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Hazard-Resilient Buildings: Sustaining Occupancy and Function After a Natural Disaster

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Hazard-Resilient Buildings: Sustaining Occupancy and Function After a Natural Disaster

SUMMARY

R47215

August 15, 2022

Linda R. Rowan
Analyst in Natural Resources Policy

Natural disasters contributed to more than $2.2 trillion in total losses in the United States between 1980 and 2021. Many in Congress are interested in reducing the losses due to buildings damaged or destroyed in disasters. One way to reduce losses and help communities recover more rapidly without disruptions or additional losses is to construct new buildings (or retrofit existing buildings) that are *hazard resilient*—that is, that are capable of being occupied and remaining functional during and/or immediately after a disaster.

Congress directed the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), and stakeholders to recommend ways to make buildings hazard resilient, with the aim of reducing disaster losses and enhancing community resilience. Two reports, one submitted to Congress in 2018 and one in 2021, recommended that the federal government and stakeholders enhance hazard-resilient designs in model building codes and facilitate adoption and enforcement of these codes at the community level.

The recommendations in these reports encouraged more research and development in four areas to move toward more hazard-resilient buildings: (1) building design, (2) community planning, (3) economic and social feasibility, and (4) adoption of building codes. In addition, the reports recommended that the federal government lead development of a national framework to increase hazard-resilient building stock nationwide. A national framework may include a national consensus that defines what services and design requirements are necessary for buildings' occupancy and function soon after a disaster. A national framework also may include coordinated, consistent hazard-resilient building assistance and incentive policies. Coordination may be between different federal government entities or programs and between the federal government and communities (including state, local, tribal, and territorial entities, as well as the private sector).

Congress established the National Flood Insurance Program, the National Earthquake Hazards Reduction Program, the National Windstorm Impact Reduction Program, and Hazard Mitigation Assistance Grants, among other initiatives, to reduce losses from hazards, including through designing buildings that are more resistant to hazards. FEMA, NIST, the National Oceanic and Atmospheric Administration, the National Science Foundation, and the U.S. Geological Survey have additional activities and programs that may increase both the hazard resiliency of buildings and the number of buildings that may perform beyond life safety to allow occupancy and function during or soon after a disaster.

Congress may consider the recommendations in the 2018 and 2021 reports and whether to take any action related to these recommendations. Congress also may consider whether current federal agency activities or grant programs respond to some or all of the recommendations. In addition, Congress could consider directing federal programs to promote the adoption of model building codes that address occupancy and function through incentives or mandates. Congress also could incentivize code adoption by offering discounts on insurance premiums, tax credits, or access to additional resources for code improvements through grants or loans.

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Introduction

Residential and commercial buildings facilitate residential, commercial, industrial, social, cultural, educational, and government functions for communities.[1] At times, natural disasters have damaged or destroyed buildings in the United States, causing additional economic, social, and cultural losses.[2] Many in Congress have indicated an interest in policies and activities to make buildings more hazard resilient, such that buildings suffer minimal damage, can be reoccupied, and can function immediately after a disaster. In the aftermath of a disaster, minimally damaged buildings may reduce immediate losses and may allow communities to recover rapidly and avoid additional losses.

According to the National Oceanic and Atmospheric Administration (NOAA), the United States sustained 323 weather and climate disasters that each resulted in overall losses at or above $1 billion from 1980 through 2021.[3] The total inflation-adjusted loss caused by these 323 events is nearly $2.2 trillion.[4] Non-weather hazards, such as earthquakes, also may damage buildings and cause large economic losses. According to the U.S. Geological Survey (USGS), nearly half of all Americans are exposed to earthquake hazards and past earthquake events have caused significant damage to buildings.[5] For example, the 1994 magnitude 6.7 Northridge earthquake in California caused economic losses of $42 billion (1998 dollars), damaged more than 114,000 buildings, and left more than 22,000 people homeless. Total insured losses caused the collapse of the earthquake insurance industry in California.[6]

The primary way to affect building performance objectives is through *building codes*, which are adopted and enforced by state, local, tribal, and territorial governments (SLTTs).[7] Currently, most

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[1] In this report, *buildings* refer to existing buildings that may need retrofits and to newly constructed buildings. *Residential buildings* include one- and two-family dwellings and townhouses not more than three stories above grade and account for about 80% of building stock in the United States. *Commercial buildings* include commercial, industrial, educational, government, and larger residential structures, such as apartment buildings. International Code Council (ICC), "Overview of the International Residential Code (IRC)," at https://www.iccsafe.org/products-and-services/i-codes/2018-i-codes/irc/.

[2] The Federal Emergency Management Agency (FEMA) defines *natural disaster* as any natural hazard event that causes significant harm to life, property, or society. FEMA, *Building Codes Save: A Nationwide Study*, November 2020, at https://www.fema.gov/emergency-managers/risk-management/building-science/building-codes-save-study (hereinafter FEMA, *Building Codes Save*, 2020).

[3] The National Oceanic and Atmospheric Administration (NOAA) defines *weather and climate disaster* as drought, wildfire, flood, winter storm, freeze, severe storm (includes hail, tornado, and high wind), and tropical cyclone (i.e., hurricane). NOAA does not provide separate descriptions of weather disasters versus climate disasters. See NOAA, "Billion-Dollar Disasters: Calculating the Costs," at https://www.ncei.noaa.gov/access/monitoring/dyk/billions-calculations; and CRS In Focus IF11446, *Weather and Climate Change: What's the Difference?*, by Jane A. Leggett.

[4] NOAA's calculations include losses due to damage to the built environment, which are often among the highest losses from a natural disaster. The calculated losses include damage to residential, commercial, and municipal buildings; material assets (content) within buildings; vehicles and boats; and roads, bridges, and utilities. NOAA also estimates *time element losses* such as business interruption or loss of living quarters. NOAA, "Billion-Dollar Disasters: Calculating the Costs," at https://www.ncei.noaa.gov/access/monitoring/dyk/billions-calculations.

[5] Kishor S. Jaiswal et al., "Earthquake Shaking Hazard Estimates and Exposure Changes in the Conterminous United States," *Earthquake Spectra*, vol. 31, no. 1 (2015), pp. S201-S220, at https://doi.org/10.1193/111814EQS195M.

[6] William J. Petak and Shirin Elahi, "The Northridge Earthquake, USA and Its Economic and Social Impacts," presented at EuroConference on Global Change and Catastrophe Risk Management, International Institute for Applied Systems Analysis, Laxenburg, Austria, July 6-9, 2000, at https://abag.ca.gov/sites/default/files/the_northridge_earthquake_and_its_economic_and_social_impacts.pdf.

[7] *Building codes* are officially adopted minimum requirements for the design, construction, alteration, materials, maintenance, and performance of buildings to provide a minimum level of safety, public health, and welfare. A *model*

building codes require a habitable structure that protects people from injury or death and do not require occupancy or functionality soon after a disaster.[8] The federal government plays almost no role in establishing and enforcing building codes in communities. However, federal agencies such as the National Institute of Standards and Technology (NIST) and the Federal Emergency Management Agency (FEMA) may facilitate design and implementation of building codes and also may encourage or incentivize adoption and enforcement of hazard-resilient model building codes.[9]

Congress has directed NIST, FEMA, and stakeholders to recommend research and implementation activities to advance building performance beyond life safety to occupancy and functionality during or soon after a disaster.[10] The Senate Committee on Appropriations, in S.Rept. 114-239 accompanying the Consolidated Appropriations Act, 2017 (P.L. 115-31), recognized that current building codes did not provide enough protection from natural disasters to enable "immediate occupancy" following a disaster. The committee asked NIST to prepare a plan describing research and implementation activities needed to develop "immediate occupancy" engineering design principles and building performance objectives for commercial and residential properties. NIST submitted to Congress a report entitled *Research Needs to Support Immediate Occupancy Building Performance Objectives Following Natural Hazards Events* in 2018 (hereinafter referred to as the IO report).[11]

In the 2018 reauthorization of the National Earthquake Hazards Reduction Program (NEHRP; P.L. 115-307, 42 U.S.C. §7705b), Congress requested that NIST and FEMA jointly convene a panel of experts to assess and recommend options for improving the built environment and critical infrastructure to allow occupancy and function immediately after an earthquake. The agencies submitted to Congress a report entitled *Recommended Options for Improving the Built Environment for Post-Earthquake Reoccupancy and Functional Recovery Time* in 2021 (hereinafter referred to as the FRT report).[12]

In addition, Congress directed NIST and FEMA to take other actions that may contribute to the development of hazard-resilient buildings. The 2018 reauthorization of NEHRP defined

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building code is a building code that is developed and maintained by a standards developing organization (SDO) independent of the jurisdiction responsible for adopting and enforcing any building codes.

[8] Building codes adopted and enforced by jurisdictions vary. FEMA tracks building codes in use by communities and notes that some of these codes include hazard-resistant design elements, which may improve a building's ability to withstand a disaster and to be occupied and functional soon after a disaster. Critical buildings, such as hospitals and emergency response centers, are built to codes that require continued occupancy and function during and after a disaster. FEMA, "Nationwide Building Code Adoption Tracking," at https://www.fema.gov/emergency-managers/risk-management/building-science/bcat.

[9] Federal entities are required to construct new buildings or alter existing buildings (owned or leased) using the latest edition of one of the "nationally recognized model building codes" (40 U.S.C. §3312). In addition, the Department of Housing and Urban Development (HUD) issues and enforces standards for the construction, design, performance, and installation of manufactured homes (i.e., HUD sets the building codes, and these codes differ from codes used for other buildings in the United States). National Manufactured Housing Construction and Safety Standards Act of 1974 (42 U.S.C. §5401-5426). Regulations are at 24 C.F.R. parts 3280, 3282, 3284, 3285, 3286, 3288, and 3800.

[10] Stakeholders may include hazard scientists, architects, engineers, builders, developers, community planners, building managers, building standards developers, state or local government officials, and others.

[11] Siamak Sattar et al., *Research Needs to Support Immediate Occupancy Building Performance Objective Following Natural Hazard Events*, National Institute of Standards and Technology (NIST), NIST Special Publication 1224, August 2018, at https://doi.org/10.6028/NIST.SP.1224 (hereinafter IO report).

[12] NIST-FEMA, *Recommended Options for Improving the Built Environment for Post-Earthquake Reoccupancy and Functional Recovery Time*, NIST-FEMA Special Publication FEMA P-2090/NIST SP-1254, 2021, at https://doi.org/10.6028/NIST.SP.1254 (hereinafter FRT report).

community resilience as "the ability of a community to prepare and plan for, absorb, recover from, and more successfully adapt to adverse seismic events" (42 U.S.C. §7703) and directed NIST to conduct research to "improve community resilience through building codes and standards" (42 U.S.C. §7704(b)(5)). Further, Congress amended Section 203 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) to permit FEMA grant funding to communities to adopt and enforce the "latest published editions of relevant consensus-based codes, specifications, and standards that incorporate the latest hazard-resistant designs" (42 U.S.C. §5172(e)(1)(A)).[13]

The recommendations from the IO and the FRT reports sought to increase the number of hazard-resilient buildings, leading to more resilient communities.[14] The recommendations did not specify actions by any federal agencies or stakeholders; however, ongoing activities at NIST and FEMA may support some aspects of these recommendations.

Recommendations to Increase Hazard-Resilient Building Stock

The IO and FRT reports encouraged development of a national framework for hazard-resilient *building* design and construction that may be connected to a national framework for resilient *infrastructure* design and construction.[15] A national framework for building design may require a consensus about what services and design requirements are necessary for the occupancy and function of buildings within some specified time frame after a disaster.

In addition, the reports recommended research and development (R&D) in four areas: (1) building design, (2) community planning, (3) economic and social feasibility, and (4) building codes adoption.

Terminology: Occupancy, Function, and Resilience

Hazard-resilient buildings are intended to maintain occupancy and functionality with minimal repairs during and after a natural disaster. The IO report stated that an *immediate occupancy*

[13] The amendment to the Robert T. Stafford Disaster Relief and Emergency Assistance Act is in Division D, Disaster Recovery Reform Act of the Federal Aviation Administration Reauthorization Act of 2018 (DRRA; P.L. 115-254). It established FEMA Building Resilient Infrastructure and Communities (BRIC) grants, which may be used to help communities adopt and enforce hazard-resistant building codes and standards. See FEMA, *BRIC Building Code Activities*, FEMA Program Support Materials, August 2021, at https://www.fema.gov/sites/default/files/documents/fema_fy21-bric-building-code-activities-psm.pdf. For more information about FEMA Hazard Mitigation Assistance, see CRS Report R46989, *FEMA Hazard Mitigation: A First Step Toward Climate Adaptation*, by Diane P. Horn. For more about DRRA, see CRS Report R45819, *The Disaster Recovery Reform Act of 2018 (DRRA): A Summary of Selected Statutory Provisions*, coordinated by Elizabeth M. Webster and Bruce R. Lindsay.

[14] The IO report did not specify any particular hazard type but noted that buildings may need to be designed for a specific hazard type and intensity level. The FRT report focused on earthquake hazards but noted that the recommended approaches may apply to other hazard types. Both reports noted the importance of considering multi-hazards (e.g., a building may be impacted by an earthquake and a hurricane at different times, or a building may be impacted by an earthquake that triggers a tsunami, resulting in shaking followed by water inundation at nearly the same time or over a matter of hours).

[15] The IO report focused on buildings while noting that infrastructure would need consideration. The FRT report discussed hazard-resilient buildings and infrastructure separately and noted that some aspects of building resilience depend on infrastructure resilience (e.g., a supply of power and water to a building may be necessary for occupancy and function after a natural disaster).

performance objective may enable buildings to remain functional or to experience interim loss of function for a limited time, while repairs may take place during occupancy and basic functioning.[16] The FRT report defined *reoccupancy* as a post-earthquake performance state in which a building is maintained or restored to allow safe reentry for the purposes of providing shelter or protecting building contents. The time frame for reoccupancy may vary, and an acceptable time frame for reoccupancy may depend on the building's occupancy levels and functions. *Functional recovery* is a post-earthquake performance state in which the building is maintained or restored to safely and adequately support its basic intended functions.[17] The *functional recovery time* is the amount of time it may take a building to recover certain basic functions after a disaster. The time may be specified in hours, days, weeks, or months, based on the hazard's intensity, the building's functions and occupancy levels, and other factors.

The reports considered hazard-resilient buildings to be one component of resilient communities. Both reports used the definition of *resilience* from the Presidential Policy Directive 21 (PPD-21): "The term 'resilience' means the ability to prepare for and adapt to changing conditions and to withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."[18] This definition is similar to the definition of *community resilience* to earthquakes in the 2018 reauthorization of NEHRP (see "Introduction") and to NIST's definition of *community resilience*.[19] Congress directed FEMA to define *resilient* and *resiliency* as part of an amendment to the Stafford Act (42 U.S.C. §5172(e)) in the Disaster Recovery Reform Act (P.L. 115-254).[20] FEMA has indicated that it is in the rulemaking process to adopt NIST's *community resilience* definition.

National Framework for Building Design

A national framework for hazard-resilient building design would establish consensus model building codes and consensus hazard-resistant design elements that are based on identified hazard risks in different communities; such a framework could be efficiently and consistently used nationwide. Standard-developing organizations (SDOs) develop and update model building codes through input and a consensus-based process involving experts and stakeholders. SLTTs may choose to adopt some or all of such model building codes or establish their own building codes. SLTTs are responsible for enforcing their building codes within their jurisdictions. The most common model building codes that are adopted in the United States are from two SDOs, the International Code Council (ICC, which publishes 15 types of model building codes referred to collectively as I-Codes) and the National Fire Protection Association.[21] In addition to these model

[16] IO report, p. 3.

[17] FRT report, p. vi.

[18] White House, Office of the Press Secretary, "Presidential Policy Directive – Critical Infrastructure Security and Resilience," PPD-21, February 12, 2013, at https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil.

[19] NIST defines *community resilience* as "the ability to prepare for anticipated hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions." See NIST, "Community Resilience," at https://www.nist.gov/community-resilience. See also CRS Report R46774, *The Disaster Recovery Reform Act of 2018 (DRRA): Implementation Update Tables for Select Provisions*, coordinated by Elizabeth M. Webster.

[20] See CRS Report R45819, *The Disaster Recovery Reform Act of 2018 (DRRA): A Summary of Selected Statutory Provisions*, coordinated by Elizabeth M. Webster and Bruce R. Lindsay.

[21] IO report, p. 9; ICC, "International Code Council," at https://www.iccsafe.org/; and National Fire Protection Association at https://www.nfpa.org/.

building codes, other organizations may provide design standards that are included in model building codes. The most commonly used minimum design standards for hazards that are referenced in I-Codes are from the American Society of Civil Engineers (ASCE). The ASCE's Structural Engineering Institute (SEI) has developed hazard load(s) (e.g., snow, wind, and/or seismic loads) for general design construction called *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE/SEI 7).[22] ASCE also has a *Flood Resistant Design and Construction* (ASCE/SEI 24) standard for flood loads for buildings constructed in flood hazard areas. According to FEMA, ASCE/SEI 24 meets or exceeds the minimum design requirements of the National Flood Insurance Program for buildings and structures.[23]

The ASCE 7 provides minimum design loads for a building based on the building's assigned risk category.[24] The four categories are as follows:

- Risk Category I: buildings that pose a low risk to human life in the event of failure (e.g., storage facilities, barns)
- Risk Category II: all buildings except those classified as Risk Categories I, III, and IV and most commercial and residential buildings
- Risk Category III: buildings designed to accommodate a high number of occupants, potentially posing substantial risk to human life in the event of failure (e.g., schools, theatres)
- Risk Category IV: buildings classified as essential facilities, the failure of which could pose substantial hazard to the community (e.g., hospitals)

Hazard-resilient model codes and design elements may include functional recovery time categories for specific hazards and hazard intensity levels (i.e., a specific time of days, weeks, or months to recover particular functions for a specified hazard intensity level), which may be applied to different building risk categories. Local communities may adopt these codes and design elements and may customize them for community needs.[25] For example, a community that is vulnerable to hurricanes could adopt the hurricane-resistant model codes and may consider including additional design elements that make buildings even more hurricane resistant (e.g.,

[22] American Society of Civil Engineers (ASCE), "ASCE 7," at https://www.asce.org/publications-and-news/asce-7. *Minimum design load* refers to the minimum hazard intensity that the building should be able to withstand without impacting building life safety or, for critical buildings such as hospitals, without impacting occupancy and function. For example, a minimum design load may be a wind speed of 100 miles per hour that a two-story house should be able to withstand without damage or collapse that would impact the safety of the building inhabitants. A building could be designed to withstand a higher wind speed event; the code specifies only a minimum wind speed (i.e., minimum design load). Please note that the acronym ASCE/SEI 7 may also be referred to as ASCE 7, ASCE 7-22 or ASCE/SEI 7-22 where the 22 refers to the year of the design edition. ASCE/SEI 7-22 is the latest edition and was published in 2022.

[23] FEMA, "American Society of Civil Engineers - Flood Resistant Design and Construction," https://www.fema.gov/node/american-society-civil-engineers-flood-resistant-design-and-construction. ASCE/SEI 24 may be called ASCE 24 or ASCE/SEI 24-14 (the latest edition of ASCE/SEI 24 was published in 2014).

[24] IO report, p. 13 and Engineering Express, "ASCE Risk Categories Explained," at https://www.engineeringexpress.com/wiki/asce-risk-categories-explained/.

[25] ASCE provides an online hazard tool that allows a stakeholder to choose a location, building risk category, and hazard type, then the tool returns the minimum design load standard (such as wind speed based on ASCE/SEI 7) that a building should meet based on the criteria chosen. See ASCE, "ASCE 7 Hazard Tool," at https://asce7hazardtool.online/. Even if a stakeholder is not designing or constructing a building, he or she can view the minimum design load criteria for many different hazards at a location to gain knowledge about hazard risks and building performance design elements for these hazards.

Florida building code requires design elements for high-velocity hurricane winds and wind-borne debris hazards in specific coastal zones across the state).[26]

No federal statutes establish national model building codes. Instead, any statutes mentioning building codes call for the adoption of either the latest edition of any nationally recognized model codes or the most recent edition of any relevant, consensus-based model codes.[27] SDOs revise their model building codes about every three to six years through a consensus-based process, and the most recent edition of I-Codes is from 2021.[28] Any stakeholder, including a federal agency such as NIST or FEMA, can offer a new or improved design element that may be considered for inclusion in the next edition of the model building codes.[29] Over time, hazard-resistant design elements have been added to the model codes. Examples include elevating structures for flood resistance, using more secure roof elements and adding window shutters for hurricane resistance, and using stronger and/or stiffer materials for earthquake resistance.

Building Design Considerations

The IO and FRT reports encouraged the adoption of building codes that prescribe hazard-resilient design and construction practices. The reports also called for R&D on enhanced engineering design and construction practices to make buildings more hazard resilient. For example, R&D on steel columns produced an improved design element for enhanced earthquake resistance; NIST submitted this design element to the ICC for consideration in the next edition of I-Codes.[30]

In addition to calling for R&D, the reports provided two overarching recommendations for building design: (1) adopt Risk Category IV building codes for all buildings and (2) move toward performance-based designs.

Risk Category IV Building Codes

Some critical buildings, such as hospitals and emergency operation centers, are designed and constructed to be occupied and remain functional during and after a disaster. These buildings are in the highest risk category (IV) of model building codes. One recommendation is to expand these design and construction practices to all buildings. This recommendation may be challenging to implement because of the differences in building function. A hospital, for example, serves a very different function than a one-family dwelling. Nevertheless, because Risk Category IV design and construction practices are already part of adopted building codes in many communities, it may be efficient and feasible to start with these standards.

[26] See Florida Building Commission, Florida Department of Community Affairs, "Setting New Standards for Safety, The Florida Building Code," at https://www.floridabuilding.org/fbc/publications/fbc.pdf.

[27] For example, federal entities are required to construct new buildings or alter existing buildings (owned or leased) using the latest edition of one of the "nationally recognized model building codes" (40 U.S.C. §3312) and FEMA may grant funding to communities to adopt and enforce the "latest published editions of relevant consensus-based codes, specifications, and standards that incorporate the latest hazard-resistant designs" (42 U.S.C. §5172(e)(1)(A)).

[28] ICC, "IBC Reference," at https://shop.iccsafe.org/international-codes/ibc-references.html.

[29] For example, FEMA recommended new earthquake-resistant design elements for possible inclusion in model building codes. FEMA, "NEHRP Recommended Seismic Provisions for New Buildings and Other Structures," January 7, 2022, at https://www.fema.gov/node/nehrp-recommended-seismic-provisions-new-buildings-and-other-structures.

[30] NIST, "Proposed Updates to Steel Building Standard Could Enhance Earthquake Resilience," at https://www.nist.gov/news-events/news/2022/01/proposed-updates-steel-building-standard-could-enhance-earthquake.

Performance-Based Design

Engineering and construction professionals may need to move from *prescriptive design* (PD) to *performance-based design* (PBD) for some building elements because those elements must perform to some specified level for a specific hazard (e.g., a steel beam must perform to a certain strength and stiffness to resist a specified shaking intensity caused by an earthquake).[31] PD is used for most building codes and prescribes the design criteria (e.g., the maximum stud spacing on the first floor of a two-story house). PBD sets the criteria based on the performance of the building element (e.g., the compressive stress of the lumber may not exceed some maximum value for the floor). PBD may be more complex to implement than PD, may require additional analysis before the standards can be applied to building construction or retrofitting, and may not be feasible for all of the components of model building codes or for all types of hazards.

Research and Development for Hazard-Resilient Building Design

The IO and FRT reports recommended three avenues of R&D in design and construction practices:

1. Determine the hazards, hazard intensity levels, and building response to different hazards (e.g., assessing post-disaster damage, modeling potential damage from disaster scenarios)
2. Determine the functional recovery time to prescribe for different hazards, hazard intensity levels, and building types (e.g., for a moderate earthquake, a commercial building should regain certain functions within a week)
3. Develop hazard-resilient innovations in materials, designs, design methods, modeling, and construction practices

Community Planning Considerations

The IO and FRT reports recommended R&D on community planning to determine how hazard-resilient buildings fit into community resilience and contribute to supporting, for example, health care, education, business, and governance. In addition, the reports noted that communities may address buildings' occupancy and functional recovery times through pre-disaster recovery planning. Pre-disaster recovery planning allows a community to consider the whole community system and all of the system parts to identify and mitigate weaknesses that may prevent recovery. For example, if the power supply to a building is lost but the community has alternative power supply plans in place, then a building may be occupied and remain functional using the alternative power supply after a disaster.

Economic and Social Feasibility Considerations

The IO and FRT reports recommended further research, analysis, and assessment of the economic and social feasibility of hazard-resilient buildings at the local, regional, and national scales (e.g., the costs for new buildings or for retrofitting older buildings over the building lifecycle). Research also may consider broader economic impacts, such as how a business could function after a disaster and how that ability may affect decisions to build or locate in a hazard-resilient

[31] IO report, p. 14.

building. In addition, the reports recommended research on social feasibility, such as stakeholders' perceptions of risks.[32]

Adoption and Acceptance Considerations

The IO and FRT reports noted that the primary mechanism for achieving hazard-resilient buildings is the adoption and enforcement of hazard-resilient building codes. Therefore, establishing national model building codes that are understood by, and acceptable to, communities may be a feasible starting point. Additional R&D on community needs, perceptions, and the effectiveness of adopted community building codes may inform approaches for nationwide adoption of hazard-resilient codes. Advancing a national framework for hazard-resilient buildings may be the most efficient, consistent pathway to adoption and enforcement of hazard-resilient building codes in communities.

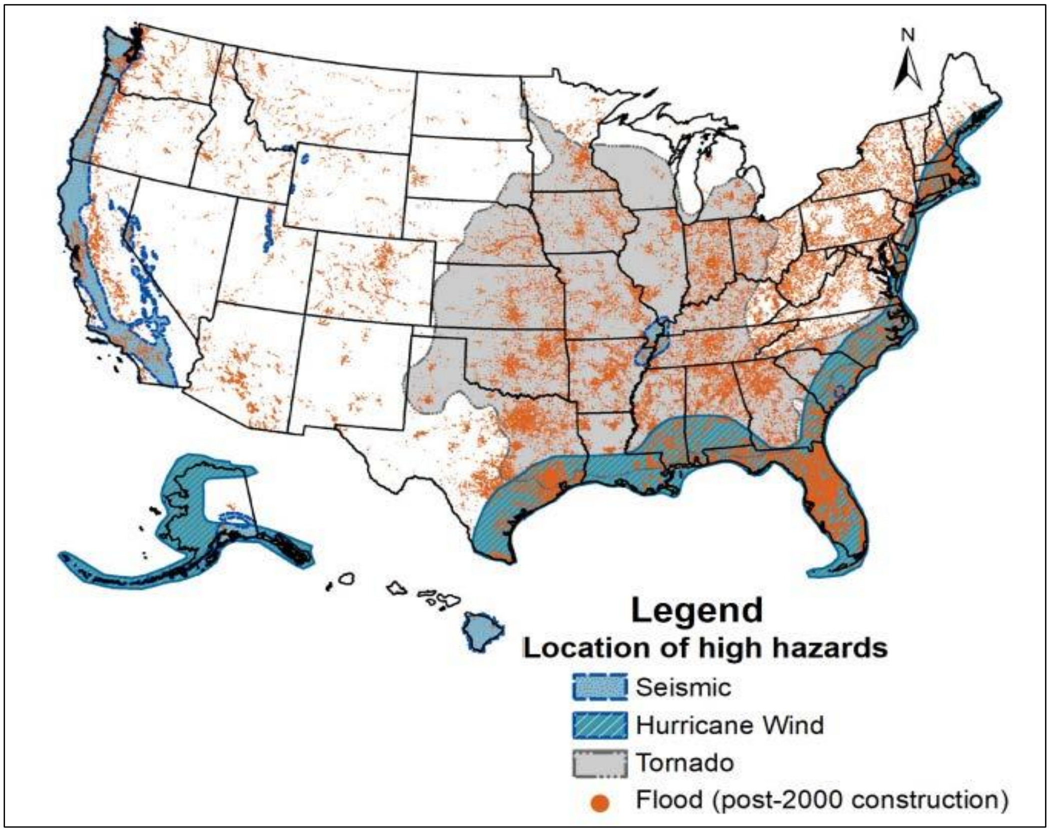
Federal Role to Increase Hazard-Resilient Building Stock

Congress established the National Flood Insurance Program, NEHRP, and the National Windstorm Impact Reduction Program (NWIRP) in part to reduce damages and losses to buildings from floods, earthquakes, and damaging winds.[33] These programs involve FEMA, NIST, the National Science Foundation, the USGS, and/or NOAA in efforts to identify the hazards (including their frequency, intensity levels, and the damage they may inflict on buildings) and to identify ways to mitigate the impacts of these hazards on the built environment. For example, FEMA has identified the hazards most likely to affect buildings in different parts of the country (**Figure 1**). In addition, the IO report replotted NOAA's billion-dollar weather and climate disasters data to show the frequency of different hazards (e.g., hurricanes or floods) by state (**Figure 2**). The USGS provides earthquake probability assessments, and these probabilities may be used to assess the intensity and frequency of earthquakes on the built environment (**Figure 3**).

[32] Hazard is not the same as risk; *hazard* is a source of danger, whereas *risk* is the possibility of loss or injury.

[33] For more information, see CRS Report R43141, *The National Earthquake Hazards Reduction Program (NEHRP): Issues in Brief*, by Linda R. Rowan; CRS In Focus IF10988, *A Brief Introduction to the National Flood Insurance Program*, by Diane P. Horn; and the following federal agency websites: NEHRP, "National Earthquake Hazards Reduction Program," at https://www.nehrp.gov/; NIST, "National Windstorm Impact Reduction Program," at https://www.nist.gov/el/materials-and-structural-systems-division-73100/national-windstorm-impact-reduction-program-nwirp; and FEMA, "Flood Insurance," at https://www.fema.gov/flood-insurance.

Figure 1. FEMA Map of Dominant Hazards in the United States

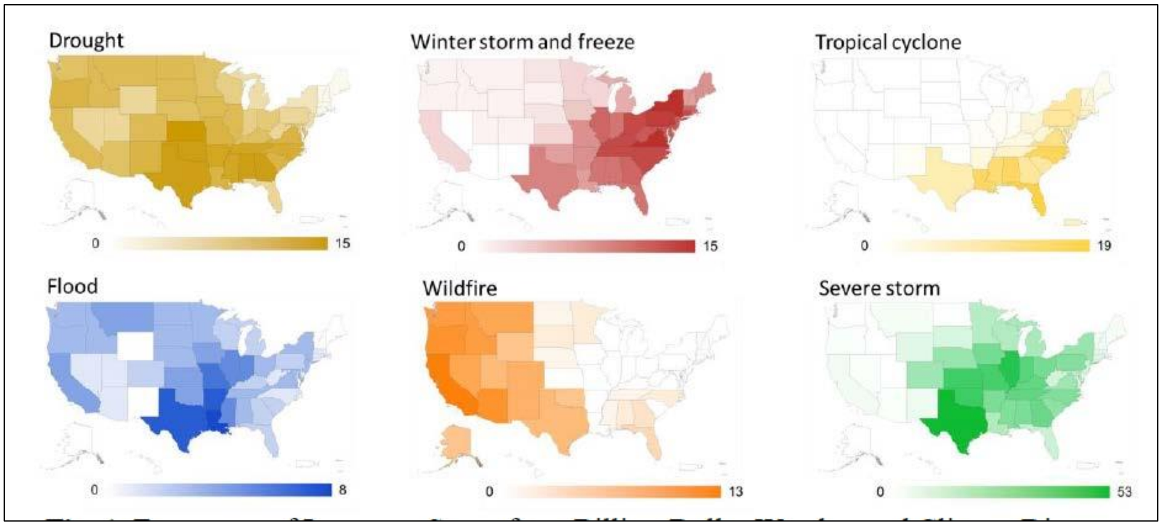


Source: Federal Emergency Management Agency (FEMA), *Protecting Communities and Saving Money: The Case for Adopting Building Codes*, November 2020, at https://www.fema.gov/sites/default/files/2020-11/fema_building-codes-save_brochure.pdf.

Notes: FEMA estimates that seismic activity, hurricane winds, tornadoes, and floods represent dominant hazards in the United States relative to other natural hazards, based on the number of occurrences of these hazards and the amount of losses due to damage to buildings from these hazards in the past.

Figure 2. NOAA Billion-Dollar Weather and Climate Disasters Frequency by State

(From 1980 to 2017, by hazard type)

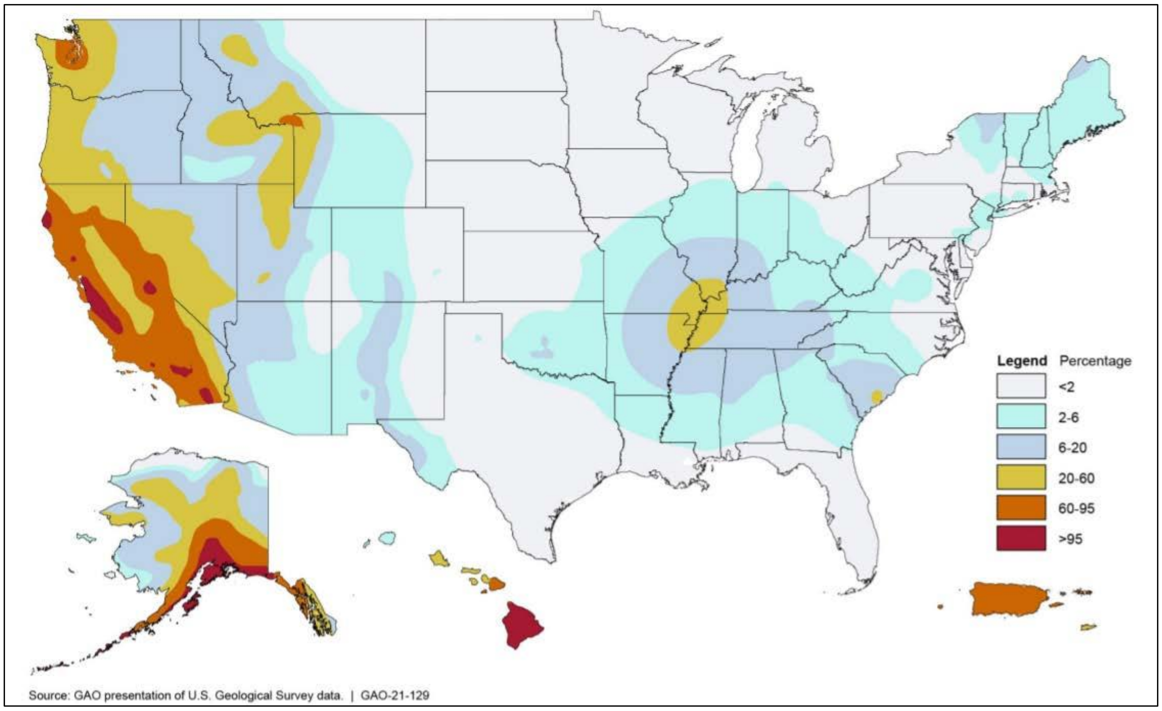


Sources: Siamak Sattar et al., *Research Needs to Support Immediate Occupancy Building Performance Objective Following Natural Hazard Events*, National Institute of Standards and Technology (NIST), NIST Special Publication 1224, August 2018, at https://doi.org/10.6028/NIST.SP.1224, using data from National Oceanic and Atmospheric Administration (NOAA), National Centers for Environmental Information, "Billion-Dollar Weather and Climate Disasters: Overview," 2018, at http://www.ncdc.noaa.gov/billions/.

Notes: Frequency with which each state has been impacted by a disaster exceeding $1 billion in damage between 1980 and 2017. For example, 15 drought disasters impacted Texas, totaling more than $1 billion for each occurrence, between 1980 and 2017 (upper left panel). NOAA estimates the total cost for each disaster as the cost in terms of dollars that would not have been incurred had the event not taken place. The dollar amounts are adjusted for inflation. The costs include physical damage to residential, commercial, and municipal buildings; material assets (content) within buildings; time element losses such as business interruption or loss of living quarters; damage to vehicles and boats; public assets including roads, bridges, levees; electrical infrastructure and offshore energy platforms; agricultural assets including crops, livestock, and commercial timber; and wildfire suppression costs, among others. NOAA estimates that increases in population and material wealth, population centers and infrastructure in vulnerable areas such as coasts and river floodplains, and climate change impacts contribute to the costs of weather and climate disasters. NOAA also notes that building codes are often insufficient in reducing damage from these extreme events. See NOAA, "Billion-Dollar Disasters – Calculating the Costs," at https://www.ncei.noaa.gov/access/monitoring/dyk/billions-calculations.

Figure 3. USGS Seismic Hazard Map

(probability of a Modified Mercalli Intensity VI earthquake in 100 years, expressed as a percentage)



Source: U.S. Government Accountability Office (GAO), *Earthquakes: Progress Made to Implement Early Warning System, But Actions Needed to Improve Program Management*, GAO-21-129, March 2019.

Notes: The Modified Mercalli Intensity Scale from Roman numeral I to X represents the shaking intensity from an earthquake felt by people or damaging property. Intensity VI is strong shaking that is felt by everyone and causes slight damage to property. See U.S. Geological Survey (USGS), "The Modified Mercalli Intensity Scale," at https://www.usgs.gov/programs/earthquake-hazards/modified-mercalli-intensity-scale. See also CRS Report R43141, *The National Earthquake Hazards Reduction Program (NEHRP): Issues in Brief*, by Linda R. Rowan.

FEMA Programs and Activities

FEMA's Building Science program, plus its NEHRP and NWIRP activities, supports R&D for improving building codes, gaining adoption of hazard-resistant model building codes, and other activities. [34] In addition, FEMA's Public Assistance Program and Hazard Mitigation Assistance Grants program may incentivize, encourage, or help facilitate the adoption of hazard-resistant model building codes leading to more hazard-resilient buildings.[35] These programs and activities may align with the recommendations in the IO and FRT reports.

[34] FEMA describes *hazard-resistant model building codes* as the 2018 or later editions of I-Codes. FEMA, "2022 Building Code Adoption Tracking Overview," fact sheet, February 2022, at https://www.fema.gov/sites/default/files/documents/fema_fy22-about-bcat-report.pdf. These model codes contain design elements that allow buildings to better withstand hazards; in some cases, this resistance may allow occupancy and function soon after a disaster. For more information about FEMA programs and activities, see FEMA, "Risk Management," at https://www.fema.gov/emergency-managers/risk-management.

[35] FEMA, "Assistance for Governments and Private Non-Profits After a Disaster," at https://www.fema.gov/assistance/public; and FEMA, "Hazard Mitigation Assistance Grants," at https://www.fema.gov/grants/mitigation. See also CRS Insight IN11733, *Recent Funding Increases for FEMA Hazard Mitigation Assistance*, by Diane P. Horn.

FEMA program activities identify the location, frequency, and intensity of hazards that may damage buildings, consider how different hazards may damage buildings, and conduct R&D on hazard-resilient building design and construction.[36] The programs may suggest model building code design elements to SDOs. In addition, the program tracks building code adoption in the United States to help understand, at a national level, the state of resiliency across communities.[37]

A study led by FEMA, entitled *Building Codes Save: A Nationwide Study*, looked at 18.1 million buildings constructed between 2000 and 2016 (more than 85% of these buildings were residential construction) and estimated the amount of damage these structures might incur from the three most common hazards: floods, hurricanes, and earthquakes.[38] The findings showed that about half the buildings (roughly 9.1 million) were built to I-Codes (2000 or later editions) and would lead to average annualized losses avoided of approximately $1.6 billion (2020 dollars).[39] The study noted that recent I-Codes (2015 or 2018 editions) were designed for life safety and to reduce property damage up to a defined risk threshold to increase the number of hazard-resistant buildings in communities nationwide. According to FEMA's Nationwide Building Code Adoption Tracking (**Table 1**), a low-to-medium percentage (11%-54%) of building stock in approximately 22,000 jurisdictions is resistant to specific hazards.

Table 1. Hazard-Resistant Code Adoption Statistics

(As of FY2022, second quarter)

Hazard	Resistant Percentage of Building Stock (%)
Damaging Wind	25
Hurricane Wind	54
Tornado	11
Flood	25
Earthquake	49
Combined	25

Source: FEMA, "Nationwide Building Code Adoption Tracking," at https://www.fema.gov/emergency-managers/risk-management/building-science/bcat.

Notes: FEMA tracks hazard-resistant building code adoption status for state, local, tribal and territorial governments, covering approximately 22,000 jurisdictions across the nation. The resistant percentage is the percentage of modern building codes in use by these communities that include hazard-resistant designs for specific hazards. FEMA considers hazard-resistant codes as the adoption of the 2018 or later editions of the International Code Council (ICC) model building codes (I-Codes), along with the hazard-resistant design standards from the American Society of Civil Engineers, Structural Engineering Institute's *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE/SEI 7-14 or later editions) and *Flood Resistant Design*

[36] FEMA, "Building Science," at https://www.fema.gov/emergency-managers/risk-management/building-science; and FEMA, "Hazard Mitigation Assistance Grants," at https://www.fema.gov/grants/mitigation.

[37] FEMA, "Nationwide Building Code Adoption Tracking," at https://www.fema.gov/emergency-managers/risk-management/building-science/bcat.

[38] The 18.1 million new buildings in the study may be divided into about 15.4 million one- and two-family dwellings; 0.5 million other residential buildings; 0.7 million commercial and industrial buildings; and 1.6 million other buildings, such as educational, religious, and government buildings. Numbers from Table 3-3, FEMA, *Building Codes Save*, 2020. The most recent codes at the time of this study were from 2018. The ICC has since updated its codes, so the most recent editions are from 2021. ICC, "IBC Reference," at https://shop.iccsafe.org/international-codes/ibc-references.html.

[39] The losses are for physical damage to buildings and do not include any economic, social, cultural, or government losses related to the loss of function of the buildings. FEMA, *Building Codes Save*, 2020.

and Construction (ASCE/SEI 24-14) design standard for flood loads for buildings constructed in flood hazard areas. I-Codes include the ASCE design standards. A jurisdiction that adopts I-Codes may choose to exclude some or parts of the ASCE design standards, so FEMA specifies the importance of adopting and enforcing I-Codes and ASCE design standards in their hazard-resistant building code adoption tracking.

FEMA has published a Building Code Strategy with three goals: (1) integrate building codes and standards across FEMA, (2) strengthen nationwide capability for superior building performance, and (3) drive public action on building codes.[40] Although the Building Code Strategy and the *Building Codes Save* report do not mention occupancy or functional recovery time, the objective of reducing property damage for a defined hazard level may contribute to increasing the probability of occupancy and functional recovery. Some of these strategies, including the following, are similar to the IO and FRT reports' recommendations:

- Advance building code research and use data-driven decisionmaking to guide the application of codes
- Understand stakeholder needs to identify opportunities that advance code adoption and enforcement
- Implement 2018 or 2021 editions of I-Codes across FEMA policies and programs and improve coordination and governance of code activities throughout FEMA

In addition to these activities, the Biden Administration announced a National Initiative to Advance Building Codes on June 1, 2022.[41] The initiative aims to help communities adopt current model building codes to make buildings more resilient to disasters and more energy efficient.[42] The Mitigation Framework Leadership Group, a collaborative interagency body, aims to identify opportunities for federal agencies to assist communities to adopt current model building codes.[43] For example, FEMA plans to implement its Building Code Strategy and use its Building Code Adoption Tracking portal. In another example, the Department of Housing and Urban Development is to require increased resilience and energy efficiency standards for residential properties constructed or rehabilitated through the 2020 and 2021 Community Development Block Grant-Disaster Recovery funds.

NIST Programs and Activities

NIST activities to advance hazard-resilient buildings are organized primarily within the Engineering Laboratory under Disaster-Resilient Buildings, Infrastructure, and Communities.[44]

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[40] FEMA, *Building Codes Strategy*, March 2022, at https://www.fema.gov/emergency-managers/risk-management/building-science/building-codes-strategy.

[41] White House, "Fact Sheet: Biden-Harris Administration Launches Initiative to Modernize Building Codes, Improve Climate Resilience, and Reduce Energy Costs," press release, June 1, 2022, at https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/01/fact-sheet-biden-harris-administration-launches-initiative-to-modernize-building-codes-improve-climate-resilience-and-reduce-energy-costs/.

[42] According to an ICC press release, the current model building codes are the current editions of I-Codes. See ICC, "White House Announces National Initiative to Advance Building Codes Based on the International Codes," press release, June 1, 2022, at https://www.iccsafe.org/about/periodicals-and-newsroom/white-house-announces-national-initiative-to-advance-building-codes-based-on-the-international-codes/.

[43] FEMA, "Mitigation Framework Leadership Group (MitFLG)," at https://www.fema.gov/emergency-managers/national-preparedness/frameworks/mitigation/mitflg#:~:text=The%20Mitigation%20Framework%20Leadership%20Group,National%20Mitigation%20Framework%20(NMF).

[44] NIST Engineering Laboratory, "Strategic Goals and Programs," at https://www.nist.gov/el/goals-programs; and NIST, "Earthquake Risk Reduction in Buildings and Infrastructure Program," at https://www.nist.gov/programs-projects/earthquake-risk-reduction-buildings-and-infrastructure-program.

This mission area includes NEHRP, NWIRP, and Community Resilience Program activities that support R&D for improving engineering design and construction for hazard resistance and developing tools and guidelines for communities to improve their resilience, including by ensuring a resilient building stock.[45] These activities may support furthering hazard-resilient buildings to sustain or rapidly recover occupancy and function after a disaster. In particular, NIST may provide guidelines and tools to help communities enhance their building code adoption and enforcement for hazard-resilient buildings. NIST also may submit building code design elements that enhance hazard resilience to SDOs for possible inclusion in consensus-based model building codes and may engage in other activities that align with the recommendations in the IO and FRT reports.

Congressional Considerations

Congress may consider whether to take any action regarding the recommendations in the IO and FRT reports. The IO report did not recommend any specific actions for Congress, federal agencies, or particular stakeholders. The FRT report, by contrast, included four actions Congress could consider. The four suggested actions and some options that Congress may consider are outlined below.

1. **Support R&D in the four areas recommended in the IO and FRT reports.** Congress may consider whether any current federal agency activities or grant programs (e.g., the programs described in "Federal Role to Increase Hazard-Resilient Building") already address some or all of the R&D recommendations.
2. **Encourage state and local communities to adopt hazard-resilient building codes and to engage in recovery-based planning and mitigation.** Congress could consider directing FEMA and NIST programs (see "Federal Role to Increase Hazard-Resilient Building") to promote the adoption of building codes that address occupancy and function (starting with adoption of the 2018 or 2021 editions of I-Codes) and to support recovery-based planning through incentives or mandates. Congress could incentivize—rather than require—federal agencies to help communities adopt enhanced building codes and develop plans for disaster response and recovery by providing a higher federal cost share, affording access to additional grants or loans, or offering tax credits or discounts on insurance premiums.
3. **Require that federally owned or leased buildings adopt and enforce hazard-resilient building codes.** Congress could enhance the federal statute that requires federally owned or leased buildings to adopt the most recent I-Codes. Doing so would require the federal government to develop more hazard-resilient codes, because the 2021 edition of I-Codes are only hazard resistant (i.e., the codes may not ensure a building can be occupied and can function immediately after a disaster). Alternatively, Congress could amend the statute to require that federally owned or leased buildings adopt the 2021 I-Codes for Risk Category IV buildings, such as hospitals, which must be able to be occupied and functional during and after a disaster.

[45] NIST, "Earthquake Risk Reduction in Buildings and Infrastructure Program," at https://www.nist.gov/programs-projects/earthquake-risk-reduction-buildings-and-infrastructure-program; NIST, "National Windstorm Impact Reduction Program Office," at https://www.nist.gov/el/materials-and-structural-systems-division-73100/national-windstorm-impact-reduction-program-nwirp; and NIST, "Community Resilience Program," at https://www.nist.gov/programs-projects/community-resilience-program.

4. **Mount an education campaign to create public awareness about and a political environment around the value of hazard-resilient buildings, so hazard-resilient codes would be adopted and enforced.** Congress could direct FEMA and/or NIST to mount an education campaign to create public awareness about and a political environment around the value of hazard-resilient buildings to increase the adoption and enforcement of hazard-resilient codes. For example, FEMA's Nationwide Building Code Adoption Tracking Portal (discussed in "FEMA Programs and Activities") may educate stakeholders or citizens about how hazard resilient their current building codes are or what type and intensity of hazard their building codes are designed to resist. FEMA's *Building Code Saves* report (see "FEMA Programs and Activities") or related informational pamphlets may explain the value of hazard-resilient building codes.[46] Congress could consider asking FEMA or NIST to continue or expand these efforts to educate and inform stakeholders and the public about the value of hazard-resilient buildings.

In addition to considering these options to move forward on the recommendations in the IO and FRT reports, Congress has seen bills introduced to increase the number of hazard-resilient buildings nationwide. For example, the Disaster Savings and Resilient Construction Act of 2021 (H.R. 1984) would allow a tax credit through 2023 for certain residential or commercial buildings in a disaster area that are designed and constructed to meet resilient construction requirements. The legislation defines *resilient construction requirements* as the ability to provide primary functions after a disaster, to reduce the magnitude and duration of the disruptive event, and to withstand and recover from the event. The legislation would require that buildings be constructed following the most recent editions of I-Codes for residential or commercial buildings to receive the tax credit. In addition, the legislation would require residential construction to meet certain criteria under the FORTIFIED certifications from the Insurance Institute for Business and Home Safety for different hazards and commercial buildings to meet certain ratings by the U.S. Resiliency Council Rating System.[47]

Independent of the IO and FRT reports but toward the same objectives, Congress has provided further directions to federal agencies. For example, in the explanatory statement accompanying the Consolidated Appropriations Act, 2022 (H.Rept. 117-97), Congress directed NIST and NOAA to improve building design so that buildings are more resistant to weather and climate change challenges, objectives that may lead to more hazard-resilient buildings. Specifically, under "Forward-Looking Building Standards" in H.Rept. 117-97, Congress directed NIST and NOAA to identify "forward-looking climate data" to use for the standard-setting process to aid federal and nonfederal entities in developing building codes that account for extreme weather events and other climate change challenges.[48]

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[46] In August 2022, FEMA published FEMA, *Building Code Adoption Playbook for Authorities Having Jurisdiction*, FEMA P-2196, August 2022, at https://www.fema.gov/sites/default/files/documents/fema_building-codes-adoption-playbook-for-authorities-having-jurisdiction.pdf. The document provides an overview of building codes, model building codes, hazard-resistant design standards, and other details that meet some of the objectives of an educational campaign suggested in the FRT report.

[47] See Insurance Institute for Business and Home Safety, "FORTIFIED Construction Standards," at https://ibhs.org/fortified/; and U.S. Resiliency Council, "USRC Rating System," at https://www.usrc.org/usrc-rating-system/.

[48] H.Rept. 117-97 calls for climate information about "chronic climate impacts, such as sea level rise, and extreme weather events, such as hurricanes, floods, and droughts."

Author Information

Linda R. Rowan
Analyst in Natural Resources Policy

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