

Energy Storage Systems Safety Roadmap

DOE OE Focus on Codes and Standards – July 2018

The goal of the DOE OE Energy Storage System Safety Roadmap¹ is to *foster confidence in the safety and reliability of energy storage systems.*

There are three interrelated objectives to support the realization of that goal: research, codes and standards and communication/coordination. The objective focused on codes and standards is.....

To apply research and development to support efforts that are focused on ensuring that codes and standards are available to enable the safe implementation of energy storage systems in a comprehensive, non-discriminatory and science-based manner.

The following activities support that objective and realization of the goal:

- Review and assess codes and standards which affect the design, installation, and operation of energy storage systems (ESS).
- Identify gaps in knowledge that require research and analysis that can serve as a basis for criteria in those codes and standards.
- Identify areas in codes and standards that are potentially in need of revision or enhancement and can benefit from activities conducted under research and development.
- Develop input for new or revisions to existing codes and standards through individual stakeholders, facilitated task forces, or through laboratory staff supporting these efforts.

The purpose of this document is to support the above activities by providing information on efforts being conducted by U.S. standards developing organizations (SDOs) and other entities that are focused on ESS safety.

The information is organized relative to the scope of each document and energy storage systems from the “macro to the micro” (e.g., from overarching covering considerable scope to covering a single system component of an energy storage system). Note also that more macro documents are likely to adopt by reference more micro documents.

Changes in current activity from the prior edition are shown in bold italics. Time-sensitive items (e.g., those having a schedule/due date) are in bold type and highlighted in yellow.



- Overarching Codes and Standards – the built environment at large that includes but is not limited to ESSs.
- Codes and Standards for ESS Installations – the installation of the ESS relative to other systems and parts of the built environment.
- Codes and Standards for a Complete ESS.
- Codes and Standards for components associated with the ESS.

¹ DOE OE Energy Storage Systems Safety Roadmap, PNNL-SA-126115 | SAND2017-5140 R https://www.sandia.gov/ess-ssl/publications/EnergyStorage_safetyroadmap_2017.pdf

OVERARCHING CODES AND STANDARDS

	
DNV GL – www.dnvgl.com/rules-standards/	
Document:	DNVGL-RP-0043, Safety, Operation, and Performance of Grid-Connected Energy Storage Systems (GRIDSTOR)
ESS relevance:	The objective of GRIDSTOR is to provide a comprehensive set of recommendations for grid-connected energy storage systems. It aims to be valid in all major markets and geographic regions, for all applications, on all levels from component to system, covering the entire life cycle. End users, operators, and other stakeholders can find specific guidance in the document and references to other relevant standards, codes, and guidelines.
Current activity:	Supporting the second edition of GRIDSTOR released in September 2017. See https://www.dnvgl.com/services/gridstor-recommended-practice-for-grid-connected-energy-storage-52177 for more information.
Date of next edition:	TBD
Document:	HEATSTOR Joint Industry Project (JIP)
ESS relevance:	The focus of HEATSTOR is on safety, operation, and performance aspects of heat storage systems. The objective of this document is to accelerate implementation of heat storage systems through creation of a globally recognized recommended practice for system safety, operation and performance.
Current activity:	An invitation is out to join the consortium that will develop HEATSTOR. For more information see https://www.dnvgl.com/article/heatstor-joint-industry-project-86759 .
Date of publication:	TBD

	
International Code Council (ICC) – www.iccsafe.org https://www.iccsafe.org/codes-tech-support/codes/code-development/current-code-development-cycle/	
Document:	2018 International Fire Code (IFC)
ESS relevance:	Chapter 12 of the IFC covers energy systems and Section 1206 in that chapter covers electrical energy storage systems.
Current activity:	<i>Updates to the report of the committee action hearing were posted June 18, 2018. Public comments received at ICC, which include public comments related to energy storage systems submitted by the ICC Fire Code Action Committee, are being compiled and the public comment agenda will be posted August 31, 2018.</i> The final action hearings following that public comment agenda will occur October 24 to 31, 2018 in Richmond, Virginia. See https://www.iccsafe.org/codes-tech-support/codes/code-development/current-code-development-cycle/ for more information.
Date of next edition:	2021
Document:	2018 International Residential Code (IRC)
ESS relevance:	A section of the IRC covers energy storage systems.
Current activity:	See current activity under the IFC above relative to the posting of proposed changes and committee action hearings.
Date of next edition:	2021



International Code Council (ICC) – www.iccsafe.org
<https://www.iccsafe.org/codes-tech-support/codes/code-development/current-code-development-cycle/>

Document:	2018 International Building Code (IBC)
ESS relevance:	Provides a basis for adoption and application of other standards and ICC model codes.
Current activity:	See current activity under the IFC above relative to the posting of proposed changes and committee action hearings.
Date of next edition:	2021
Document:	2018 International Mechanical Code (IMC)
ESS relevance:	Includes basic requirements for stationary fuel cell power systems and criteria for ventilation and exhaust of spaces.
Current activity:	See current activity under the IFC above relative to the posting of proposed changes and committee action hearings.
Date of next edition:	2021



IEEE – www.ieee.org
<http://standards.ieee.org/about/nesc/>

Document:	IEEE C2-17, National Electric Safety Code (NESC)
ESS relevance:	Covers electrical safety for utility systems and equipment.
Current activity:	The final date to receive change proposals from the public for revision of the 2017 edition leading to the 2022 edition was July 16, 2018. See http://standards.ieee.org/about/nesc/ and http://standards.ieee.org/about/nesc/nesc_2022_schedule.pdf for more information. NESC Sub-Committees will meet in September and October of 2018 to consider all change proposals and prepare recommendations.
Date of next edition:	2022.
Activity:	IEEE Energy Storage and Stationary Battery Committee (ESSB)
ESS relevance:	This is a growing subcommittee of the power and energy society that manages many of the standards related to energy storage and battery technologies. http://sites.ieee.org/pes-essb/
Current activity:	An ESSB task force on codes and standards is organizing their future efforts associated with development of IEEE standards related to energy storage systems and batteries as well as laying out their involvement in the development of codes and standards by other organizations that are related to energy storage systems and batteries.



National Fire Protection Association (NFPA) – www.nfpa.org

Document:	NFPA 1-18, Fire Code
ESS relevance:	Chapter 52 (new in the 2018 edition) includes requirements related to the installation of energy storage systems. Requirements recognize both established battery technologies and new energy storage technologies. Provisions apply to new and existing energy storage system applications.
Current activity:	The public input closing date was June 27, 2018. Six public comments were submitted to Chapter 52 on energy storage systems. <i>The first draft meeting to act on public inputs will be held September 18 and 19, 2018, and the first draft report is scheduled to be posted on March 27, 2019.</i> See https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1&tab=nextedition for more information.
Date of next edition:	2021
Document:	NFPA 70-17, National Electrical Code (NEC)
ESS relevance:	Article 706 (new in the 2017 edition) applies to energy storage systems and Article 480 remains applicable to batteries, in addition to other criteria in the NEC relevant to electrical equipment and installations.
Current activity:	<i>The first draft report has been posted and has a second draft public comment closing date of August 30, 2018. See https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=70&tab=nextedition for more information.</i>
Date of next edition:	2020
Document:	NFPA 5000-18, Building Code
ESS relevance:	Provides a basis for adoption and application of other standards.
Current activity:	<i>The first draft meeting is scheduled for December 4 and 5, 2018, and the first draft report is scheduled to be posted on February 27, 2019.</i>
Date of next edition:	2021

CODES AND STANDARDS FOR ESS INSTALLATIONS

	<p>FM Global – http://www.fmglobal.com https://www.fmglobal.com/research-and-resources/fm-global-data-sheets</p>
Document:	FM Global Property Loss Prevention Data Sheet # 5-33, Electrical Energy Storage Systems
ESS relevance:	<p>The data sheet describes loss prevention recommendations for the design, operation, protection, inspection, maintenance, and testing of electrical energy storage systems, which can include batteries, battery chargers, battery management systems, thermal management and associated enclosures and auxiliary systems. The focus of this data sheet is primarily on lithium-ion battery technology.</p>
Current activity:	Work to update the data sheet via an interim revision is planned for 2018.
Date of next edition:	Publication of an interim revision is expected in 2019.

	<p>IEEE – www.ieee.org</p>
Document:	IEEE 1635-12/ASHRAE Guideline 21-12, Guide for Ventilation and Thermal Management of Batteries for Stationary Applications
ESS relevance:	Covers how energy storage systems are provided appropriate ventilation and thermal management.
Current activity:	A revised edition of the standard, based on input from the public review is at IEEE RevCom, who makes recommendations for approval or disapproval of standards submitted to the IEEE-SA Standards Board. Their approval or adoption is focused on whether IEEE-SA Standards Board procedural requirements have been satisfied.
Date of next edition:	TBD, however, a December 2017 draft is available from IEEE.
Document:	IEEE P1578 (new standard), Recommended Practice for Stationary Battery Electrolyte Spill Containment and Management
ESS relevance:	Covers how electrolyte spills can be contained and managed. Covered are vented lead-acid, valve regulated lead-acid, vented nickel-cadmium and partially recombinant Ni-Cd batteries.
Current activity:	<i>The draft standard is available at https://standards.ieee.org/develop/project/1578.html.</i>
Date of next edition:	TBD



National Electrical Contractors Association (NECA)—www.necanet.org

Document:	NECA 416-16, Recommended Practice for Installing Stored Energy Systems
ESS relevance:	National Electrical Installation Standards (NEISs) are designed to improve communication among specifiers, purchasers, and suppliers of electrical construction services and are intended to be referenced in contract documents for electrical construction projects. NECA 416-17 describes installation practices for energy storage systems such as battery systems, flywheels, ultra-capacitors, and smart chargers used for electric vehicle (EV) vehicle-to-grid (V2G) applications.
Current activity:	Suggestions for revisions and improvements to this document are welcome and can be directed to NECA at www.neca-neis.org
Date of next edition:	TBD based on current activity.
Document:	NECA 417 (new standard), Recommended Practice for Designing, Installing, Maintaining, and Operating Micro-grids
ESS relevance:	The document is designed to improve communication among specifiers, purchasers, and suppliers of electrical construction services and are intended to be referenced in contract documents for electrical construction projects. NECA 417 will cover the design, installation, maintenance, and operation of microgrids.
Current activity:	<i>NECA staff compiled the comments received during the first public comment period for consideration by the drafting committee and have released a second circulation of the first ANSI canvass ballot for the standard that closed July 30, 2018. See http://www.neca-neis.org/ballot/neca-417-201x-recommended-practice-for-designing-installing-operating-and-maintaining-microgrids for more information.</i>
Date of next edition:	<i>The goal is to complete NECA-417 in 2018.</i>



National Fire Protection Association (NFPA) – www.nfpa.org

Document:	NFPA 855, Standard for the Installation of Stationary Energy Storage Systems
ESS relevance:	The standard covers the safety of all energy storage systems and their installation in the built environment. Chapters of the standard cover equipment, protection and installation, limitations on energy storage system capacity as a function of technology and location and then provide additional criteria focused on specific energy storage system technologies.
Current activity:	<i>The first draft report was posted for public review and comment with a closing date of July 12, 2018 and NFPA received over 800 public comments. See http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=855&tab=nextedition for more information. A second draft meeting was held July 24 to 26, 2018, in Salt Lake City, Utah and a second meeting to continue consideration of the public comments will be held August 21 to 23, 2018. The second draft report is scheduled to be posted November 1, 2018.</i>
Date of first edition:	2020
Document:	NFPA 1078 (new standard), Standard for Electrical Inspector Professional Qualifications
ESS relevance:	Addressed qualifications of those who would review and approve electrical plans and conduct electrical inspections. Such plan reviews and electrical inspections would include, but not be limited to, energy storage systems.
Current activity:	<i>The first draft report is being prepared and is scheduled to be posted August 22, 2018. The second draft public comment period will close on October 31, 2018. See https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1078&tab=nextedition for more information.</i>
Date of next edition:	2021
Document:	NFPA 78 (new standard), Guide on Electrical Inspections (proposed edition).
ESS relevance:	This document covers the minimum criteria to aid in organizing and conducting electrical inspections, including plan review and field inspection. Such plan reviews and electrical inspections would include, but not be limited to, energy storage systems.
Current activity:	<i>The first draft report is being prepared and is scheduled to be posted August 22, 2018. The public comment period will close on October 31, 2018. https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=78&tab=nextedition for more information.</i>
Date of next edition:	2021

CODES AND STANDARDS FOR A COMPLETE ESS

	
American Society of Mechanical Engineers (ASME) – www.asme.org	
Document:	TES-1 (new standard) Safety Standard for Thermal Energy Storage Systems
ESS relevance:	Provides safety-related criteria for molten salt thermal energy storage systems.
Current activity:	<i>The standard has been drafted by the TES-1 committee and has been circulated for a TES-1 committee ballot with a due date of August 20, 2018. Work continues on the standard and the document will continue to be recirculated for committee ballot until a consensus on the technical content of the document is achieved. At that point the document will be circulated for public review and comment.</i>
Date of next edition:	TBD

	
National Electrical Manufacturers Association – www.nema.org	
Document:	ESS-1-2017, Standard for Uniformly Measuring and Expressing the Performance of Electrical Energy Storage Systems
ESS relevance:	Provides safety-related criteria for electrical ESSs.
Current activity:	<i>The standard was approved by the NEMA Codes and Standards Committee and was balloted through ANSI with a closing date of July 24, 2018.</i>
Date of next edition:	August 2018

	
National Fire Protection Association (NFPA) – www.nfpa.org	
Document:	NFPA 791-2018, Recommended Practice and Procedures for Unlabeled Electrical Equipment
ESS relevance:	Could form a basis for assessing an energy storage system that is not labeled. Note that recommended practices are guides and are not documents that can be enforced by jurisdictions.
Current activity:	<i>The deadline for public comment was June 27, 2018 and 34 public comments were received. The first draft report is scheduled to be posted on February 27, 2019. See https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=791&tab=nextedition for more information.</i>
Date of next edition:	2021



Document:	UL 9540, Energy Storage Systems and Equipment
ESS relevance:	Product safety standard for an energy storage system.
Current activity:	UL is preparing a proposed second edition of UL 9540 based on the proposal requests submitted. Once final input is received from the proposal submitters, the proposed second edition will be sent out for preliminary review.
Date of next edition:	TBD – UL standards are under continuous maintenance and are updated as warranted
Document:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (BESSs)
ESS relevance:	Provides a recommended practice for conducting testing with the results available to document the safety of battery energy storage systems in relation to the separation requirements in codes and standards covering the separation of battery energy storage systems from one another and structures.
Current activity:	<i>A third edition of the standard was issued June 15, 2018.</i>
Date of next edition:	TBD – UL standards are under continuous maintenance and are updated as warranted

CODES AND STANDARDS FOR ESS COMPONENTS

 CSA Group	CSA GROUP (CSA) – www.csagroup.org
Document:	CSA C22.2 No. 107.1-2016, Power Conversion Equipment
ESS relevance:	Applies to alternating current (AC) and direct current (DC) type power conversion equipment, which can be associated with an energy storage system.
Current activity:	The standard is under continuous maintenance and updated as warranted.
Date of next edition:	TBD
Document:	CSA C22.2 No. 340-201 (new standard), Battery Management Systems
ESS relevance:	The standard covers the design, performance, and safety of battery management systems (electronic or electromechanical systems that control or regulate a battery or batteries, which may include external communication capabilities).
Current activity:	
Date of next edition:	TBD

 Advancing Technology for Humanity	IEEE – www.ieee.org
Document:	IEEE 1679.1-17, Guide for the Characterization and Evaluation of Lithium-Based Batteries in Stationary Applications
ESS relevance:	Provides appropriate information about the safety attributes and operating conditions related to stationary applications of lithium-based batteries. It provides recommendations for how to characterize lithium-ion battery performance and safety in stationary applications. The guide is very general and nonprescriptive, offering common challenges and solutions with the caveat to “consult the manufacturer’s recommendations” for specific devices or technologies. The guide points to existing standards (e.g., UL 1642) and existing regulatory requirements (e.g., adoption of NFPA 70) wherever possible.
Current activity:	An active working group is engaged in considering updates to the standard.
Date of publication:	2017
Document:	IEEE P1679.2 (new standard), Guide for the Characterization and Evaluation of Sodium-Beta Batteries in Stationary Applications
ESS relevance:	Provides appropriate information about the safety attributes and operating conditions related to stationary applications of sodium-beta batteries. It provides recommendations for how to characterize sodium-beta battery performance and safety in stationary applications. The guide is very general and nonprescriptive, offering common challenges and solutions with the caveat to “consult the manufacturer’s recommendations” for specific devices or technologies.
Current activity:	A revised version of the standard is about to be sent out for recirculation.
Date of publication:	The unapproved draft is available from IEEE.

 Underwriters Laboratories Inc.®	Underwriters Laboratories (UL) – www.ul.org
Document:	UL 810A, Electrochemical Capacitors
ESS relevance:	Addresses the safety of electrochemical capacitors, which can be used as an energy source in energy storage systems.
Current activity:	
Date of next edition:	TBD - UL standards are under continuous maintenance and are updated as warranted.
Document:	UL 1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources
ESS relevance:	Applies to the subject technology when used in conjunction with an energy storage system.
Current activity:	Changes to the second edition of the standard were issued in a bulletin dated June 18, 2018 that expands requirements for AC modules and includes requirements for photovoltaic (PV) modules with integrated electronics.
Date of next edition:	TBD - UL standards are under continuous maintenance and are updated as warranted.
Document:	ANSI/CAN/UL 1973, Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications
ESS relevance:	Battery systems that would be employed in energy storage systems
Current activity:	
Date of next edition:	TBD – UL standards are under continuous maintenance and are updated as warranted.
Document:	UL 1974, Evaluation for Repurposing Batteries
ESS relevance:	This standard covers the sorting and grading process of battery packs, modules and cells, and electrochemical capacitors that were originally configured and used for other purposes, such as electric vehicle (EV) propulsion, and that are intended for a repurposed use application, such as for use in stationary energy storage systems and other applications. The process of sorting and grading these devices is essentially determining their state of health and other parameters to identify continued viability and the rating mechanisms the repurposing manufacturer may use for those that are determined suitable for continued use. This standard also covers application specific requirements for battery packs utilizing repurposed batteries and components.
Current activity:	<i>Comment and ballot by the standard technical panel closed June 13, 2018 and is likely to be recirculated in late August after revisions are made to address the comments received.</i>
Date of first edition:	TBD based on work to be done after the above mentioned review.

An Important Note to Readers

Every effort is made by the Pacific Northwest National Laboratory (PNNL) and Sandia¹ staff to ensure the accuracy of the information presented in this report. PNNL and Sandia very much appreciate the input from staff of the standards developing organizations (SDOs) covered in the report as well as volunteers who are involved in one or more of the SDO initiatives covered in this document. Suggestions for revision, additions, and enhancements to this document are welcome and encouraged. We at PNNL and Sandia, on behalf of the U.S. Department of Energy, Office of Energy, Energy Storage System Program whose support has made this report possible, want this document to be "the" source of information about codes and standards related to ESS safety. With your help we can make that happen and as outlined on page one achieve the codes and standards related objective in the ESS Safety Roadmap and the goal of fostering confidence in the safety and reliability of ESSs. For more information about the ESS Safety Roadmap efforts visit <http://www.sandia.gov/ess/>. For questions related to or to provide input on this document, please contact david.conover@pnnl.gov or pam.cole@pnnl.gov.

¹ Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.