

Energy Storage Systems

Based on the IBC®, IFC®, IRC® and NEC®, Second Edition



**Energy Storage Systems: Based on the
IBC®, IFC®, IRC® and NEC®:
Based on the 2021 *Energy Storage
Systems*®**

2nd Edition

Shawn Shaw, PE

International Code Council Staff:

Chief Operating Officer:
Mark A. Johnson

Chief Knowledge Officer/Executive Vice
President:
Joan O'Neil

Senior Vice President, Business and
Product Development:
Hamid Naderi

Vice President, Product Development:
Sandra Hyde, PE

Product Development Coordinator
and Analyst:
Isabella Monteiro

Publisher:
Katie Mohr

Publications Manager:
Anne F. Kerr

Manager of Publications Production:
Jen Fitzsimmons

Project Manager:
Hamid Naderi

Project Editor:
Jessica Roe

Production Technician:
Linda Foegen

Cover Design:
Ricky Razo and Carmel Gieson

COPYRIGHT © 2025
by INTERNATIONAL CODE COUNCIL, INC.

ALL RIGHTS RESERVED.



ISBN: 978-1-968942-78-6 (soft-cover edition)
ISBN: 978-1-968942-79-3 (PDF download)

This publication is a copyrighted work owned by the International Code Council, Inc. ("ICC"). Without separate written permission from the ICC, no part of this publication may be reproduced, distributed or transmitted in any form or by any means, including, without limitation, electronic, optical or mechanical means (by way of example, and not limitation, photocopying or recording by or in an information storage and/or retrieval system). For information on use rights and permissions, please contact: ICC Publications, 4051 Flossmoor Road, Country Club Hills, Illinois 60478; 1-888-ICC-SAFE (422-7233); <https://www.iccsafe.org/about/periodicals-and-newsroom/icc-logo-license/>.

The information contained in this document is believed to be accurate; however, it is being provided "as-is" without representation or warranty for informational purposes only and is intended for use only as a guide. Publication of this document by the ICC should not be construed as the ICC engaging in or rendering engineering, legal or other professional services. Use of the information contained in this publication should not be considered by the user as a substitute for the advice of a registered professional engineer, attorney or other professional. If such advice is required, it should be sought through the services of a registered professional engineer, licensed attorney or other professional.

Trademarks: "International Code Council," the "International Code Council" logo, "ICC," the "ICC" logo, "International Building Code," "IBC," "International Fire Code," "IFC," "International Residential Code," "IRC" and other names and trademarks appearing in this publication are registered trademarks of the International Code Council, Inc., and/or its licensors (as applicable), and may not be used without permission.

Errata on various ICC publications may be available on the Content Updates site at www.iccsafe.org/contentupdates.

First Printing: December 2025

PRINTED IN THE USA



Contents

Chapter 1: Introduction	1
1.1 A Brief History of Energy Storage Technologies	2
1.2 The Benefits of Energy Storage	7
1.3 Acronyms	8
1.4 Terminology	11
1.5 A Quick Overview of Common Energy Storage Technologies	16
1.6 Brief Overview of Lithium-Ion Batteries	24
1.7 Next Generation Batteries	34
1.8 Future Energy Storage Considerations	39
Chapter 2: Understanding Utility-Scale and Large Commercial-Scale ESS Projects	41
2.1 Major Parties Involved in Utility-Scale ESS Projects	42
2.2 Major Equipment on Utility-Scale ESS	44
2.3 The Use Cases for Utility-Scale BESS	52
Chapter 3: Residential and Small Commercial-Scale Projects	59
Chapter 4: Fire and Explosion Risk in Lithium-Ion Battery Energy Storage Systems	63
4.1 Battery Fire and Explosion Risk Background	63
4.2 Other Risks Associated with BESS Fires	70
4.3 BESS Fires in Everyday Context	74
4.4 Key BESS Fire Safety Systems	78
4.5 Emergency Planning and Response	85
Chapter 5: Applicable Codes and Standards	95
5.1 Aligning Code Requirements for ESS	95
5.2 <i>International Building Code (IBC)</i>	97
5.3 <i>International Residential Code (IRC)</i>	97
5.4 <i>National Electrical Code (NEC)</i>	98
5.5 <i>International Fire Code (IFC)</i>	99

5.6 Determining Code Applicability	100
5.7 A Review of Relevant Standards	104
5.8 What Lies Ahead	114
Chapter 6: Reviewing and Inspecting Energy Storage Systems	117
Chapter 7: Checklists and Resources	123



Preface

Energy storage devices surround us and are an everyday part of our modern world, from cell phone and laptop batteries to thermal storage in passive solar homes. Energy storage systems (ESS) have now become a key enabling technology to facilitate the shift to renewable energy sources, such as solar and wind power, for an ever-greater share of our electricity needs. ESS are playing a critical role in this transition, allowing for a variety of functions that provide much-needed support to the aging electrical grid, as well as providing the ability to store abundant renewable energy generated during periods of high sun or wind for later use. With the growing connectedness of electrical infrastructure, ESS are the glue that bind together variable resources and variable loads, providing the certainty that the average consumer expects when they turn on their equipment or appliances that they will, in fact, have access to sufficient energy to operate.

It would be a mistake, however, to envision ESS as a monolithic technology. In fact, the term ESS encapsulates a tremendous range of technologies, from flywheels to flow batteries, and most of these are generally unfamiliar to building officials, inspectors, emergency services, planners, architects and engineers. The goal of this guide is to provide a handy reference to ESS technologies with an eye toward the key information that these groups need to safely plan, design, permit and build ESS in the built environment. This information includes consideration of how the technologies function, safety considerations and the applicability of current codes and standards, which are evolving to address these, and other, related new technologies.

Beginning in 2010 and extending into the 2020s, lithium-ion battery-based ESS dominate the global market, representing over 90 percent of all new energy storage capacity installed; as such, much of this guide will focus on this group of technologies. Attention will also be given to a number of other technologies that are gaining ground and seeing successful commercial or near-commercial projects in construction globally.



Acknowledgments

The International Code Council® (ICC®) is grateful to Shawn Shaw, PE, Chief Executive Officer, Camelot Energy Group, who wrote the original contents of this publication and Charles Picard, Senior Engineer at Tesla; James Kennedy, Sales Engineer at Fluence; Shawn Martin, ICC-SRCC Vice President of Technical Services; and Jerica Stacey, ICC Energy Code Specialist for their technical review and input. Mr. Shaw has now

updated the original contents to this new second edition that is based on the 2024 International Codes® (I-Codes®) and *National Electrical Code®* (NEC®) 2023.

The author and ICC express their gratitude to Christine Reed, ICC Fire and Disaster Mitigation Program Manager, for her technical review and feedback of the updated second edition.



About the International Building Code® (IBC®)

Building officials, design professionals and others involved in the building construction industry recognize the need for a modern, up-to-date building code addressing the design and installation of building systems through requirements emphasizing performance. The *International Building Code* (IBC), 2024 edition, is intended to meet these needs through model code regulations that safeguard public health and safety in all communities, large and small. The IBC is kept up to date through the open code development consensus process of the International Code Council. The provisions of the 2021 edition, along with those code changes approved in the most recent code development cycle, make up the 2024 edition.

The IBC is one of 15 I-Codes published by the ICC. This comprehensive building code establishes minimum regulations for building systems through prescriptive and performance-related provisions. It is founded on broad-based principles that make possible the use of new materials and new building designs. The IBC is available for adoption and use by jurisdictions internationally. Its use within a governmental jurisdiction is intended to be accomplished through adoption by reference, in accordance with proceedings established by the jurisdiction's laws.



About the International Fire Code® (IFC®)

Fire code officials, fire inspectors, building officials, design professionals, contractors and others involved in the field of fire safety recognize the need for a modern, up-to-date fire code. The *International Fire Code* (IFC), 2024 edition, is intended to meet these needs through model code regulations that safeguard the public health and safety in all communities, large and small. The IFC is kept up to date through ICC's open code development consensus process. The provisions of the 2021 edition, along with those changes approved in the most recent code development cycle, make up the 2024 edition.

One in a family of International Codes published by ICC, the IFC is a model code that establishes minimum fire safety requirements for new and existing buildings, facilities, storage and processes. It addresses fire prevention, fire protection, life safety and safe storage and use of hazardous materials. The IFC provides a total approach of controlling hazards in all buildings and sites, regardless of the hazard being indoors or outdoors.

The IFC is a design document. For example, before a building is constructed, the site must be provided with an adequate water supply for fire-fighting operations and a means of building access for emergency responders in the event of a medical emergency, fire or natural or technological disaster. Depending on the building's occupancy and uses, the IFC regulates the various hazards that may be housed within the building, including refrigeration systems, application of flammable finishes, fueling of motor vehicles, highpiled combustible storage and the storage and use of hazardous materials. The IFC sets forth minimum requirements for these and other hazards and contains requirements for maintaining the life safety of building occupants, the protection of emergency responders, and to limit the damage to a building and its contents as the result of a fire, explosion or unauthorized hazardous material discharge and electrical systems. The IFC is available for adoption and use by jurisdictions internationally. Its use within a governmental jurisdiction is intended to be accomplished through adoption by reference, in accordance with proceedings establishing the jurisdiction's laws.



About the International Residential Code® (IRC®)

The *International Residential Code* (IRC), 2024 edition, is a comprehensive, stand-alone residential code that establishes minimum regulations for the construction of one- and two-family dwellings and townhouses up to three stories in height, including provisions for fire and life safety, structural design, energy conservation and mechanical, fuel-gas, plumbing and electrical systems. The IRC incorporates prescriptive provisions for conventional construction as well as performance criteria that allow the use of new materials and new building designs. The provisions of the 2021 edition, along with those changes approved in the most recent development cycle, make up the 2024 edition.

The IRC is one of the codes in the family of International Codes published by ICC. All are maintained and updated through an open code development consensus process and are available internationally for adoption by the governing authority to provide consistent enforceable regulations for the built environment.



• About the NFPA 70®, National Electrical Code® (NEC®)

NFPA 70, *National Electrical Code* (NEC) was first published in 1897 and is continually put through a rigorous review process to keep it up to date with the most current industry practices, emerging trends, and the development and introduction of new technologies. The latest requirements for safe and more effective electrical design, installation and inspection, including provisions for wiring, overcurrent protection, grounding and equipment, are covered. NFPA 70, NEC, is a standard of the National Fire Protection Association and is the benchmark standard for electrical safety in residential, commercial and industrial settings.



• About the International Code Council®

The International Code Council is the leading global source of model codes and standards and building safety solutions that include product evaluation, accreditation, technology, codification, consulting, training and certification. The International Code Council's codes, standards and solutions are used to ensure safe, affordable and sustainable communities and buildings worldwide.

The International Code Council family of solutions includes the ICC Evaluation Service (ICC ES), S. K. Ghosh Associates, the International Accreditation Service (IAS), General Code, ICC NTA, ICC Community Development Solutions, Alliance for National & Community Resilience (ANCR) and American Legal Publishing.

Office Locations:

Headquarters:

200 Massachusetts Avenue, NW, Suite 250
Washington, DC 20001
888-ICC-SAFE (888-422-7233)
www.iccsafe.org

Eastern Regional Office

900 Montclair Road
Birmingham, AL 35213

Central Regional Office

4051 Flossmoor Road
Country Club Hills, IL 60478

Western Regional Office

3060 Saturn Street, Suite 100
Brea, CA 92821

MENA Regional Office

Dubai Association Centre Office, One Central
Building 2, Office 8, Dubai World Trade Centre Complex
PO Box 9292, Dubai, UAE

OCEANIA Regional Office

Level 9, Nishi Building
2 Phillip Law Street
Canberra ACT 2601 Australia

Family of Solutions:



• About the Independent Alliance of the Electrical Industry

Independent Alliance of the Electrical Industry (IAEI) is a 501(c)(6) not-for-profit professional trade association committed to public safety from electrical hazards by providing expert, unbiased leadership in electrical code and standards development and premier education and certification for electrical professionals. IAEI was established in, and has been in continuous operation since, 1928.

901 Waterfall Way, Suite 602, Richardson, TX 75080

Phone: (800) 786-4234

Email: customerservice@iae.org