2.1 Used materials, products and equipment. The use of used materials, products and equipment that meet the requirements of this code for new materials is permitted. Used equipment and devices shall be permitted to be reused subject to the approval of the code official.

105.3 Modifications. Wherever there are practical difficulties involved in carrying out the provisions of this code, the code official shall have the authority to grant modifications for individual cases, upon application of the owner or owner's representative, provided the code official shall first find that special individual reason makes the strict letter of this code impractical and that the modification is in compliance with the intent and purpose of this code and that such modification does not lessen the minimum requirements of this code. The details of granting modifications shall be recorded and entered in the files of the department.

105.4 Innovative approaches and alternative materials, design, and methods of construction and equipment. The provisions of this code are not intended to prevent the installation of any material or to prohibit any design, innovative approach, or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design, innovative approach or method of construction shall be reviewed and approved where the code official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, design, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code. The details of granting the use of alternative materials, designs, innovative approach and methods of construction shall be recorded and entered in the files of the department.

105.4.1 Research reports. Supporting data, where necessary to assist in the approval of materials or assemblies not specifically provided for in this code, shall consist of valid research reports from approved sources.

105.4.2 Tests. Wherever there is insufficient evidence of compliance with the provisions of this code, or evidence that a material or method does not conform to the requirements of this code, or in order to substantiate claims for alternative materials or methods, the code official shall have the authority to require tests as evidence of compliance to be made at no expense to the jurisdiction. Test methods shall be as specified in this code or by other recognized test standards. In the absence of recognized *and accepted test methods, the code official shall approve the testing procedures. Tests shall be performed by an approved agency. Reports of such tests shall be retained by the code official for the period required for retention of public records.*

105.5 Compliance materials. The code official shall be permitted to approve specific computer software, worksheets, compliance manuals and other similar materials that meet the intent of this code.

105.6 Approved programs. The code official or other authority having jurisdiction shall be permitted to deem a national, state or local program to meet or exceed this code. Buildings approved in writing by such a program shall be considered to be in compliance with this code.

105.6.1 Specific approval. The code official or authority having jurisdiction shall be permitted to approve programs or compliance tools for a specified application, limited scope or specific locale. For example, a specific approval shall be permitted to apply to a specific section or chapter of this code.[14]

Each entity that has adopted and enforces CSR that contain the above type of provision then provides an avenue for approval of an ESS installation on the basis of equivalent performance. The burden of proving equivalent performance (e.g., no more hazardous nor less safe than something specifically provided in the CSR) is with the technology proponent (manufacturer or entity wishing to use the technology). Unless the approval authority can provide details of what information they require to document equivalent performance, the technology proponent will generally have to review the existing CSR being used, which can tend to be prescriptive in nature, as the equivalency metric as well as other research related to ESS safety and develop the rationale and documentation of equivalency themselves. While what is developed by the ESS proponent may be acceptable to one approval authority, it may not be acceptable to others. As a result, the application of this path to documenting the safety of ESS before updated and more appropriate CSR are available can differ from one approval authority to the next. Clearly having examples of how other ESS installations have been approved, as covered in Section 4.0, can serve to augment the available documentation. This is something each ESS manufacturer might undertake in an effort to standardize documenting the safety of their ESS and its intended installations until CSR are available that provide the needed criteria upon which to approve an ESS installation. Where the manufacturer of the ESS chooses not to pursue activities to document the safety of their ESS, then that responsibility may fall on those specifying or installing the ESS. Faced with having to take on that responsibility specifiers or installers of ESS could choose to forgo ESS application and use or select an ESS from a manufacturer that has addressed this issue.

In most instances, the AHJ enforcing the CSR will not conduct an assessment of equivalency if what is proposed does not satisfy their CSR requirements but instead rely on the technology proponent (permit applicant) to provide the necessary documentation. In this case, the documentation is provided using the provisions in the current CSR as a metric. This can also be accomplished by a third-party on the basis of a failure modes and effects analysis or other methodology that is focused on the safety related aspects of an ESS regardless of what may or may not be in CSR. Either way, there are multiple AHJs whose application of the CSR they have adopted can and will vary. While the ESS proponent can develop their own documentation and customize it for each particular ESS installation and AHJ, the use of an accredited third party can simplify the approval process.

[14] Text reproduced with permission via email from the ICC, August 2014.

5.3 Third-party Safety Documentation

The involvement by an accredited third-party in an assessment of an ESS or ESS installation is relevant to the two paths identified above. Outside those two paths, a third-party independent assessment of ESS safety can be considered and would include their identification of the issues that would need to be addressed, the documentation needed that the ESS proponent would have to supply and the preparation of a report of findings that documented the acceptability of the ESS supported by failure modes and effects analysis of FMEA (as noted this analysis could also focus on equivalency with the current CSR). An FMEA will provide a logical assessment and documentation of safety outside the specifics in any CSR.

Where a third party is assessing safety based on equivalency with current CSR they may include the criteria to be used in their assessment in an acceptance criteria document, pre-standard, protocol or guideline that serves as a surrogate for CSR that may not be approved and published and that address the technology. Accredited third-party agencies will perform such assessments and issue reports of findings that can be provided to AHJs to document ESS safety and used to secure ESS installation approvals until CSR are revised to specifically address ESS technology. When the specific criteria needed to address ESS safety exist in the CSR then more traditional means of testing and listing the ESS and its components and evaluation of an ESS installation can be applied in documenting and validating ESS safety.

Because some ESS installations may be unique and not readily assessed as discussed above third-parties can also be employed to assess the acceptability of a specific ESS technology installation on site and as installed. Those third parties would have to be accredited as field evaluation bureaus (FEBs) in order for the information they provide to be acceptable to AHJs because they are in essence doing what the AHJ is authorized to do themselves in approving an ESS installation. For instance, FEBs can be assessed and accredited by the International Accreditation Service (IAS) to conduct evaluations of electrical equipment based on the International Accreditation Service *Accreditation Criteria for Field Evaluation of Unlisted Electrical Equipment (AC354)*. The request for these types of evaluations usually comes from a building department, code enforcement official, fire marshal or similar regulatory body and is primarily to determine compliance with applicable codes or standards of innovative, one-of-a-kind, limited production, used or modified products that are not listed or labeled under a full testing, listing or certification program. Such an evaluation process may be completed at the point of manufacture, interim points of distribution, in the evaluating organization's facilities, in situ or a combination of the above. Similar programs exist to support utilities in assessing grid side technologies. In the United States, those include the Canadian Standards Association, UL, LLC, Factory Mutual, Intertek Testing Services, ETL and in Canada include the Electrical Safety Authority (ESA) field evaluation, CSA, Entela, Intertek Testing Services, the Quality Auditing Institute, and UL of Canada. Information on third parties that have been ANSI accredited can be found at https://www.ansica.org/wwwversion2/outside/Portfolio.asp.

Organizations meeting IAS FEB accreditation requirements also meet the requirements of the *Recommended Competency Guidelines for Third-Party Field Evaluation Bodies* and the *Recommended Practice and Procedure for Unlabeled Electrical Equipment Evaluation*. These guidelines and recommended practices have been developed by the American Council for Electrical Safety and, as such, these bodies could also be used by ESS proponents to secure necessary ESS technology and installation approvals.

Most governmental authorities provide information on the means and methods for securing approvals on a performance equivalency basis. For instance, details were found for the following jurisdictions by searching on "alternative methods and materials."

- Laguna Beach City, CA http://lagunabeachcity.net/civicax/filebank/blobdload.aspx?BlobID=5505
- Berkeley, CA http://www.cityofberkeley.info/uploadedFiles/Online_Service_Center/Planning/ApplicationorAlternateMaterialsormethodsofconstruction.pdf
- Bellevue, WA http://www.ci.bellevue.wa.us/pdf/Development%20Services/forms_alternatematerials.pdf
- Orange County, CA http://www.ocfa.org/_uploads/pdf/guidea01.pdf
- Reedy Creek, FL http://www.rcid.org/Portals/0/Documents/Permitting/Request_for_Alternative_Materials-Methods.pdf
- Clark County, NV http://www.clarkcountynv.gov/Depts/development_services/Forms/Form_1003.pdf

In summary, a path to securing ESS technology and installation approvals does exist in CSR. That path can bridge the gap until CSR are updated to provide specific criteria for ESS components, ESS "products," and ESS installations. That said, the implementation of this path is up to the entity responsible for documenting CSR compliance (e.g., component manufacturer, ESS manufacturer, ESS installer, etc.) based on what AHJs coving the envisioned ESS installations require of that documentation as supporting ESS safety and CSR compliance. As such, there is a possibility that each entity using these paths may choose to evaluate equivalent performance on a different basis.

Increased uniformity in assessment and approval of ESS technology can be facilitated through the use of accredited third parties who would issue reports of findings of equivalency and acceptability for consideration by AHJs responsible for approving ESS installations. To facilitate the uniformity and acceptability of those reports of findings, the development of acceptance criteria or a protocol could be undertaken. Such a document would essentially mirror or contain criteria that most AHJs would develop on their own and use as a basis for approval under a performance equivalency based compliance path. In using these provisions, the ESS proponent then has guidance in preparing documentation of CSR compliance (on the basis of equivalent performance) as does an accredited third party in reviewing that documentation and issuing a report of findings as to verification of compliance. That report of findings can then be used by any AHJ in considering the approval of an ESS and conducting the necessary inspections to validate compliance with their CSR. The basis is that the report of findings documents equivalent safety and performance to outcomes derived from compliance with the current CSR, and that the ESS is installed in accordance with those findings.

Organizations and entities that would develop such criteria and issue such reports include the following:

- Federal, state or local AHJs in the enforcement of their CSR using this alternative path to compliance verification.
- Registered design professionals who are licensed to practice in states where an ESS installation is proposed.
- Manufacturers and ESS proponents (although this would be considered first party self-certification and not generally accepted by AHJs).
- Third-party accredited testing and certification agencies.

Note that those acceptance criteria or protocols can form the basis for revisions to existing CSR or development of new CSR.

It is also important to separate the manner in which utilities would engage in approval of ESS installations on the basis of safety-related performance for ESS installations on the grid side of the meter. The utility can follow the performance equivalency path above and rely on information documenting the acceptance of the ESS on the basis of equivalent performance to the specific CSR. Where the utility does not adopt those CSR or is not inclined to recognize information provided by third-party agencies, the utility may act as the AHJ and conduct specific safety testing themselves, develop their own acceptance criteria and undertake any other activities they feel are needed to detail a basis for ESS safety and validate that a proposed ESS complies with what the utility has adopted. For instance, as reported above, one utility required the conduct of destructive testing to validate that the batteries being supplied would not "run-away" if an incident were to occur.

Ideally, the proponents of ESS technology can agree on the criteria upon which an ESS is considered safe in conjunction with AHJs on both sides of the meter, thereby fostering uniformity and more timely and less complicated review and approval of ESS installations in both the short term to assess ESS safety on the basis of performance equivalency and the long term in formulating new and revising existing CSR.

6.0 Next Steps

6.1 Identification of Apparent Gaps in Current CSR

Based on the information provided in Sections 4.0 and 5.0 and a closer review of the CSR provided in Section 3.0, gaps between current and future ESS technology and the CSR will need to be identified. As discussed in Section 1.2, those gaps could be updating of existing CSR to more appropriately address ESS technology, removal of unintended barriers in existing CSR to ESS technology or development of new CSR criteria to facilitate the deployment of safe ESS where current CSR may not provide appropriate guidance. Once identified the gap will need to be evaluated as to the severity of its impact on safe ESS deployment and necessary research, analysis and additional work to determine how to fill the gap identified and conducted. Filling these gaps can occur through future revisions to existing or development of new CSR. The availability of updated and appropriate CSR will foster the ability to readily test and list ESS as to their safety for the intended purpose and use, appropriately install ESS to ensure their safety and foster the ability for those involved with ESS O&M or incident response to address any safety-related situations that might arise during ESS installation or after the ESS is placed into service.

Work outlined in Sections 6.2 through 6.4 is intended to start to address the identification of gaps using current CSR and ESS technology as a basis for identifying gaps (i.e., the CSR are the driver). Concurrent with these activities additional research and analysis and other activities should be undertaken separately and without CSR criteria as a driving force to identify what constitutes a safe ESS (i.e., the research and analysis associated with safety as the driver). Those additional research and analysis activities and identification of gaps that would be focused on safety are intended to be addressed by the DOE ESS Safety Strategy and the activities outlined therein on CSR undertaken as a part of that strategy.

6.2 Identification of Opportunities to Revise Current CSR During 2014

The following opportunities to revise existing CSR during 2014, or where the bulk of proposal development would need to occur during 2014, were mentioned during at the DOE ESS safety workshop in February 2014 (Sandia and PNNL 2014) and are identified in Table 6.1. The information provided includes an identification of the document, the due date for any changes to be submitted, a summary of the general thrust of the needed changes, a summary of needed research or analysis to support the change and identification of any other relevant factors to revising the CSR in question.

Table 6.1. 2014 CSR Revisions

Document	Due Date for Changes	Summary of Changes
NFPA 70 National Electrical Code	November 7, 2014	The general thrust of the needed changes is to re-validate that the provisions applicable to lead-acid batteries remain current and if not update them and then to add similar provisions covering other battery technologies. A meeting of interested parties lead by NEMA was conducted June 3, 2014 to discuss this issue. Provisions in the NEC that need to be reviewed and evaluated for possible revisions were identified and communications were undertaken to work with an existing industry-lead working group tasked with review of the entire NEC and provide ESS-related input to their effort (proposed changes and reasons) for submission to NFPA. That work is ongoing in anticipation of development of proposed changes to NFPA 70 and their submittal by the deadline as a component of the existing industry-lead working group.
NFPA 550 Fire Concepts Tree	January 5, 2015	NFPA 550 was reviewed in relation to ESS to determine if any changes were warranted so that the document could more appropriately cover ESS. The results of that review indicated that Sections 3.3 and 3.4 (definitions) cover control of heat-energy transfer and a definition might be needed for ESS in terms of power-energy (e.g., an ESS incident that includes not only heat-energy but power/electrical capacity). The broader issue is that all criteria in Chapter 3 could apply to ESS but maybe after a more thorough review of Chapter 3 it might be appropriate to see if any criteria might apply to ESS uniquely, if any that are needed are missing and if any need to be revised to apply to ESS. A further read of NFPA 550 suggests that it is broad enough to apply to ESS following either the control combustion or control by construction/isolation provisions. Based on the short time frame for additional review, proposed changes were halted. In addition, the manner in which the document is written is considered broad and technology non-specific such that to propose changes specific to ESS might result in work being done at an unnecessary level of detail in relation to NFPA 550 criteria. In addition it appeared that an unlisted ESS assessed in accordance with NFPA 791 that is installed in accordance with NFPA 550 would be acceptable now in documenting a safe ESS and a safe installation of that ESS on the basis of performance. Additional review work on NFPA 550 could be undertaken to outline how it could be most appropriately applied to ESS as currently written and if deemed appropriate based on that further review guidance in applying NFPA 550 to ESS could be prepared and disseminated as a component of the DOE ESS Safety Strategy. In addition when proposed changes to NFPA 550 are published they should be reviewed to determine if any have an impact on ESS and appropriate steps taken to influence any changes that do impact ESS.

Document	Due Date for Changes	Summary of Changes
NFPA 704 ID of Material Hazards	July 7, 2014	This document was reviewed in relation to ESS to determine if any changes were warranted so the document could more appropriately cover ESS. A review of the standard indicated that nothing should be changed for ESS. The document covers a specific scope under which an ESS would fall, and it appears that the ESS manufacturers and those involved in ESS installations will have to know that this standard exists, that it applies to ESS and commence using it in identifying any hazards with ESS installation.
NFPA 921 Fire and Explosion Investigations	January 5, 2015	This document was reviewed in relation to ESS to determine if any changes were warranted so that the document could more appropriately cover ESS. A review of the document suggests the following: a. No recommended changes to Chapter 7 on building systems or Chapter 8 on fire protection systems b. Chapter 9 on electricity and fire is primarily focused on basic electrical theory and protective devices, wiring and 120/240 VAC application receptacles and cabling. There is no mention of storage batteries, energy storage devices or inverters (although DC circuits are briefly discussed). Perhaps a mention of commercial batteries, UPS and ESS could be added for general knowledge and understanding. c. Chapter 13 Safety, Section 13.3.3 covers electrical hazards (at an investigation scene) and the current wording [live electrical systems] “could come from standby power systems” might be revised to mention ESS or large (MW) stored energy systems that remain live after electrical isolation. d. No recommended changes to Chapter 23 on explosions or Chapter 24 on incendiary fires.

6.3 Identification of Opportunities to Revise Current CSR Beyond 2014

The following opportunities exist to revise existing CSR covered in Section 3.0 where proposed changes to the CSR are due in 2015 in accordance with updating cycles adopted by the SDO. It is important to note that where existing model codes or standards do not have established deadlines they would be considered on continuous maintenance and as such revisions could be submitted at any time for consideration by the committee within the SDO working on revisions to the standard. When approved, such revisions could be published in the form of addenda to the last edition of the standard and/or revisions compiled and combined at particular intervals on the order of 3 to 5 years to yield a new edition of the standard.

Note also that participation in revising current CSR can be realized in ways other than submitting proposed changes pursuant to established schedules and processes provided by an SDO. Individuals, organizations or associations representing the interests of the ESS industry can become members of the SDO committees and through that process engage in development of revisions to a CSR from the "inside." This does not necessarily mean that what is proposed would ultimately be included in the CSR but it does provide a longer term and more robust way to interact in CSR development.

The list below is not all inclusive but contains information on opportunities published by the SDO. It is intended that after transferal of this document to a web-based database and pursuant to its maintenance in support of the DOE ESS Safety Strategy that additional opportunities will be identified, information on them provided and activities to develop changes and foster their adoption outlined and updated over time.

1. ICC International Building (egress, fire safety and general), International Existing Building Code, International Fuel Gas Code, International Mechanical Code, International Plumbing Code, International Residential Code (mechanical and plumbing) and International Zoning Code proposed changes are due January 12, 2015.

2. ICC International Building Code (administrative and structural), International Energy Conservation Code, International Fire Code, International Residential Code (building) and International Urban Wildland Interface Code proposed changes are due January 11, 2016.

3. ICC International Green Construction Code proposed changes are due January 9, 2017.

4. NESC IEEE C2 proposed changes to the 2013 edition and committee recommended changes will be published September 1, 2014 and available for review and comment. The 2017 edition of the NESC will be published August 1, 2016. While the deadline has passed to submit proposed changes, participation in the ongoing process associated with the 2017 edition is warranted. Proposed changes to the 2017 edition that will form the basis for the 2021 edition of the NESC will be due in July 2017 (http://standards.ieee.org/about/nesc/erp/schedule.pdf).

5. NFPA 791 Unlabeled Electrical Equipment. Proposed changes are due to NFPA by July 6, 2015, and it was agreed at the meeting June 3, 2014 noted above that this document would be reviewed in relation to ESS to determine if any changes were warranted so the document could more appropriately cover ESS. That review indicated that Section 3.3.4 should mention storage in the list of

things provided and that Sections 5.2 to 5.13 could all apply to ESS and are likely acceptable as written for ESS but there may be other things unique to ESS that might be included. Section 5.4 "Disconnecting Means" could be enhanced by including a reference to ESS to possibly identify on the disconnecting means that "Live voltage may still be present when the disconnect open."

6. NFPA 790 Standard for Competency of Third-Party Field Evaluation Bodies. Proposed changes are due to NFPA by July 6, 2015. Possible changes for consideration might focus on revisions necessary to ensure such third parties are competent to address ESS safety assessment and evaluation.

7. Other NFPA standards that are referenced in Section 3.0 have due dates that will occur after 2015 and should be addressed as discussed where they appear in Section 3.0 based on the applicable due date for proposed in July of years after 2015.

6.4 Identification of Opportunities to Develop New CSR

Opportunities always exist to develop new CSR where no provisions exist to address a particular issue or where a myriad of provisions may exist in different documents and the combination of those provisions into one document would prove beneficial. In the case of new provisions for existing CSR such as a new chapter to the NESC to cover some aspect of ESS, that activity would be addressed as discussed in Section 6.3. Where there are no CSR criteria and no logical CSR to locate them or where there are a myriad of different CSR that each address parts of ESS that could be better combined into one document, then a new CSR initiative could be undertaken.

An example of this is the installation of stationary fuel cell power plants. About 20 years ago as this technology was being developed and deployed, experiences with installation in relation to existing CSR indicated that some CSR addressed some aspects of the installation indirectly. That is, they were not written to apply to fuel cells but were "force fitted" to address fuel cells because nothing else existed. Rather than attempt to address the myriad of CSR that covered "pieces" of the installation the fuel cell industry in collaboration with DOE requested made a request to NFPA to initiate a new standards development committee to write a standard covering the installation of stationary fuel cell power plants. In addition, the industry with assistance from DOE developed a protocol (pre-standard) on the subject that was used as a basis for the NFPA standard once NFPA approved the project. The result was the publication of NFPA 853 Installation of Stationary Fuel Cell Power Plants. This standard continues to be maintained by NFPA and is referenced in other relevant NFPA standards and ICC model codes. A similar standard would be advantageous for ESS and work could be undertaken later in 2014 to draft a new NFPA standard covering installation of ESS following the format of NFPA 853.

It is intended that after transferal of this document to a web-based database and pursuant to its maintenance in support of the DOE ESS Safety Strategy that opportunities for new CSR will be identified, described and where warranted pursued.

7.0 References

ANSI—American National Standards Institute. 2012. *Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation,* 2012 Edition. National Fire Protection Association (NFPA) 791-2012.

Conover DR. 2014. *Overview of Development and Deployment of Codes, Standards and Regulations Affecting Energy Storage System Safety in the United States*. PNNL-23578, Pacific Northwest National Laboratory, Richland, WA.

DOE—U.S. Department of Energy. 2014. *DOE OE Strategy for Energy Storage Safety*. In progress.

Sandia—Sandia National Laboratories and PNNL—Pacific Northwest National Laboratory. 2014. DOE OE Energy Storage Safety Workshop. Alburquerque, NM. February 17−18.

Appendix A

Materials Relevant to Facilitate Review and Approval of ESS Installations

Appendix A
Materials Relevant to Facilitate Review and Approval of ESS Installations

This Appendix contains two examples of materials that are considered relevant to facilitating the review and approval of ESS installations either directly because they apply to ESS or indirectly because while not applying to ESS they offer some insight into resources available to address the installation and approval of other related technologies. After transferal of this document to a web-based database and pursuant to its maintenance in support of the DOE ESS Safety Strategy, it is intended that additional existing resources can be identified and ideally as additional work on ESS safety is undertaken that models for documenting and verifying compliance with CSR and ensuring ESS safety can be developed for consistent and uniform application and use in fostering the acceptance of safe ESS.

County of Santa Clara Inspection Checklist for Rooftop Photovoltaic (PV) Systems

All National Electrical Code (NEC) references are to both the 2008 and 2011 versions unless otherwise noted. All International Residential Code (IRC), International Building Code (IBC) and International Fire Code (IFC) references are to the 2012 versions unless otherwise noted.
California amendments to the IRC are noted as CRC

Section 1: PV Array Configuration

- ☐ Module manufacturer, make, model, and number of modules match the approved plans. (2009 & 2012 IBC 107.4)
- ☐ PV modules are listed to UL 1703. (NEC 110.3, 690.4 & IBC 1509.7.4 & CRC R908.1.5). NOTE: AC modules need to be listed to UL 1703 and UL 1741.
- ☐ DC modules are properly marked and labeled. (NEC 110.3, 690.4(D) & 690.51)
- ☐ AC modules are properly marked and labeled. (NEC 110.3, 690.4(D) & 690.52)
- ☐ Modules are attached to the mounting structure according to the manufacturer's instructions and the approved plans. (NEC 110.3(B), 2009 & 2012 IBC 107.4 & CRC R908.1.4)
- ☐ Roof penetrations are flashed and counter-flashed. (2009 & 2012 IBC Chapter 15 & 2012 IRC Chapter 9)
- ☐ PV modules are in good condition (i.e., no broken glass or cells, no discoloration, frames not damaged, etc.). (NEC 110.12(B))
- ☐ Residential one- and two-family dwelling limited to maximum PV system voltage of 600 V. (NEC 690.7)
- ☐ Rooftop systems are designed in accordance with the IBC. (2012 IBC 1509.7 & CRC R908.1)

- ☐ Roof access points, paths and clearances need to comply with the IFC. (IFC 605.11.3.1 - 605.11.3.3.3, CRC R331.4.1 through R331.4.2.4)

Section 2: Grounding

- ☐ A complete grounding electrode system is installed. (NEC 690.47(A) & (B))
- ☐ Modules are grounded in accordance with manufacturer's installation instructions using the supplied hardware or listed equipment specified in the instructions and identified for the environment, and using the grounding point identified on the module and in the manufacturer's instructions. (NEC 690.43 & 110.3(B))
- ☐ Properly sized equipment grounding conductor is routed with the circuit conductors. (NEC 690.45, 250.134(B) & 300.3(B))
- ☐ AC and DC grounding electrode conductors are properly connected. Separate electrodes, if used, are bonded together. (NEC 690.47, 250.50 & 250.58)
- ☐ Bonding fittings are used on concentric/eccentric knockouts with metal conduits for circuits over 250 volts. (NEC 250.97) (*see also* exceptions 1 through 4)
- ☐ Bonding fittings are used for ferrous metal conduits enclosing grounding electrode conductors. (NEC 250.64(E))

Section 3: Wire Management

- ☐ Wires are secured by staples, cable ties, straps, hangers or similar fittings at intervals that do not exceed 4.5 feet. (NEC 334.30 & 338.12(A)(3))
- ☐ Wires are secured within 12 inches of each box, cabinet, conduit body or other termination. (NEC 334.30 & 338.12(A)(3))
- ☐ Cable closely follows the surface of the building finish or of the running boards. (2011 NEC 690.4(F) & IFC 605.11.2, CRC R331.3) NOTE: see Section 12 below for additional guidance on routing of conductors for fire fighter safety concerns
- ☐ Exposed single conductors, where subject to physical damage, are protected. (NEC 230.50(B) & 300.5(D))

Section 4: Conductors

- ☐ Exposed single conductor wiring is a 90C, wet rated and sunlight resistant type USE-2 or listed PV wire. (NEC 690.31(B)) If the wiring is in a conduit, it is 90C, wet rated type RHW-2, THWN-2, or XHHW-2. (NEC 310.15)
- ☐ Exposed single conductors used for ungrounded (transformerless) systems are listed and identified as "PV wire." (NEC 690.35(D)(3)) For other conductor requirements for ungrounded systems see NEC 690.35(D)
- ☐ Conductor insulation is rated at 90C to allow for operation at 70C+ near modules. (NEC 310.15)

- ☐ Where conductors or cables are installed in conduits exposed to direct sunlight on or above rooftops, correction factors for ambient temperature adjustments are applied. (2008 NEC 310.15(B)(2)(c) & 2011 NEC 310.15(B)(3)(c))
- ☐ Grounded conductor is identified white or grey. (NEC 200.6)
- ☐ Open conductors are secured and protected. (NEC 338.12(A)(3) & 334.30)
- ☐ Conductors are not in contact with the roof surface. (NEC 334.30)
- ☐ DC conductors inside a building are in a metal raceway or MC metal-clad cable that complies with 250.118(10), or metal enclosures. (NEC 690.31(E))
- ☐ If more than one nominal voltage system conductor is installed in the raceway, permanent identification and labeling is required. (NEC 200.6(D) & 210.5(C))
- ☐ For underground conductor installations, the burial depth is appropriate and warning tape is in place. (NEC 300.5(D)(3) & Table 300.5)
- ☐ Aluminum is not placed in direct contact with concrete. (NEC 250.120(B) & 110.11)
- ☐ DC source circuit conductors are rated at 1.25 x 1.25 = 156% short-circuit (ISC) current from modules. NOTE: The module ISC x number of combined strings, if strings are combined. When DC source circuits (strings) are connected in parallel the short-circuit current multiplies and PV output conductors from combined strings need to be sized appropriately. (NEC 690.8(1) & (B)(1))
- ☐ PV circuit and premises wiring is separated. (NEC 690.4(B))
- ☐ PV system conductors shall be grouped and identified. (2011 NEC 690.4(B))

Section 5: Overcurrent Protection

- ☐ Overcurrent devices in the DC circuits are listed for DC operation. (NEC 110.3(A), (B) & 690.9(D))
- ☐ DC source circuit overcurrent protection devices are rated at 1.25 x 1.25 = 156% short-circuit (ISC) current from modules. NOTE: The module ISC x number of combined strings, if strings are combined. When DC source circuits (strings) are connected in parallel the short-circuit current multiplies DC overcurrent protective devices need to be sized appropriately. (NEC 690.8(B)(1))
- ☐ Inverter output circuit overcurrent protection device (point of connection to AC system breaker) is sized based on the maximum inverter output current x 125%. (NEC 690.8(A)(3) & 690.8(B)(1))
- ☐ Overcurrent protection is required for the PV source circuit (modules and parallel connected modules), PV output circuit (conductors between source circuits and inverter), inverter output circuit, battery circuit conductors and equipment. (NEC 690.9(A))
- ☐ Where three or more strings are combined, a listed combiner box (UL1741) is used and fuses are required. When DC source circuits (strings) are connected in parallel, the current through a failed circuit can be the sum of the current connected from the other strings,

therefore special consideration must be taken to ensure the sum of the total number of strings minus one does not exceed the module manufacturers series fuse rating, or conductor ampacity. (NEC 110.3(B), 690.9(A)) NOTE: there are a few exceptions where the module has a higher series fuse rating and a low ISC rating.

- ☐ When a back-fed breaker is used as a utility interconnection means, the breaker does not read "line and load." (2008 NEC 690.64(B)(5) & 2008 & 2011 NEC 110.3(B), 705.12(D)(5))
- ☐ PV interconnect breaker is located at the opposite end of the buss from the feeder connection, unless using 100% rated equipment. (2008 NEC 690.64(B)(7), 705.12(D)(7) & 2011 NEC 705.12(D)(7))

Section 6: Electrical Connections

- ☐ Crimp on terminals are listed and installed using a listed tool specified for use in crimping those specific crimps. (NEC 110.3(B) & 110.14)
- ☐ Pressure terminals are listed for the environment and tightened to manufacturer recommended torque specifications. (NEC 110.11, 110.3(B) & 110.14)
- ☐ Connectors are listed for the voltage of the system and have appropriate temperature and ampere ratings. (NEC 110.3(B) & 110.14)
- ☐ Twist on wire connectors are listed for the environment (i.e. wet, damp, direct burial, etc.) and installed per manufacturer's instructions. (NEC 110.11, 110.3(B), 110.14 & 300.5(B))
- ☐ Power distribution blocks are listed. (NEC 690.4 & 2011 NEC 314.28(E))
- ☐ Terminals containing more than one conductor are listed for multiple conductors. (NEC 110.14(A) & 110.3(B))
- ☐ Connectors and terminals used for fine strand conductors are listed for use with such conductors. (NEC 110.14(A) & 110.3(B))
- ☐ Connectors that are readily accessible and operating at over 30 volts require a tool for opening. (NEC 690.33(C))
- ☐ Module connectors are tight and secure. (NEC 110.3(B) & 110.12)
- ☐ Wiring and connections of inverters, PV source circuits, battery connections, etc., and all interconnections are performed by qualified personnel. (2011 NEC 690.4(E))

Section 7: Charge Controllers

- ☐ Charge controller is listed to UL Standard 1741. (NEC 110.3 & 690.4(D))
- ☐ Exposed energized terminals are not readily accessible. (NEC 110.27)
- ☐ Diversion charge controllers that are used as the sole means of regulating charging of batteries have a second independent means of control to prevent overcharging. (NEC 690.72(B)(1))

Section 8: Disconnects

- ☐ Disconnects used in DC circuits are listed for DC operation. (NEC 110.3)
- ☐ Disconnects are installed for all current carrying conductors of the PV source. (NEC 690.13 - 690.14)
- ☐ Disconnects are installed for the PV equipment. NOTE: For inverters and other equipment that are energized from more than one source, the disconnecting means must be grouped and identified. (NEC 690.15)
- ☐ Disconnects and overcurrent protection are installed for all ungrounded conductors in ungrounded (transformerless) PV power systems. (NEC 240.15 & 690.35)

Section 9: Inverters

- ☐ Inverters are listed to UL 1741. (NEC 690.4(D)) NOTE: grid-tied system inverters need to be identified for use in interactive power systems.
- ☐ Point of connection is at a dedicated breaker or disconnect. (2008 NEC 690.64(B)(1), 705.12(D)(1) & 2011 NEC 705.12(D)(1))
- ☐ Total rating of the overcurrent devices supplying equipment does not exceed 120% of the equipment rating. (2008 NEC 690.64(B)(2), 705.12(D)(2) & 2011 NEC 705.12(D)(2))
- ☐ Listed AC and DC disconnects and overcurrent protection are grouped and identified. (NEC 690.15)
- ☐ No multi-wire branch circuits are installed where single 120-volt inverters are connected to 120/240-volt load centers. (NEC 690.10(C))
- ☐ The plastic barrier is re-installed between the AC, DC wiring and communication wires. (NEC 110.3(B) & 110.27)

Section 10: Batteries

- ☐ Storage batteries for dwellings have the cells connected to operate at less than 50 volts. (NEC 690.71(B)(1))
- ☐ Live parts of battery systems for dwellings are guarded to prevent accidental contact by persons or objects. (NEC 690.71(B)(2))
- ☐ Flexible battery cables are listed RHW or THW, 2/0 minimum for battery cell connections. (NEC 690.74) NOTE: welding cables, marine, locomotive (DLO), and automotive cables do not meet the current Electrical Code requirements. (NEC 110.3(A) & (B))
- ☐ Flexible battery cables do not leave the battery enclosure. (NEC 690.74 & 400.8)
- ☐ Flexible, fine strand cables are only be used with terminals, lugs, devices, and connectors that are listed and marked for such use. (NEC 690.31(F), 690.74, 110.3(B) & 110.14)

- ☐ High interrupt, listed, DC rated fuses or circuit breakers are used in battery circuits. The amps interruption current (AIC) is at least 20,000 amps. (NEC 690.71(C) & 110.9)
- ☐ Cables to inverters, DC load centers, and/or charge controllers are in a conduit. (NEC 690.31(A) & 690.31(E))
- ☐ Conduits enter the battery enclosure below the tops of the batteries. NOTE: this is to avoid accidental ventilation of gases into electrical equipment where sparks may occur. Follow battery enclosure manufacturer's instructions for venting and conduit locations. (NEC 110.3(B), 480.9(A) & 480.10)
- ☐ A disconnect means is provided for all ungrounded conductors derived from a stationary battery system over 30 volts. (NEC 480.5 & 690.15) NOTE: see NEC 690.71(E) for additional service disconnecting means requirements for series connected battery circuits.
- ☐ Area is well ventilated and the batteries are not installed in living areas. (NEC 408.9(A) & 408.10)

Section 11: Signs and Labels

- ☐ All interior and exterior DC conduit, enclosures, raceways, cable assemblies, junction boxes, combiner boxes, and disconnects are marked. (IFC 605.11.1, 2011 NEC 690.31(E)(3)& CRC R331.2)
- ☐ The markings on the conduits, raceways and cable assemblies are every 10 feet, within one foot of all turns or bends and within one foot above and below all penetrations of roof/ceiling assemblies, walls and barriers. (IFC 605.11.1.4 & CRC R331.2.4)
- ☐ Marking is placed adjacent to the main service disconnect in a location clearly visible from where the disconnect is operated. (IFC 605.11.1.3 & CRC R331.2.3)
- ☐ The markings say "WARNING: PHOTOVOLTAIC POWER SOURCE" and have 3/8 inch (9.5 mm) minimum-sized white letters on a red background. The signs are made of reflective weather resistant material. Self-adhesive signs are available from suppliers. (IFC 605.11.1.1, 605.11.1.2, 2011 NEC 690.4(E)(3)& CRC R331.2.1-R331.2.2)
- ☐ Where PV circuits are embedded in built-up, laminate, or membrane roofing materials in roof areas not covered by PV modules and associated equipment, the location of circuits shall be clearly marked. (2011 NEC 690.4(F))
- ☐ Labels are phenolic where exposed to sunlight. Labels required on conduit are permanent, weather resistant and suitable for the environment. Labels have a red background with white lettering. The following labels are required as applicable:

Table: Signage Requirements for PV systems

Code Section	Location of Label	Text
NEC 690.5(C)	Utility-interactive inverter & battery enclosure	WARNING: ELECTRIC SHOCK HAZARD IF A GROUND FAULT IS INDICATED, NORMALLY GROUNDED CONDUCTORS MAY BE UNGROUNDED AND ENERGIZED
NEC 690.35(F)	All enclosures with ungrounded circuits or devices which are energized and may be exposed during service	WARNING: ELECTRIC SHOCK HAZARD. THE DC CONDUCTORS OF THIS PV SYSTEM ARE UNGROUNDED AND MAY BE ENERGIZED.
NEC 690.14(C)(1)	On main service when DC wiring is run through the building and DC disconnect is located other than at the main service	DC DISCONNECT IS LOCATED….
NEC 690.14(C)(2)	On the AC and DC disconnects	PV SYSTEM DISCONNECT
NEC 690.53	On the DC disconnects	OPERATING CURRENT ___ OPERATING VOLTAGE ___ MAXIMUM SYSTEM VOLTAGE ___ SHORT-CIRCUIT CURRENT ___
NEC 690.54	At interactive points of interconnection, usually the main service	RATED AC OUTPUT CURRENT ___ AMPS NORMAL OPERATING AC VOLTAGE ___ VOLTS
NEC 690.56(B)/ 690.14(D)(4), 705.10 2011 NEC 690.4(H)	At the electrical service and at the PV inverter if not at the same location	A directory providing the location of the service disconnecting means and the PV system disconnecting means
NEC 690.17	On the DC disconnect and on any equipment that stays energized in the off position from the PV supply	WARNING! ELECTRIC SHOCK HAZARD. DO NOT TOUCH TERMINALS. TERMINALS ON BOTH LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION.
NEC 690.64(B)(7)	Inverter output overcurrent protective device (OCPD)	WARNING: INVERTER OUTPUT CONNECTION DO NOT RELOCATE THIS OVERCURRENT DEVICE.
Common Utility Requirement	At the main electrical service when a supply side tap is used	CAUTION! SUPPLY SIDE TAP. OPEN AND LOCK AC PV DISCONNECT BEFORE REMOVING METER.
NEC 690.55	Battery enclosure	MAXIMUM OPERATING VOLTAGE, EQUALIZATION VOLTAGE POLARITY OF GROUNDED CONDUCTORS

Code Section	Location of Label	Text
When approved by the AHJ through NEC load calculations. NOTE: this is for a reduction of the existing main breaker to facilitate the added PV OCPD. There are no exceptions to 690.64 (B)(2) and 705.12 (D)(2) for the sum of OCPDs exceeding 120% of bus rating, even based on calculations. The main breaker may not be reduced below minimum requirements of NEC 230.79.	Main electric service	MAXIMUM MAIN BREAKER SIZE: XXX AMPS
IFC 605.11.1.4	On conduit, raceways, and enclosures, mark every 10 feet, at turns, above/below penetrations	WARNING: PV POWER SOURCE

Section 12: Fire Safety

- ☐ Rooftop mounted PV panels and modules have the proper fire classification rating. (IBC 1509.7.2& CRC R908.1.2)
- ☐ Rooftop DC Conduits are located as close as possible to the ridge or hip or valley and from the hip or valley as directly as possible to an outside wall to reduce trip hazards and maximize ventilation opportunities. (IFC 605.11.2& CRC R331.3)
- ☐ Conduit runs between sub-arrays and to DC combiner boxes are installed in a manner that minimizes total amount of conduit on the roof by taking the shortest path from the array to the DC combiner box. (IFC 605.11.2& CRC R331.3)
- ☐ DC Combiner Boxes are located so that conduit runs are minimized in the pathways between arrays. (IFC 605.11.2& CRC 331.3)
- ☐ DC wiring in enclosed spaces in buildings is installed in metallic conduit or raceways. Conduit runs along the bottom of load bearing members. (IFC 605.11.2 & 2011 NEC 690.4(F)& CRC R331.3)
- ☐ DC wiring methods shall not be installed within 25cm (10”) of the roof decking or sheathing except where directly below the roof surface covered by the PV modules and associated equipment. (2011 NEC 690.31(E)(1))
- ☐ All roofs have an access point that does not place ground ladders over openings such as windows or doors, are located at strong points of building construction, and in locations

where the access point does not conflict with overhead obstructions such as tree limbs, wires, or signs. (IFC 605.11.3.1& CRC R331.3)

- ☐ Roofs with slopes greater than 2:12 have solar panel layouts that meet the following criteria: (some exceptions apply, see diagrams in IFC)
  - Hip Roofs: Panels/modules are located so that there is a 3-foot wide clear access pathway from the eave to the ridge on each roof slope where panels/modules are located. (IFC 605.11.3.2.1& CRC R331.4.2.1)
  - Hips and Valleys: If panels/modules are placed on both sides of a hip or valley they are located no closer than 18 inches to a hip or valley. If the panels are located on only one side of a hip or valley that is of equal length, then the panels can be placed directly adjacent to the hip or valley. (IFC 605.11.3.2.3& CRC R 331.4.2.3)
  - Single Ridges: Panels/modules are located so that there are two 3-foot wide access pathways from the eave to the ridge on each roof slope where there are panels/modules installed. (IFC 605.11.3.2.2& CRC R331.4.2.2)
  - Ridges: Panels/modules are located no higher than 3 feet from the top of the ridge in order to allow for fire department smoke ventilation operations. (IFC 605.11.3.2.4& CRC R331.4.2.4)
  - Access pathways are located at a structurally sound location capable of supporting the load of fire fighters accessing the roof. (IFC 605.11.3.2.1& CRC R331.4.2.1)

Control of Hazardous Energy Sources

Self-Inspection Checklist

Optional Information

Name of school:
Date of inspection:
Career-Technical program/course/room:
Signature of inspector:

Guidelines

This checklist covers regulations issued by the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) as a general industry standard under 29 CFR 1910.147. Another name for control of hazardous energy sources is lockout/tagout. It covers the servicing and maintenance of machines and equipment in which the unexpected energization or startup of the machines or equipment, or release of stored energy could cause injury. The regulations cited apply only to private employers and their employees, unless adopted by a State agency and applied to other groups such as public employees. A “yes” answer to a question indicates that this portion of the inspection complies with the OSHA or EPA standard or with a nonregulatory recommendation.

General Energy Control

1. Does the program require that all hazardous energy sources be isolated, locked or tagged, and otherwise disabled before anyone performs any activity where the unexpected energization, startup, or release of stored energy could occur and cause injury? [29 CFR 1910.147(c)(1)]
2. Have procedures been developed, documented, and implemented for the control of hazardous energy when working with such equipment? [29 CFR 1910.147(c)(4)]
3. Do the procedures clearly outline the scope, purpose, responsibility, authorization, rules, and techniques to be applied to the control of hazardous energy, and measures to enforce compliance? [29 CFR 1910.147(c)(4)(ii)]
4. Do procedures exist for shutting down, isolating, blocking, and securing (locks and tags) energy? [29 CFR 1910.147(c)(4)(ii)(B)]

5. Do procedures exist and is someone assigned responsibility for removing and transferring locks and tags? [29 CFR 1910.147(c)(4)(ii)(C)]
6. Do requirements exist for testing a machine or equipment to determine and verify the effectiveness of lockout/tagout and other energy control measures? [29 CFR 1910.147(c)(4)(ii)(D)]

Protective Materials and Hardware

7. Are locks, tags, chains, adapter pins, or other hardware available for securing or blocking energy sources? [29 CFR 1910.147(c)(5)(i)]
8. Are these devices durable and substantial? [29 CFR 1910.147(c)(5)(ii)(A)]
9. Are these devices standardized in either color, shape, size, or format? [29 CFR 1910.147(c)(5)(ii)(B)]
10. Do these devices have a provision for identifying the person applying the device? [29 CFR 1910.147(c)(5)(ii)(D)]
11. Do tagout devices or danger tags warn against hazardous conditions if the equipment is re-energized? [29 CFR 1910.147(c)(5)(iii)]

    Note: Acceptable wording includes Do Not Open, Do Not Start, Do Not Close, and Do Not Energize.

Inspection

12. Are inspections conducted at least annually by an authorized person (other than the ones using the energy control procedures) to ensure control procedures are being implemented? [29 CFR 1910.147(c)(6)(i)(A)]
13. Is each inspection certified by identifying the machine or equipment on which the energy control procedure was being used, the date of the inspection, the people included in the inspection, and the person performing the inspection? [29 CFR 1910.147(c)(6)(ii)]

Training and Communication

14. Is training provided and documented to ensure that (a) the purpose and function of the energy control procedures are understood, and (b) the knowledge and skills required for the safe application and removal of energy controls are acquired? [29 CFR 1910.147(c)(7)(i)]
15. Is this training repeated periodically when changes or deviations occur in the energy control procedure? [29 CFR 1910.147(c)(7)(iii)

Energy-Isolating Devices

16. Are all energy-isolating devices operated only by authorized persons or under the direct supervision of an authorized person? [29 CFR 1910.147(c)(8)]

Notification of Employees

17. Are all employees notified of the application and removal of lockout and tagout controls whenever such controls directly affect their work activities? [29 CFR 1910.147(c)(9)]

Application of Control

18. Does the application of energy control follow the sequence listed below? [29 CFR 1910.147(d)]

    - Machine or equipment shutdown by authorized personnel
    - Machine or equipment isolation: all energy-isolating devices that are needed shall be located and operated in a manner that isolates the machine or equipment from the energy source(s).
    - Lockout and tagout device application:
        – Lockout devices shall be affixed in a manner that will hold the energy-isolating device in a safe or off position.
        – Tagout devices shall be affixed in a manner that clearly indicates that the operation or movement of energy isolating devices from the safe or off position is prohibited.
        – If a tag cannot be affixed directly to the energy isolating device, the tag shall be located as close as safely possible to the device, in a position that will be immediately obvious to anyone operating the device.
    - Stored energy: following the application of lockout and tagout devices, all hazardous, stored, or residual energy shall be relieved, disconnected, restrained, or otherwise rendered safe.
    - Verification of isolation: before starting work on the isolated equipment or process, an authorized person must verify that isolation and de-energization of the machine or equipment has been accomplished.

19. Has the work area been inspected before the removal of lockout and tagout devices? [29 CFR 1910.147(e)(1)]

20. Has the lockout and tagout device been removed by the person who put it on? [29 CFR 1910.147(e)(3)]

    Note: This rule has some limited exceptions.

21. Are outside servicing personnel informed of the lockout and tagout procedures before equipment is serviced? [29 CFR 1910.147(f)(2)]

Appendix B

CSR-Related Presentation Material

Appendix B
CSR-Related Presentation Material

This Appendix contains extractions of CSR relevant information presented at the DOE OE Energy Storage Safety Workshop (Sandia and PNNL 2014). The speaker and presentation title are shown in bold followed by the summary of information relevant to CSR.

Gina L. Borcra, RA, Chief Sustainability Office, New York Department of Buildings – "Health and Life Safety Considerations for Energy Storage Systems in Buildings"

<u>Existing Resources</u>

- ICC Codes- IBC, IMC and IFC
- NFPA
- NEC
- IEEC and NEMA
- UL, FM, Intertek (UL 94, UL 1973)

<u>Questions and Concerns - Occupant Safety (DOB)</u>:

- How does each technology fall into separation requirements?
- Are there blast concerns?
- What are conditioning requirements for standard operation?
- Requirement for electrical equipment: 3[rd]-party testing, listing
- Is spill containment necessary?

Relevant portions of current NYC Building and Fire Codes

USE AND OCCUPANCY CLASSIFICATION

TABLE 307.7(1)
MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA OF HAZARDOUS MATERIALS POSING A PHYSICAL HAZARD[a, j, m, n, q]

MATERIAL	CLASS	GROUP WHEN THE MAXIMUM ALLOWABLE QUANTITY IS EXCEEDED	STORAGE[b]			USE-CLOSED SYSTEMS[b]			USE-OPEN SYSTEMS[b]	
			Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas SCF (standard cubic foot)‡	Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas SCF (standard cubic foot)‡	Solid pounds (cubic feet)	Liquid gallons (pounds)
Combustible liquid[c, i]	II	H-2 or H-3	N/A	120[d, e]	N/A	N/A	120[d]	N/A	N/A	30[d]
	IIIA	H-2 or H-3		330[d, e]			330[d]			80[d]
	IIIB	N/A		13,200[e, f]			13,200[f]			3,300[f]
Combustible fiber	Loose	H-3	(100)	N/A	N/A	(100)	N/A	N/A	(20)	N/A
	Baled		(1,000)			(1,000)			(200)	
Cryogenics flammable	N/A	H-2	N/A	45[d]	N/A	N/A	45[d]	N/A	N/A	10[d]
Cryogenics, oxidizing	N/A	H-3	N/A	45[d]	N/A	N/A	45[d]	N/A	N/A	10[d]
Explosives	Division 1.1	H-1	1[e, g]	(1)[e, g]	N/A	0.25[g]	(0.25)[g]	N/A	0.25[g]	(0.25)[g]
	Division 1.2	H-1	1[e, g]	(1)[e, g]	N/A	0.25[g]	(0.25)[g]	N/A	0.25[g]	(0.25)[g]
	Division 1.3	H-1 or 2	5[e, g]	(5)[e, g]	N/A	1[g]	(1)[g]	N/A	1[g]	(1)[g]
	Division 1.4	H-3	50[e, g]	(50)[e, g]	N/A	50[g]	(50)[g]	N/A	N/A	N/A
	Division 1.4G	H-3	125[d, e,]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Division 1.5	H-1	1[e, g]	(1)[e, g]	N/A	0.25[g]	(0.25)[g]	N/A	0.25[g]	(0.25)[g]
	Division 1.6	H-1	1[d, e, g]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Flammable gas	Gaseous	H-2	N/A	N/A	1,000[d, e]	N/A	N/A	1,000[d, e]	N/A	N/A
	liquefied			30[d, e]	N/A		30[d, e]	N/A		
Flammable liquid[c, k]	IA[o]	H-2 or H-3	N/A	30[d, e]	N/A	N/A	30[d]	N/A	N/A	10[d]
	IB and IC			120[d, e]			120[d]			30[d]
Combination flammable liquid (IA[o], IB, IC)	N/A	H-2 or H-3	N/A	120[d, e, h]	N/A	N/A	120[d, h]	N/A	N/A	30[d, h]
Flammable solid										
Pigs, ingots, billets, heavy castings	N/A	H-3	1,000[d,c]	N/A	N/A	1,000[d,c]	N/A	N/A	1,000[d,c]	N/A
Light castings, light metallic products			125[d, e]			125[d, e]			125[d, e]	
Scraps, shavings, powders, dusts			1[d,c]			1[d,c]			1[d,c]	
Organic peroxide	Unclassified Detonable	H-1	1[e, g]	(1)[e, g]	N/A	0.25[g]	(0.25)[g]	N/A	0.25[g]	(0.25)[g]
	I	H-2	5[d, e]	(5)[d, e]	N/A	1[d]	(1)	N/A	1[d]	(1)[d]
	II	H-3	50[d, e]	(50)[d, e]	N/A	50[d]	(50)[d]	N/A	10[d]	(10)[d]
	III	H-3	125[d, e]	(125)[d, e]	N/A	125[d]	(125)[d]	N/A	25[d]	(25)[d]
	IV	N/A	NL	NL	N/A	NL	NL	N/A	NL	NL
	V	N/A	NL	NL	N/A	NL	NL	N/A	NL	NL
Oxidizer	4	H-1	1[e, g]	(1)[e, g]	N/A	0.25[g]	(0.25)[g]	N/A	0.25[g]	(0.25)[g]
	3[k]	H-2 or H-3	10[d, e]	(10)[d, e]	N/A	2[d]	(2)[d]	N/A	2[d]	(2)[d]
	2	H-3	250[d, e]	(250)[d, e]	N/A	250[d]	(250)[d]	N/A	50[d]	(50)[d]
	1	N/A	4,000[e,f]	(4,000)[e,f]	N/A	4,000[f]	(4,000)[f]	N/A	1,000[f]	(1,000)[f]
Oxidizing gas	Gaseous	H-3	N/A	N/A	1,500[d, e]	N/A	N/A	1,500[d, e]	N/A	N/A
	liquefied		N/A	15[d, e]	N/A	N/A	15[d, e]	N/A	N/A	N/A

(continued)

2008 NEW YORK CITY BUILDING CODE

TABLE 307.7(2)
MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA OF HAZARDOUS MATERIAL POSING A HEALTH HAZARD[a,b,c,j,k]

MATERIAL	STORAGE[d]			USE-CLOSED SYSTEMS[d]			USE-OPEN SYSTEMS[d]	
	Solid pounds[e, f]	Liquid gallons (pounds)[e, f]	Gas SCF[e] (standard cubic foot)$	Solid pounds[e]	Liquid gallons (pounds)[e]	Gas SCF[e] (standard cubic foot)$	Solid pounds[e]	Liquid gallons (pounds)[e]
Corrosive	5,000	500	810[f, g]	5,000	500	810[f, g]	1,000	100
Highly toxic	10	(10)[i]	20[h]	10	(10)[i]	20[h]	3	(3)[i]
Toxic	500	(500)[i]	810[f]	500	(500)[i]	810[f]	125	(125)[i]

For SI: 1 cubic foot = 0.028 m^3, 1 pound = 0.454 kg, 1 gallon = 3.785 L.

a. For use of control areas, see Section 414.2.
b. In retail and wholesale sales occupancies, the quantities of medicines, foodstuffs, consumer or industrial products, and cosmetics, containing not more than 50 percent by volume of water-miscible liquids and with the remainder of the solutions not being flammable, shall not be limited, provided that such materials are packaged in individual containers not exceeding 1.3 gallons.
c. For storage and display quantities in Group M and storage quantities in Group S occupancies complying withthe *New York City Fire Code.*
d. The aggregate quantity in storage, handling and use shall not exceed the quantity listed for storage.
e. Quantities shall be increased 100 percent in buildings equipped throughout with an approved automatic sprinkler system in accordance with Section 903.3.1.1. Where Note f also applies, the increase for both notes shall be applied accumulatively.
f. Quantities may be increased 100 percent when stored in approved storage cabinets, gas cabinets or exhausted enclosures as specified in the *New York City Fire Code.* Where Note e applies, the quantities increased shall be as set forth in both notes.
g. A single container of anhydrous ammonia containing not more than 150 pounds in a single control area in a nonsprinklered building shall be considered a maximum allowable quantity. Two containers of anhydrous ammonia, each containing not more than 150 pounds, shall be considered a maximum allowable quantity provided the building is equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1.
h. Allowed only when stored in approved exhausted gas cabinets or exhausted enclosures as specified in the *New York City Fire Code.*
i. Quantities in parenthesis indicate quantity units in parenthesis at the head of each column.
j. For gallons of liquids, divide the amount in pounds by 10 in accordance with the *New York City Fire Code.*
k. The maximum allowable quantities shall be limited by Section 419 for chemical laboratories classified as Occupancy Group B and operating as nonproduction facilities for testing, research, experimental, instructional or education purposes.

Is the chemistry Corrosive, Highly toxic, or Toxic?

CORROSIVE MATERIAL. A material that causes full thickness destruction of human skin at the site of contact within specified periods of time when tested by methods described in DOTn 49 CFR § 173.136 and 173.137. Liquid that has a severe corrosion rate on steel or aluminum based on the criteria in DOTn 49 CFR § 173.173(c)(2) is also a corrosive material.

HIGHLY TOXIC MATERIAL. A material that is lethal at the following doses or concentrations:

1. A chemical that has a median lethal dose (LD50) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each; or
2. A chemical that has a median lethal dose (LD50) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each; or
3. A chemical that has a median lethal concentration (LC50) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 grams each.

TOXIC MATERIAL. A chemical that is lethal at the following doses or concentrations:

1. A chemical that has a median lethal dose (LD50) of more than 50 milligrams per kilogram, but not more than 500 milligrams per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each; or
2. A chemical that has a median lethal dose (LD50) of more than 200 milligrams per kilogram but not more than 1,000 milligrams per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each; or
3. A chemical that has a median lethal concentration (LC50) in air of more than 200 parts per million but not more than 2,000 parts per million by volume of gas or vapor, or more than 2 milligrams per liter but not more than 20 milligrams per liter of mist, fume or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 grams each.

Exception: For purposes of this code, chlorine shall be classified as a highly toxic material.

Questions and Concerns – Fire Safety:

- What types of suppression systems are required for each battery type? Are hazardous vapors or gasses generated?
- What operational changes are necessary for the FDNY depending on the chemical composition of the battery type or hazard Classifications?
- Notification system requirements, internal and external to the building, alarm requirements?

[F] TABLE 414.2.2
DESIGN AND NUMBER OF CONTROL AREAS

FLOOR LEVEL		PERCENTAGE OF THE MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA[a]	NUMBER OF CONTROL AREAS PER FLOOR[b]	FIRE-RESISTANCE RATING FOR FIRE BARRIERS IN HOURS[c]
Above grade	Higher than 9	5	1	2
	7-9	5	2	2
	6	12.5	2	2
	5	12.5	2	2
	4	12.5	2	2
	3	50	2	1
	2	75	3	1
	1	100	4	1
Below grade	1	75	3	1
	2	50	2	1
	Lower than 2	Not Allowed	Not Allowed	Not Allowed

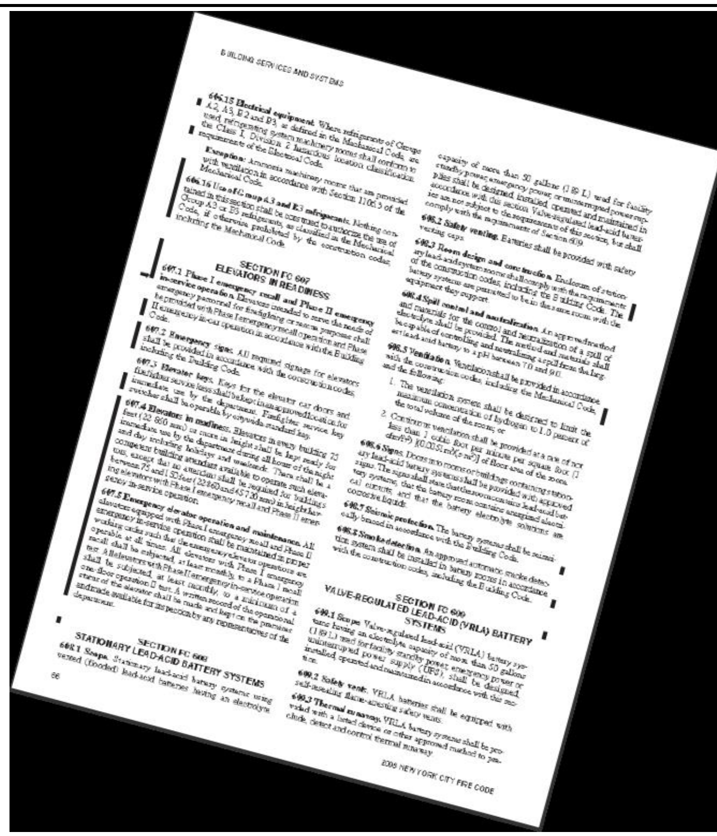
a. Percentages shall be of the maximum allowable quantity per control area shown in Tables 307.7(1) and 307.7(2), with all increases allowed in the notes to those tables.

b. There shall be a maximum of two control areas per floor in Group M occupancies and in buildings or portions of buildings having Group S occupancies with storage conditions and quantities in accordance with Section 414.2.4.

c. Fire barriers shall include walls and floors as necessary to provide separation from other portions of the building.

Depending on the battery type, can the desired storage capacity be achieved within the existing control area requirements?

- Some recognition of stationary Battery Systems allows for their installation in NYC
- Fire Code update coming next month


BUILDING SERVICES AND SYSTEMS

SECTION FC 607
ELEVATORS IN READINESS

SECTION FC 608
STATIONARY LEAD-ACID BATTERY SYSTEMS

SECTION FC 609
VALVE-REGULATED LEAD-ACID (VRLA) BATTERY SYSTEMS

2008 NEW YORK CITY FIRE CODE

Questions and Concerns

- Environmental Safety (Department of Environmental Protection)
- Community Right-to-Know
- What are the potential airborne or water-borne hazards?

Douglas Danley, Technical Liaison to Cooperative Research Network (CRN), Contractor at NRECA – "Energy Storage at Electric Cooperatives Overview and Safety"

•Adherence to IEE 1547, appropriate UL listings, NEC, NESC and other standards
•GIS integration – as energy storage systems become more common, it is important to know where they are.
•Documented procedures (lockouts, etc.) for outage events

Fire Safety

•Consider whether it is better to put a large system inside a warehouse type structure, or install as smaller, individual modules.

•Fixed Extinguishing Systems
•Are they appropriate for the planned facility?
•Easier for containerized vs. warehouse systems
•Need to address both electrical and chemical fires

- Consider what is "downwind" of the site. What would the effect of a fire with potentially noxious fumes be?
- Work with the local fire authorities in advance to make sure they understand what is installed, and what plans have been developed to deal with fire emergencies.

Ryan Bowles, Corporate Environment Services, Duke Energy – "Notrees Windpower, LP and Battery Energy Storage System (BESS)"

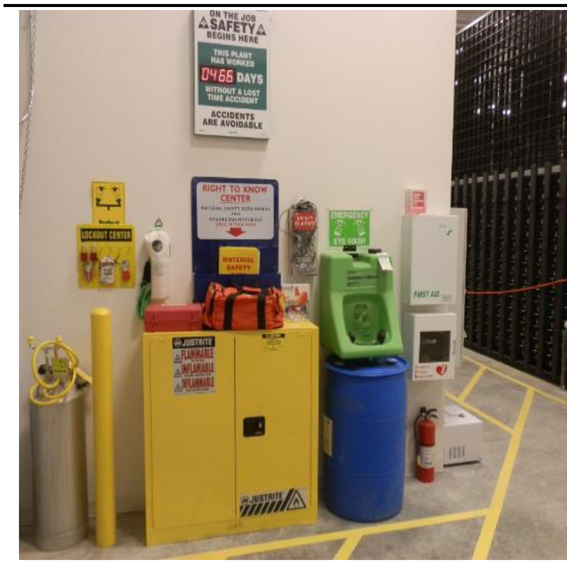
EHS Issues/Concerns During Construction and Commissioning

- Each construction project will have its own unique hazards as a result of the environment, the size of the project and/or unique work processes associated with the project. Below is a list of items we made sure that the general contractor and their sub-contractors had in place prior to work beginning. In short, a site specific construction and commissioning EHS Plan.
  - Company EHS Philosophy
  - Basic Site Safety/Training requirements
  - Basic Environmental requirements
  - Pre-Job briefing and Hazard Recognition (JHA's)
  - Accountability/Discipline
  - Personal Protective Equipment requirements
  - Incident/Injury reporting and Investigation requirements
  - Site emergency plan and procedures
  - Hazard Communication/SDS/Right to Know
  - Blood-borne Pathogen Program
  - Substance Abuse Program
  - Equipment Safety/Operator Qualifications
  - Rigging and Lifting Program
  - Critical lift procedures/Requirements
  - Fall Prevention/Protection Program/Elevated Personnel Lifts
  - Permitting Procedures
  - Fire prevention/protection
  - Electrical Safety/Lock out/Tag out
  - Confined space entry
  - Housekeeping
  - Compressed gas/welding/cutting
  - Safety related warning signs and Barricades
  - Scaffold Safety/Tagging
  - Excavation and Trenching Safety
- Arc Flash, Arc Flash Study and appropriate Arc Flash Labeling on all applicable equipment.
- Stormwater Permit Coverage (if applicable), Stormwater Pollution Prevention Plan (SWP3) and BMPs
- Spill Prevention, Control and Countermeasures (SPCC) Plan for Construction
- Wildlife Issues – Snakes, Spiders and other Wildlife
- Waste Management, Chemical Control and Inventories
- Inclement Weather – Tornados, Lightning and Severe Hot or Cold Weather

Primary EHS Issues/Concerns During Operations

➢ Primary Operations and BESS EHS Issues/Concerns

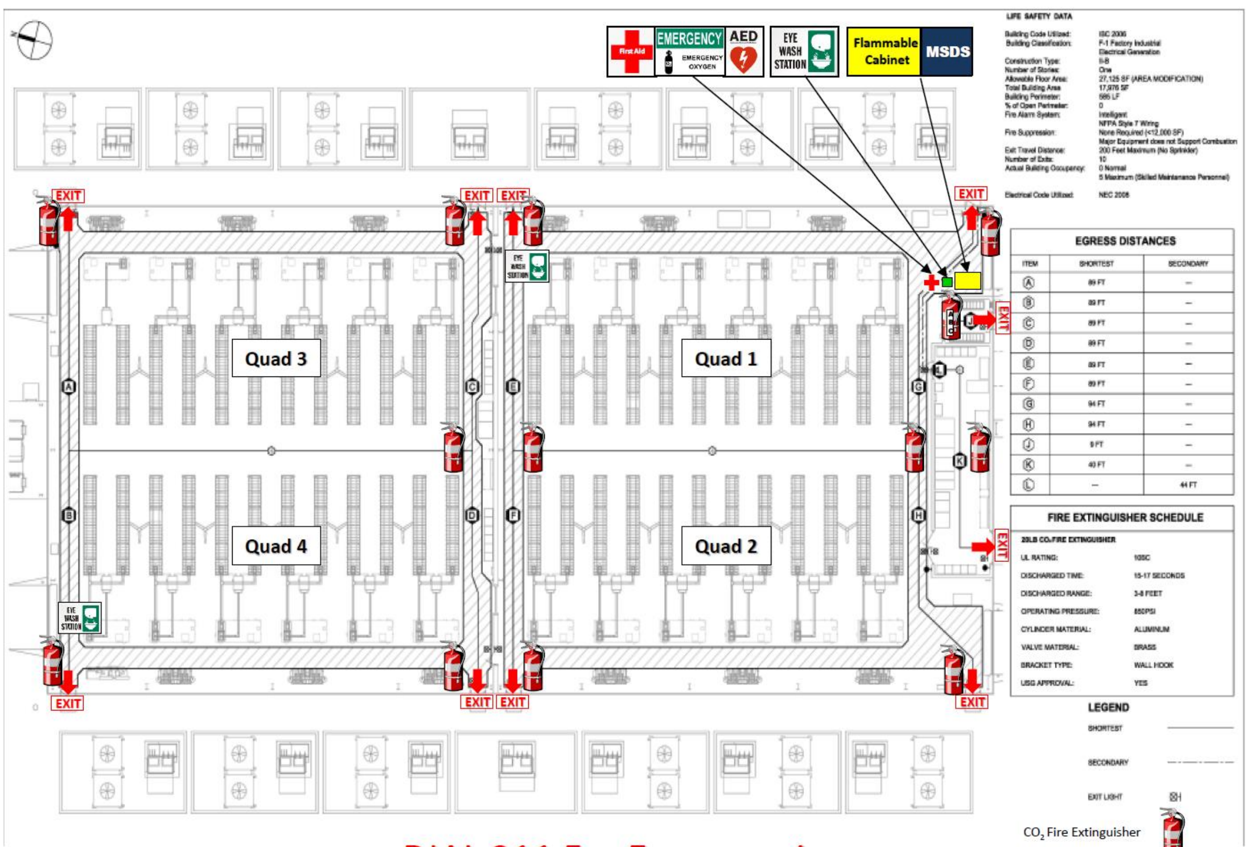
- High Voltage Hazards
- Electrical Safety, Arc Flash and Arc Flash PPE
- Lock Out/Tag Out (LOTO) Program
- BESS Building Fire Suppression and Detection
- Emergency Ingress and Egress
- Emergency Response, Medical Emergencies and Pre-Incident Planning/Coordination with Local Emergency Responders
- Personal Protective Equipment (PPE)
- Ergonomics, Battery Replacement and Work From Elevated Platforms
- Waste Management, Chemical Control and Inventories
- Hazard Communication/SDS/Right-to-Know
- Spill Prevention, Control and Countermeasures (SPCC) Plan for Operations



BESS Safety Area | FE-25 Clean Agent Fire Suppression System

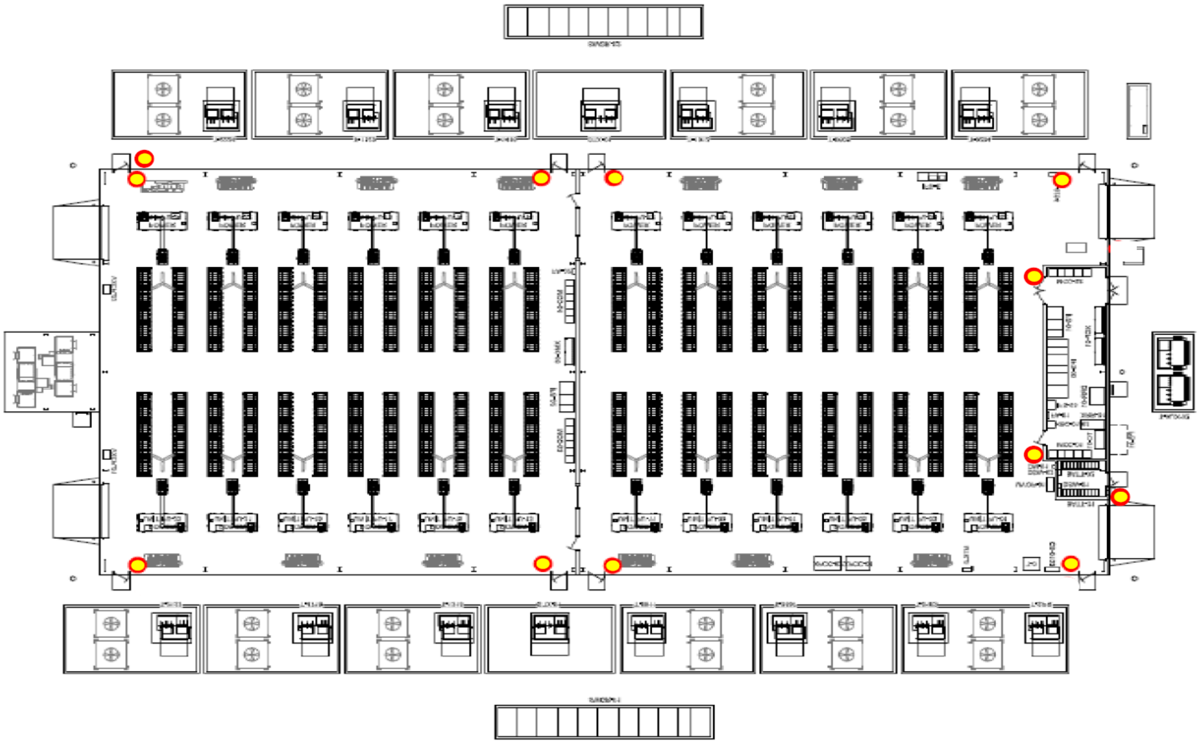
FE-25 Pre-Action Alarm Fike Detection System

BESS Building Life Safety / Emergency Evacuation Diagram – Notrees, TX



DIAL 911 For Emergencies

BESS Building E-Stop Switch Locations



Tier II Reporting Matrix for Duke Notrees BESS Building - PowerCell Batteries

Component	CAS #	Weight (in lbs)	% Weight by Volume	# of Batteries	Total Weight (in lbs)	EPCRA 311/312 TPQ (lbs)	SERC / LEPC Notification	Tier II Report Required
Lead	7439-92-1	11.50	20%	29,220	336,030	10,000	YES	YES
Lead Tetraoxide (Red Oxide)	1314-41-6	13.27	23%	29,220	387,749	10,000	YES	YES
Lead Monoxide (Litharge)	1317-36-8	10.50	18%	29,220	306,810	10,000	YES	YES
Polypropylene Case	9003-07-0	1.00	2%	29,220	29,220	10,000	YES	YES
Sulfuric Acid*	7664-93-9	15.20	26%	29,220	444,144	500	YES	YES
AGM	N/A	1.60	3%	29,220	46,752	N/A	N/A	NO
Wax	N/A	3.85	7%	29,220	112,497	N/A	N/A	NO
Other Components	N/A	1.10	2%	29,220	32,142	N/A	N/A	NO
			100%		1,695,344			

NOTES:

Weight of XP Battery	58	
# of Batteries in BESS	**29,220**	(Includes 420 spares on average - 14 pallets of 30 batteries)
Total Weight	1,694,760	

* Electrolyte contains 30% sulfuric acid / 70% DI Water. Adjusted weight of H_2SO_4 is 133,243 lbs.

Notes:

Lead Componds (Oxides)

Red Oxide (redish-orange powder) contains 90% lead tetraoxide and 10% lead monoxide

Litharge contains 100% lead monoxide

Polypropylene Case added to Tier 2 due hazardous decomposition during fire. In and of itself, our battery cases are not hazardous under normal operating conditions.

Facility Address: Duke Energy Notrees Wind Farm
19991 Sheep Pasture Road
State Highway 302 West
Notrees, TX 79759

Matt Paiss, Fire Captain, Bureau of Field Operations, San Jose Fire Department – "Safety Needs & Challenges for First Responders Or…. You want to put what where?!"

Safety Concerns	Results of Concerns
1. Limited roof access	1. Vague installation guidelines
2. Confusing or non-existent labeling	2. Local Fire Marshal requirements lacking technical knowledge
3. Lack of power isolation features	3. Reduction of available roof space
4. Inadequate fault detection/interruption	4. Inconsistent regulatory path
5. Improper grounding	5. Permit delays
6. Wire management issues	6. Increased BOS costs

Recommendations

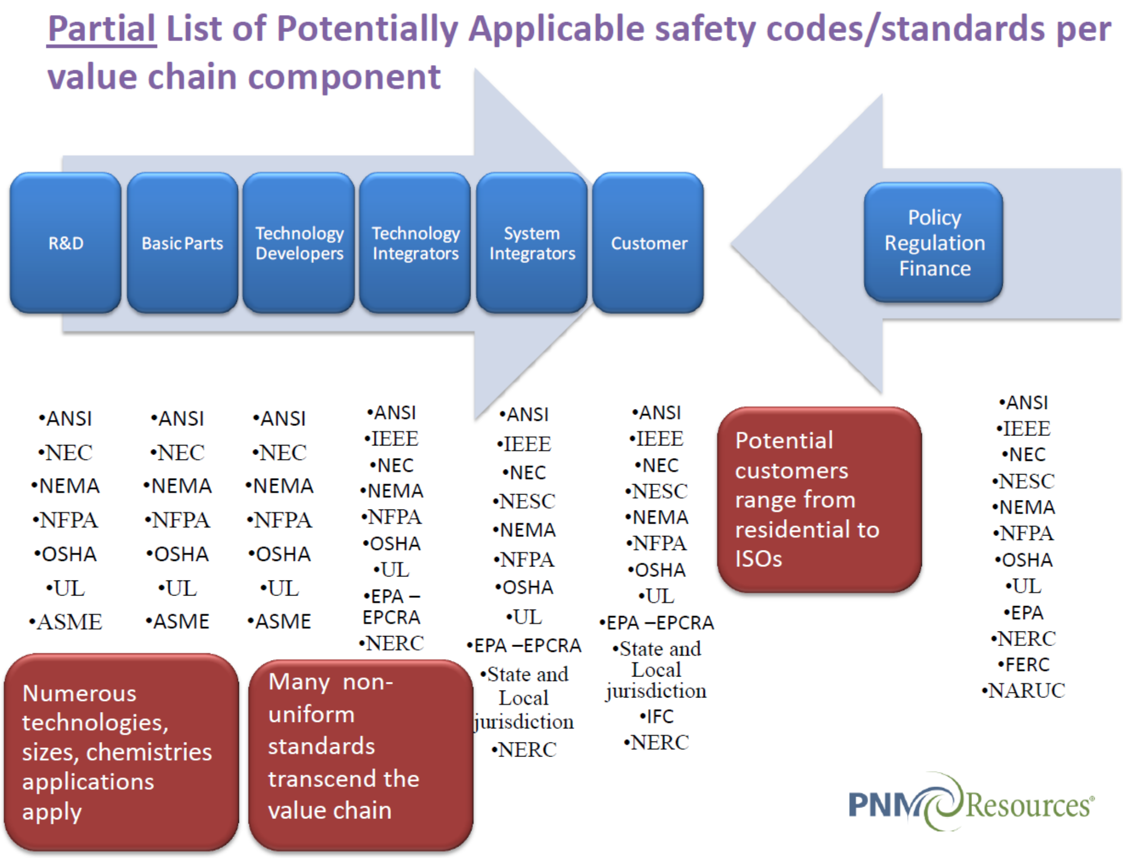
- Clear Markings
  – Identification, location & disconnects
- Adequate Clearances & Engineering
  – Access, seismic, fire loading, and structural
- Appropriate Fire Protection Systems
  – Agents & application recommendations
- Emergency Discharge
  – Post damage response & handling

Haresh Kamath, Program Manager, Energy Storage and Distributed Generation, Electric Power Research Institute (EPRI) – "Perspectives on Needs and Challenges for Energy Storage Safety"

Product Safety Best Practices

- Product must demonstrably meet appropriate safety codes for the jurisdiction
  –NFPA, OSHA, ANSI, IEEE, UL, and other standards bodies as appropriate
  –Local jurisdictions often have their own codes
- Product must have an appropriate Failure Modes and Effects Analysis (FMEA)
- Product must have appropriate safety mechanisms and must have a documented process for how those mechanisms are applied
- Product must have good documentation for both standard operating practice and contingency measures

Steve Willard, P.E., PNM Resources – “Risk and Safety Issues and Solutions from Recent Storage Installations”



Michael A. Stosser, Energy Attorney, Sutherland Asbill & Brennan LLP – “What Are the Risks and What Regulations Should We Consider?”

Development of Testing Standards

- Most issues occur with multi-cell batteries, because of thermal instability of active materials in the battery and interaction at high temperatures
- Global independent organizations have developed testing protocols, but studies are not complete:
  - International Electrotechnical Commission (Safety requirements)
  - Underwriters Laboratories (UL) testing for batteries
  - Institute of Electrical and Electronic Engineers (cell batteries) Electrical Manufacturers Association(safety standards)
  - Society of Automotive Engineers (electric vehicles)
  - United Nations (transportation of dangerous goods)
  - Japanese Standards Association (electric vehicles)

- Battery Safety Organisation (electric vehicles and Lithium-ion)
- International Electrochemical Commission (Electrical Energy Storage Systems) (TC 120 for smart grid integration)

Common Product Safety Tests for Lithium-ion Batteries

- The most commons safety tests are designed to assess specific risk from electrical, mechanical, and environmental conditions
  - Electrical
    - Test of current flow
    - Abnormal charging test, overcharging and charging time
    - Forced discharge
  - Mechanical
    - Crush test
    - Impact test
    - Shock test
    - Vibration test
  - Environmental
    - Heating test
    - Temperature Cycling test, testing each cell
    - Low pressure altitude test
  - Various UL tests

Occupational Safety and Health Administration (OSHA) - Safety

- Currently, OSHA captures the primary safety regulations that would relate to energy storage installation and operation of facilities
  - Electricity has long been recognized as serious workplace hazard
  - OSHA currently has regulations that address, among others:
    - Construction of electric equipment
    - Eye and face protection
    - Respiratory Protection
    - Safety
  - 25 states, Puerto Rico and the Virgin Islands have OSHA-approved state plans and have adopted virtually all federal guidelines, some states have adopted different standards

Issues We Should Consider for Future Regulation – Moving Forward

- Need to conduct a comprehensive review of federal, state and local regulations relating to the construction and operation of energy storage technologies, primarily those using batteries and electric capacitors

- OSHA
- National Renewable Energy Lab (NREL) Guidelines on Safety Hazards of Batteries
- Construction, including applicable local building codes
- Interconnection to utilities, and the North America Reliability Corporation (NERC)
- Insurance
- Permitting
- Environmental impacts

Issues to Consider for Future Regulation

- Need to develop regulations for installation of energy storage systems that address issues prior to installation:
  - Compliance with UL specifications for batteries and related equipment
  - Fire testing
  - Packing, handling and transportation of batteries
  - Storage of batteries, especially if bulk stored in corrugated boxes
- Electric Power Research Institute (EPRI)
  - Developing an industry forum to study safety regulations for installation of electric energy storage systems
- National Electrical Installation Standards (NEIS) and National Electrical Contractors Association (NECA)
  - Developing standards for the installation of energy storage systems

Issues We Should Consider for Future Regulation

- Need to develop regulations for energy storage systems after installation that include standard operating procedures and guidelines for safety, response, containment, and aftermath
- Need to focus on regulations that address prevention:
  - Provide specialized safety training for employees, including battery and electric capacitor fire behavior
  - Create compliance programs and a culture of safety
  - Install pre-programmed warning signals
  - Provide periodic OSHA instructions on employee safety standards for storage facilities
  - Develop rules for containment and suppression systems for storage of batteries and related equipment
  - Establish procedures for, and train, first responders to deal specifically with fire behavior of energy storage equipment, that address battery and fire behavior

- Mandate the installation of specialized fire extinguishers - both inside a storage building and in local fire departments
- Establish clear procedures for response and containment
- Mandate training exercises and emergency simulations
- Develop regulations for disposal, recycling, and clearing debris

Issues We Should Consider for Future Regulation

- Potential Environmental Consequences
  - The EPA and local environmental agencies set environmental standards regarding safety for workers and first responders after incidents – when is it safe to return or remove debris
  - In cases where there are no such regulations, they should be written and implemented
  - First responders may be subject to tort actions that result from their actions
  - First responders can use The Comprehensive Environmental Response, Compensation, and Liability Act's (CERCLA's) Good Samaritan provision as defenses to such an action if they cause chemicals to run off, harming the environment
  - These defenses must be available outside of CERCLA

Laurie Florence, Principal Engineer, UL, LLC – "Energy Storage System Safety – Standards & Certification"

Overview of Current Standards

Document No.	Title
ANSI UL 1973	Batteries for Use in Light Electric Rail (LER) and Stationary Applications
UL Subject 9540	Safety for Energy Storage Systems and Equipment (under development)
IEEE 3575	Guide for the Protection of Stationary Battery Systems
IEEE 1679	Recommended Practice for the Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications
IEC 62485-2	Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries
IEC CD 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 (under development)
IEC NP 62897	Stationary Energy Storage Systems with Lithium Batteries – Safety Requirements (under development)

Overview of Current Standards

UL 1973

- Scope:
  - Stationary EESSs – safety standard
    - Batteries - non chemistry specific
    - Electrochemical capacitors

UL Subject 9540

- Scope
  - Energy Storage Systems – safety standard
    - Electrochemical
    - Chemical
    - Mechanical
    - Thermal

IEC 62485-2

- Scope
  - Stationary Batteries – safety standard
    - Lead acid and Nickel Batteries

IEC CD 62619 & IEC NP 62897

- Scope:
  - Stationary lithium ion batteries – safety standards

IEEE 3575

- Scope
  - Stationary batteries – safety guide
    - Lead Acid
    - Nickel Cadmium

IEEE 1679

- Scope
  - ES characterization (performance, life, safety consideration) – Rec. practice
  - Emerging technologies:
    - electrochemical, kinetic, electrostatic, thermal, etc.

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UL 1973

Construction Criteria

- Materials
- Enclosures
- Electrical Spacings
- Electrical Wiring and Controls
- FMEA and Functional Safety
- Thermal management systems
- Cells and electrochemical capacitors
  - Lithium ion, nickel, sodium, LA, flow, electrochemical capacitors
- Markings and Instructions

Tests:

Electrical

- Overcharge
- Short Circuit
- Overdischarge Protection
- Imbalanced Charging
- Temperature
- Dielectric Withstand
- Grounding Continuity
- Failure of Cooling/Thermal Stability System

Mechanical Tests

- Enclosure Tests
- Drop Test

Environmental tests

- External Fire
- Internal Fire
- IP Exposure Tests

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UL Subject 9540

Scope

- Safety
- Energy Storage Systems for connection to utility or local grids
- Includes different technologies:
  - Electrochemical (batteries, electrochemical capacitors and hybrid systems)
  - Chemical (hydrogen storage with fuel cell system
  - Mechanical (fly wheels, etc.)
  - Thermal (CAES, etc.)

Construction

- Reference to technology standards & applicable codes
- Enclosures/guarding of hazardous parts
- Electrical wiring connections
- Connection to the grid
- Piping and pressure vessels
- Fuel connections and controls
- Hazardous locations issues
- Fire suppression
- Markings & signage
- Instructions

Tests

- Dielectric voltage withstand
- Grounding check
- External leakage test (fuel leakage)
- Hazardous moving parts containment

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UL Subject 9540

ES Technology References

Batteries
- UL 1973

Electrochemical Capacitors
- UL 1973 and UL 810A

Fuel Cell Systems
- CSA-America FC1

Hydrogen storage and equipment
- NFPA 2 (ISO 22734-1, -2)

Engine generators
- UL 2200

Flywheels
- SAE, AIAA, ISO

Equipment standard references

Inverters
- UL 1741, IEEE 1547 series

Electrical equipment
- NFPA 70, IEEE C2

Functional safety
- IEC 61508, IEC 60730-1, UL 991/1998

Pressure vessels
- ASME B & PV Code

Piping systems
- ASME B31 series

Hazardous Locations
- NFPA 70, NFPA 497

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UL Standards Development Process

Outline of Investigation, UL Subject 9540 published

- Standard that has not gone through consensus process
- Can be used for certification

→

Establishment of UL Standards Technical Panel (STP)

- Balanced membership in accordance with ANSI Guidelines

→

Publish Bulletin Subject 9540

- Based upon OOI UL subject 9540
- Reviewed and balloted by UL Subject 9540 STP members
- Preliminary review and ballot review

→

Publication of ANSI UL 9540 Standard

- Consensus achieved on ballot UL subject 9540

Certification Programs

UL ES Certification Programs

- UL Certification Programs including evaluation and ongoing production evaluation
- UL 1973
  - BBFX, BBFX2, BBFX7, BBFX8
- UL Subject 9540
- To be set up after publication

UL Field Evaluation Program

- Applied to one product (not ongoing production)
- Often conducted after installation of production

IECEE Certification Program

- CB Scheme
  - Applies to IEC standards determined to be part of the CB Scheme
  - Does not include ongoing production inspections
  - CE marking is a manufacturer's self declaration
- ETF13 BATT
  - IEC 62133
  - IEC 60896-1
  - IEC 60896-21
  - IEC 60896-22
  - (IEC 62619, 62485-2, etc.)
  - Includes IEC 62282 fuel cell standards
- CE marking is mfg.'s self cert. mark

Underwriters Laboratories

FIELD EVALUATED PRODUCT

PNNL-23618

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