Green Building Overview and Issues

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SUMMARY

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Green Building Overview and Issues

Buildings, whether residential, commercial, government, or special-use, are core components of the nation's infrastructure. Their construction, operation, and demolition are increasingly recognized as major sources of environmental impact. Without significant transformation of building construction and operations, that impact is expected to increase with population growth and changes in other demographic and economic factors. One strategy for achieving that transformation is most widely known by the term green building.

In general, *green building* can be characterized as integrated building practices that significantly reduce the environmental footprint of a building in comparison to standard practices. Descriptions of green building generally focus on a number of common elements, especially siting, energy, water, materials, waste, and health. Serviceability or utility is also an explicit design element for a class of green buildings known as high-performance buildings.

One of the most salient features of green building is integration of the various elements. Although individual elements can be addressed separately, the green building approach is more comprehensive, focusing on the environmental footprint of a building over its life cycle, from initial design and construction to operations during the building's useful life, through eventual demolition and its aftermath.

The desire to integrate the various elements of green building has led to the development of rating and certification systems to assess how well a building project meets a specified set of green criteria. The best-known system is Leadership in Energy and Environmental Design (LEED). Developed by the U.S. Green Building Council, it focuses on site, water, energy, materials, and indoor environment. Recently, green building practices have found their way into model building codes and standards. These model codes and standards are then adapted and incorporated into enforceable municipal and state building codes. The federal government has no enforcement responsibilities of building codes, but does play a role in the development, adoption, and compliance of codes by state and local governments.

Green building has received substantial attention from government, industry, and public interest groups. Several federal laws and executive orders have provisions relating to green building. Among these are the energy policy acts (EPACTs) of 1992 and 2005 (P.L. 102-486 and P.L. 109-58), the Energy Independence and Security Act of 2007 (EISA, P.L. 110-140), the Energy Act of 2020 (Division Z of the Consolidated Appropriations Act, 2021, P.L. 116-260), Executive Order (E.O.) 13834, E.O. 13990, and E.O. 14008. EISA and other policy instruments require all federal agencies to implement green building practices. However, several agencies have programs and activities that have a focus that goes beyond reducing the environmental impacts of the facilities used by that agency—for example, by performing research or facilitating the green-building activities of nonfederal entities. Among those agencies are the General Services Administration, the Environmental Protection Agency, the Office of Federal Sustainability, the National Institute of Standards and Technology, and the Departments of Defense, Energy, and Housing and Urban Development.

Green building raises issues relating to performance, cost, market penetration, and the approach itself. Among the questions Congress may face with respect to such issues are the following: How well are current green building programs working? How effective are current methods for coordinating the green building activities of different agencies? To what extent and by what means should Congress extend its efforts to facilitate and support the adoption and effective implementation of green building measures? What priorities should Congress give to the different elements of green building? What actions should Congress do to facilitate the growth of the scientific and technical knowledge base relating to green building?

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Introduction

The environmental impacts of human activity have been a source of controversy and concern for many years. Much of the focus over that time has been on impacts such as pollution and the destruction or degradation of wildlife habitats and ecosystems. Over the past few decades, however, concerns have increased greatly about greenhouse gases, resource depletion, and degradation of ecological services such as water supply. Over that time, the impacts of buildings have come under increasing scrutiny.

There are many different kinds of buildings—residential, commercial, government, and those with special uses such as schools and hospitals—and they form a large and core component of the nation's infrastructure. The construction, characteristics, operation, and demolition of buildings are now recognized as a major source of environmental impact, including direct effects on the humans who use them. U.S. buildings consume vast amounts of resources annually in the form of electricity for lighting and temperature control, drinkable water for indoor and outdoor use, and construction materials with diverse supply chains and manufacturing processes; they also produce substantial waste streams throughout their life cycles, from construction to daily operations to demolition. Such resource use can impose high environmental and financial costs. For example, residential and commercial buildings account for about 40% of energy consumption in the United States, producing approximately 35% of anthropogenic greenhouse gas emissions, and costing consumers more than $420 billion a year in energy bills.[1]

A portion of those combined energy bills can be attributed to a lack of energy efficiency. How energy efficient a building must be is set by building energy codes. Energy codes assure that energy use and emissions are both being reduced over the life of a newly built or renovated building. Total annual energy savings directly related to model building energy codes are estimated at $5.6 billion in 2019 dollars.[2] Energy codes are not set at the federal level, but adopted and enforced by local and state governments. They are a subset of a larger group of building codes (e.g., fire, safety) that regulate almost every aspect of a building's operation, maintenance, and lifecycle. This regulation is seen by many as necessary due to the impact the built environment has on the natural environment and the building occupants.

A building's location and interaction with its surrounding environment influences its ecological and human health impacts. Buildings create impervious surfaces that can have substantial effects on stormwater management and associated health and environmental impacts. A building's proximity to public transportation affects the energy required to transport occupants to and from the premises. If an office is not accessible by walking or public transit, for example, occupants may need to commute by car, contributing to traffic delays, smog, and greenhouse gas emissions. Occupant health and productivity is also affected by building features that determine indoor air quality. People spend almost 90% of their time indoors, and the air in buildings often has

[1] Department of Energy (DOE), Energy Information Administration (EIA), "Table A2. Energy Consumption by Sector and Source," *Annual Energy Outlook 2021*, February 2021, https://www.eia.gov/outlooks/aeo/excel/aeotab_2.xlsx; DOE, EIA, "Table A3. Energy Prices by Sector and Source," *Annual Energy Outlook 2021*, February 2021, https://www.eia.gov/outlooks/aeo/excel/aeotab_3.xlsx; and DOE, EIA, "Table A18. Energy-Related Carbon Dioxide Emissions by Sector and Source," *Annual Energy Outlook 2021*, February 2021, https://www.eia.gov/outlooks/aeo/excel/aeotab_18.xlsx.

[2] O.V. Livingston, P.C. Cole, and D.B. Elliott, et al., *Building Energy Codes Program: National Benefits Assessment, 1992-2040*, Pacific Northwest National Laboratory, PNNL-22610, October 2013, p. 5.1. CRS adjusted the dollars from $5.0 in 2012 dollars according to U.S. Bureau of Economic Analysis, Gross Domestic Product: Chain-Type Price Index [GDPCTPI], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GDPCTPI, December 23, 2020.

substantially higher concentrations of pollutants than the air outside, contributing in extreme cases to a phenomenon known as "sick building syndrome."[3] In light of the Coronavirus Disease 2019 (COVID-19) pandemic, concerns over occupant health also include the potential risks of transfer of airborne pathogens in indoor spaces.[4]

These and other undesirable environmental and health impacts can be addressed for construction, renovation, and operations of both new and existing buildings. *Green building* is a tool for transforming the ways in which buildings are designed, built, operated, and demolished that has generated substantial interest in recent decades. Since emerging as a relatively novel concept in the 1990s, green building has grown into what many consider a respected approach to building, with an increasing number of stakeholders. They include, among others, private construction firms, building owners and occupants, green building certification and standards-developing organizations, federal and state lawmakers, local code officials, and a variety of government agencies. Policies by these green building stakeholders can come in many forms and include goals such as reduction of energy consumption and greenhouse gas emissions, or increasing energy efficiency and incorporating on-site renewable energy generation.

This report discusses the concept of green building, related major federal policies and programs, and associated issues. Topics covered include how green building is defined, what it consists of, the major areas of environmental impact it seeks to address, an overview of the tools available for ensuring that a building conforms to green criteria, outstanding issues in the implementation of green building, an overview of the major statutory and executive authorities that address it, and programs in federal agencies that involve one or more elements related to it.

What Is Green Building?

Environmentally sensitive building is not a particularly recent phenomenon,[5] but the modern practice of green building began emerging in the 1990s. One milestone in the United States was the formation in 1990 of the Committee on the Environment within the American Institute of Architects (AIA),[6] followed within a few years by the founding of the U.S. Green Building Council (USGBC)[7] and other organizations. The most prominent federal green building project in

[3] N. Klepeis, W C. Nelson, W R. Ott, J. P. Robinson, A. M. Tsang, P. Switzer, J V. Behar, S C. Hern, and W H. Engelmann. "The National Human Activity Pattern Survey (NHAPS): A Resource for Assessing Exposure to Environmental Pollutants," *Journal of Exposure Analysis and Environmental Epidemiology*, vol. 11, no. 3 (2001), pp. 231-252.

[4] Centers for Disease Control and Prevention (CDC), *Interim Guidance for Businesses and Employers Responding to Coronavirus Disease 2019 (COVID-19), May 2020*, May 6, 2020, https://www.cdc.gov/coronavirus/2019-ncov/community/guidance-business-response.html; CDC, *COVID-19 Employer Information for Office Buildings*, July 9, 2020, https://www.cdc.gov/coronavirus/2019-ncov/community/office-buildings.html; ASHRAE, *Filtration/Disinfection*, https://www.ashrae.org/technical-resources/filtration-disinfection#airborne; Occupational Safety and Health Administration, *Guidance on Preparing Workplaces for COVID-19*, OSHA 3990-03 2020, 2020, pp. 12-13, https://www.osha.gov/Publications/OSHA3990.pdf.

[5] For a brief history, see, for example, Robert Cassidy, ed., "White Paper on Sustainability," *Building Design and Construction* Supplement, November 2003, 48 p., https://www.bdcnetwork.com/sites/default/files/BD%2BC%202003%20White%20Paper%20on%20Sustainability.pdf; Osman Attmann, *Green Architecture: Advanced Technologies and Materials*, McGraw-Hill's GreenSource Series (New York: McGraw-Hill, 2010).

[6] American Institute of Architects (AIA), "AIA/COTE: A History Within a Movement," 2008, https://network.aia.org/committeeontheenvironment/home/cotehistory.

[7] The U.S. Green Building Council (http://www.usgbc.org) is a U.S. nonprofit cross-sector organization (including representatives of industry, government, and academia) founded in 1993. The Sustainable Buildings Industry Council (https://www.nibs.org/?page=sbic), a trade association, also became involved in green building in the 1990s. The

that decade was the "Greening of the White House."[8] From those beginnings, the concept of green building has expanded to encompass both the movement to promote environmentally conscious design principles and the set of practices and strategies by which builders seek to reduce harmful impacts of the built environment.

There is no single consensus definition of green building; efforts exist along a design and performance continuum. What some call green building is barely distinguishable from standard building practices. At the extreme, the term can be used in an almost meaningless way, purely as a marketing tool. Such practices are sometimes called "greenwashing."[9]

In contrast, some practitioners aim to provide buildings with environmental impacts that are greatly reduced from those of typical buildings. Examples include the so-called "zero-impact" building, which is intended to have no net environmental impact, including but not limited to net-zero energy use; and the "minus-impact" building, which would provide a net environmental benefit. Most green building efforts have less ambitious reduction goals.

In general, *green building* might best be characterized as an integrated approach to building design, construction, and operations that significantly reduces the environmental footprint of buildings in comparison to standard practices. The *environmental footprint* is the overall impact of a structure or activity on the environment, including the human environment.[10]

This characterization captures two common features of the various meanings given to the term. First, green is a relative concept—a green building is one that is greener than average, and as more green buildings are constructed, the performance requirements for a green building increase.[11] Second, it is not limited to only one factor, such as energy consumption, but involves integration across several, as is discussed below. The green building approach can be applied to any class of building: large or small, commercial or residential.

Green builders seek to achieve improvements in environmental performance through a variety of techniques and strategies, from the implementation of innovative technologies (such as energy-efficient heating and cooling systems) to design features intended to influence occupant behavior (such as placing stairways prominently to encourage their use). Some of these techniques will be discussed in more detail below. Decisions about which of these techniques will be used are often made in the design and planning phase, but can impact the environmental footprint of a building

international World Green Building Council (http://www.worldgbc.org) was founded several years later, in 1999. That organization and others, such as the International Initiative for a Sustainable Built Environment (http://www.iisbe.org) may be especially important for green building in China, India, and other developing nations.

[8] See The White House, "Greening of the White House," November 1999, http://clinton4.nara.gov/Initiatives/Climate/WHgreening.html.

[9] Greenwashing refers to the false or exaggerated promotion of a product as green or sustainable.

[10] See, for example, Commission for Environmental Cooperation, "Green Building in North America," 2008, http://www3.cec.org/islandora/en/item/2335-green-building-in-north-america-opportunities-and-challenges-en.pdf. Related terms include ecological footprint, which refers to impacts on ecosystems, often measured as the acreage required to absorb the impact; see for example, Aaron Best et al., "Potential of the Ecological Footprint for Monitoring Environmental Impacts from Natural Resource Use" (European Commission, DG Environment, May 2008), http://ec.europa.eu/environment/archives/natres/pdf/footprint.pdf; and Global Footprint Network, "Ecological Footprint," 2017, http://www.footprintnetwork.org/our-work/ecological-footprint/. Another term is carbon footprint, which can be characterized as the net amount of greenhouse gases being produced as a result of an activity; see, for example, James Morton Turner, "Counting Carbon: The Politics of Carbon Footprints and Climate Governance from the Individual to the Global," Global Environmental Politics 14, no. 1 (2014), pp. 59–78.

[11] The "moving target" of performance requirements can result in older green buildings losing their "green" status without undergoing renovations to meet new green performance targets.

throughout its lifecycle. As a result, green building techniques are most often applied to new construction, though there is a growing incidence of green renovation and retrofit projects.

The term *green building* is often used interchangeably with others such as *sustainable building*, and that practice is followed in this report. However, the terms may also be used in ways that are not exactly synonymous. For example, sustainable building may be described as a form of green building, but with a more stringent goal of indefinitely maintaining environmental footprints that are small enough that they will not impede future human activity and the functioning of ecosystems.[12]

Another term often used interchangeably with green building is *high-performance building.* However, high-performance building usually involves other factors such as security in addition to environmental ones. There are two federal statutory definitions:

> a building that integrates and optimizes all major high-performance building attributes, including energy efficiency, durability, life-cycle performance, and occupant productivity,[13]

and

> a building that integrates and optimizes on a life cycle basis all major high performance attributes, including energy conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality, and operational considerations.[14]

Additional objectives may also be considered in the design of high-performance buildings, including aesthetics and historical preservation.[15]

Section 401 of the Energy Independence and Security Act (EISA) of 2007 (P.L. 110-140, 42 U.S.C. §17061(13)) further refined the concept by establishing a detailed definition for a *high-performance green building*. According to Section 401 of EISA, a high-performance green building

> means a high-performance building that, during its life-cycle, as compared with similar buildings (as measured by Commercial Buildings Energy Consumption Survey or Residential Energy Consumption Survey data from the Energy Information Agency)—
>
> (A) reduces energy, water, and material resource use;
>
> (B) improves indoor environmental quality, including reducing indoor pollution, improving thermal comfort, and improving lighting and acoustic environments that affect occupant health and productivity;
>
> (C) reduces negative impacts on the environment throughout the life-cycle of the building, including air and water pollution and waste generation;
>
> (D) increases the use of environmentally preferable products, including biobased, recycled content, and nontoxic products with lower life-cycle impacts;
>
> (E) increases reuse and recycling opportunities;

[12] These characterizations draw most heavily on descriptions in some documents from the Building Science Corporation (http://www.buildingscience.com/index_html). Some observers may argue for other characterizations of "sustainable building," such as "zero-impact."

[13] 42 U.S.C. §16194(a).

[14] 42 U.S.C. §17061(12).

[15] Dan Prowler and Stephanie Vierra, "Whole Building Design," Whole Building Design Guide, August 17, 2017, http://www.wbdg.org/resources/whole-building-design.

(F) integrates systems in the building;

(G) reduces the environmental and energy impacts of transportation through building location and site design that support a full range of transportation choices for users of the building; and

(H) considers indoor and outdoor effects of the building on human health and the environment, including—

(i) improvements in worker productivity;

(ii) the life-cycle impacts of building materials and operations; and

(iii) other factors that the Federal Director or the Commercial Director consider to be appropriate.

Elements of Green Building

Descriptions of green building generally focus on specified elements.[16] Commonly cited elements are energy, water, materials, waste, and health.[17] Another is siting, particularly with respect to transportation, ecology, smart growth, and resiliency.[18] The siting element has increased in prominence over the last several years as more attention has focused on the built environment beyond the building itself and as climate change has increased the frequency of natural disasters in primarily coastal regions. Lastly, serviceability is included explicitly among the objectives for high-performance buildings, which may also consider other elements such as disaster and climate resilience.[19]

The goals of a given green building project may vary depending on the needs of the stakeholders, including a building's expected occupants. As a result, different elements may be prioritized in different projects. Local factors such as climate zone and flood risk may influence the design process in ways that affect the relative emphasis placed on the various elements discussed below. Emphasis on increased performance in one element may come at the expense of decreased performance in another element. Many green building elements are interdependent. For example, material selection for environmentally preferable products can affect occupant health, which in turn can affect productivity. A building with on-site renewable energy generation may be well-prepared to function during periods when power is unavailable from utilities, such as after a

[16] These elements may also be referred to by other terms such as attributes, life-cycle parameters, performance areas, or impact categories.

[17] Different sources may emphasize different factors. For example, the Environmental Protection Agency (EPA) lists the following components: energy efficiency and renewable energy, water efficiency, environmentally preferable building materials and specifications, waste and toxics reduction, indoor air quality, and smart growth and sustainable development (Environmental Protection Agency, "Components of Green Building," February 20, 2016, https://archive.epa.gov/greenbuilding/web/html/components.html). The Living Future Institute has developed the "Living Building Certification" with seven "performance areas": place, energy, materials, water, health and happiness, equity, and beauty (International Living Future Institute, "Living Building Challenge," 2017, https://living-future.org/lbc/).

[18] Smart growth is defined differently by different organizations, but it generally refers to a common a set of planning strategies aimed at managing growth to improve livability and economic viability while reducing environmental impact. For a detailed discussion, see Environmental Protection Agency, "Our Built and Natural Environments, A Technical Review of the Interactions Among Land Use, Transportation, and Environmental Quality, Second Edition," June 2013, https://www.epa.gov/smartgrowth/our-built-and-natural-environments.

[19] Most descriptions do not explicitly include a serviceability, productivity, or functionality element, but that may be because those would be commonly expected to be integral elements of any building design.

natural disaster. On-site stormwater management can facilitate the provision of other ecological services.

Energy

A reduced energy footprint is probably the most widely cited element of green building.[20] Techniques include

- energy efficiency and conservation,[21] through such means as energy-efficient appliances and lighting, weatherization,[22] and daylighting;[23]
- use of alternative, renewable sources of energy, such as solar or geothermal power or combustion of biomass;
- utilization of energy storage technologies, often in combination with on-site renewable energy generation; and
- participation in smart-grid innovations, such as demand-response programs.[24]

Energy is widely considered a crucial element because of the economic costs and environmental impacts associated with energy use. In a 2015 report on energy technologies, the Department of Energy (DOE) estimated that buildings using the best available energy efficiency technologies would consume about half as much energy on average as those in the current building stock.[25]

Federal law sets numeric requirements for reductions in energy use by federal buildings.[26] Although the energy intensity[27] of such buildings declined by more than 25% from 2003 to 2019, in 2019 the federal government did not meet the federal goal of a 30% reduction in energy intensity compared with a 2003 baseline.[28]

An ambitious energy reduction target for buildings is net-zero energy consumption. A Net-Zero Energy Building (NZEB) meets all of its energy consumption requirements through a combination of energy efficiency and the use of onsite renewable energy sources such as wind,

[20] See, for example, Government Accountability Office, "Green Building: Federal Initiatives for the Nonfederal Sector Could Benefit from More Interagency Collaboration," GAO-12-79, November 2, 2011, http://www.gao.gov/products/GAO-12-79; Alex Lukachko and Joseph W. Lstiburek, "Towards Sustainability—Green Building, Sustainability Objectives, and Building America Whole House Systems," Research Report (Building Science Corporation, February 8, 2008), https://buildingscience.com/documents/bareports/ba-0801-towards-sustainability-green-building-sustainability-objectives-and-building-america-whole-house-systems-research/view. This report compared the different emphases among several national green building programs for residences. It found that energy efficiency was the only issue that was a primary focus for all, with indoor environmental quality the next most important.

[21] *Energy efficiency* means using less energy to perform the same function, whereas energy conservation refers to practices that reduce consumption, often by changing behavior. Using a lightbulb that produces the same amount of light with less energy would be an example of energy efficiency, while turning off the light when leaving a room would be an example of energy conservation.

[22] *Weatherization* is the process of fortifying a building, usually a home, from the natural elements (precipitation, sunlight, wind, etc.) to reduce energy consumption and increase energy efficiency.

[23] *Daylighting* refers to the practice of designing windows and skylights to utilize sunlight for indoor lighting needs.

[24] See the textbox "Smart Buildings and the Internet of Things" below for more on demand-response and building smart-grid integration.

[25] DOE, "Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities," September 2015, https://energy.gov/sites/prod/files/2017/03/f34/quadrennial-technology-review-2015_1.pdf.

[26] See the section on "Legislative and Policy Framework" below.

[27] Building energy intensity is measured in annual British thermal units (Btu) per gross square foot.

[28] Office of Federal Sustainability, "Facility Energy Use," https://www.sustainability.gov/government_data.html#btu.

biofuels, and geothermal power. NZEBs may sometimes rely on delivered energy from an energy network such as the electricity grid, but they produce and export enough renewable energy to the network to fully offset what they draw from it. EISA directed DOE to establish an initiative to develop net-zero energy commercial buildings, with the goal of achieving net-zero energy in all U.S. commercial buildings by 2050.

Given its importance, energy is sometimes mistakenly treated as the predominant or even the sole element to be considered in green building. However, while a green building almost always addresses the energy element, a building that focuses solely on energy may not be a green building: It could have other environmental impacts that outweigh any benefits from its reduced use of energy.[29]

Smart Buildings and the Internet of Things

Increasingly, green building design is incorporating internet-connected technologies. The spread of Internet access and falling prices for web-enabled technologies have given rise to what has become known as the "Internet of Things" (IoT). The term refers to networks of "smart" objects that communicate with each other and with computers through the internet. A smart object is any noncomputer device with a unique identifier and internet connectivity. The IoT and smart technologies have impacted the operations of sectors, such as manufacturing, transportation, energy, and government services. In the context of buildings, IoT has led to the development of a new generation of "smart buildings."[30]

Smart buildings incorporate resource monitoring, data analytics, and automation to manage building operations more efficiently.[31] More than 80% of the energy used by a building throughout its life, from construction to demolition, is associated with operations.[32] Examples of smart building technologies that target environmental performance include networked energy and water meters, connected thermostats, and automated leak and fault-detection sensors, all of which can be used in concert to optimize a building's resource use.[33] Building systems may also be networked with the electricity grid, water infrastructure, and waste collection systems to leverage operational efficiencies at the campus, neighborhood, or city scale.[34] For instance, buildings can monitor and respond to real-time electricity pricing signals from the grid to shift consumption to periods of low demand and high supply. This process is known as demand-response, and it can be used by smart grids to reduce the use of inefficient power plants during periods of peak demand, increasing efficiency and minimizing overall emissions of pollutants.

Smart building technologies and fully integrated building systems have the potential to reduce the amount of operational energy consumed in a building. Congress may wish to facilitate the development and adoption of these technologies. One option could be to increase funding for federal R&D programs in building technologies. Other

[29] For example, some energy-efficiency measures may also negatively impact indoor air quality. For examples of other impacts that potentially outweigh savings from energy efficiency, see Alex Wilson and Rachel Navaro, "Driving to Green Buildings," *Environmental Building News* 16, no. 9 (2007): 1–18, http://search.ebscohost.com/login.aspx?direct=true&db=eih&AN=26824144&site=ehost-live.

[30] CRS Report R44227, *The Internet of Things: Frequently Asked Questions*, by Patricia Moloney Figliola.

[31] The Energy Act of 2020 (Division Z of the FY2021 Omnibus and COVID Relief and Response Act, P.L. 116-260) defines "smart building" as " a building, or collection of buildings, with an energy system that—(A) is flexible and automated; (B) has extensive operational monitoring and communication connectivity, allowing remote monitoring and analysis of all building functions; (C) takes a systems-based approach in integrating the overall building operations for control of energy generation, consumption, and storage; (D) communicates with utilities and other third-party commercial entities, if appropriate; (E) protects the health and safety of occupants and workers; and (F) incorporates cybersecurity best practices."

[32] National Institute of Standards and Technology, "Embedded Intelligence in Buildings Program," July 17, 2017, https://www.nist.gov/programs-projects/embedded-intelligence-buildings-program.

[33] Jennifer King and Christopher Perry, "Smart Buildings: Using Smart Technology to Save Energy in Existing Buildings," American Council for an Energy-Efficient Economy, Feb 2017, https://www.aceee.org/sites/default/files/publications/researchreports/a1701.pdf,

[34] Jim Sinopoli, "Smart Controls," Whole Building Design Guide, August 15, 2016, https://www.wbdg.org/resources/smart-controls.

options could include authorizing a program specifically for smart building technologies or providing incentives to encourage the adoption of smart building technologies.

Water

Reducing water usage in buildings can provide cost savings. It can also aid management of water resources, especially in arid areas and in response to periodic drought elsewhere.[35] Reductions can be achieved through such measures as reduced-flow plumbing fixtures,[36] recycling of wastewater,[37] and xeriscaping.[38]

Water management may also include how the building and associated land handle rain, on-site water, and run-off. Development designed to ensure that the way a site handles water is similar to how it did so before development is called *low-impact development*, which "uses natural and engineered infiltration and storage techniques to control stormwater where it is generated."[39] Among the methods used are reduction in impervious surfaces through landscaping, use of porous materials and green roofs, and use of holding ponds, swales, rain gardens, and similar measures. Such techniques for water management are sometimes referred to collectively as *green infrastructure* (see the section on "Environmental Protection Agency," below).

Materials

The materials used in a building, during both construction and operations, can contribute substantially to the building's environmental footprint. The choice and use of materials affects resource depletion, pollution, embodied energy,[40] embodied carbon,[41] and health. "Environmentally preferable" or "green-labelled" products can reduce the impact. Such materials may have significant recycled content, be made from renewable biological resources (so-called "biobased" products), or be created with processes that use low amounts of energy and produce low amounts of pollutants.[42] The energy intensity of making, packaging, and transporting a product is its embodied energy. Since the energy used to create the products is most likely carbon-

[35] See CRS Report R43407, *Drought in the United States: Causes and Current Understanding*, by Peter Folger.

[36] Federal manufacturing standards for certain plumbing products were established by the Energy Policy Act of 1992 (P.L. 102-486).

[37] Much wastewater from buildings can be reused in other applications on site, although some treatment may be required or preferred. For example, grey water, which is residential wastewater from sources other than kitchens and toilets, can be reused for irrigation and in toilets.

[38] *Xeriscaping* is landscaping that eliminates the need for supplemental water from irrigation.

[39] Anne Guillette, "Low Impact Development Technologies," *Whole Building Design Guide*, November 3, 2016, http://www.wbdg.org/resources/low-impact-development-technologies. Low-impact building is sometimes used as a synonym for low-impact development and sometimes as a synonym for green or sustainable building.

[40] For a discussion of the term in the context of building construction, see Ben McAlinden, "Embodied Energy and Carbon," *Institution of Civil Engineers (ICE)*, May 15, 2015, https://www.ice.org.uk/knowledge-and-resources/briefing-sheet/embodied-energy-and-carbon.

[41] *Embodied Carbon* is defined similarly to embodied energy as the summation of all carbon emissions that are associated, directly or indirectly, with the delivery of a service or product.

[42] Some federal agencies have developed guidance for obtaining such products (see, for example, Environmental Protection Agency, "Sustainable Marketplace: Greener Products and Services," March 9, 2017, https://www.epa.gov/greenerproducts; General Services Administration, Sustainable Facilities Tool, "Green Procurement Compilation," 2017, https://sftool.gov/greenprocurement; U.S. Department of Agriculture, "BioPreferred," 2017, https://www.biopreferred.gov/BioPreferred/).

based like coal, natural gas, gasoline, etc., the higher the embodied energy of a product, the higher the embodied carbon. The production of concrete, which is a common building material, contributes as much as 10% of global carbon emissions.[43] For some buildings, a portion of the concrete could include less energy-intensive materials such as fly ash, slag sand, and even recycled glass.[44] Even more advanced concrete technology is being developed that can actually sequester carbon dioxide through reaction with naturally found minerals, a process known as carbonation.[45] Building materials may also be designed to reduce health risks such as those from formaldehyde and other volatile organic compounds (VOCs).

There is some debate about what constitutes an environmentally preferable material. The lack of a consistent vocabulary for describing the sustainability attributes of materials, as well as inconsistencies in the measurement methodologies and reporting frameworks used by various eco-labelling systems, can make it difficult to determine whether a given material is preferable to a substitute.[46]

Waste

The environmental impacts from a building's waste stream over its life cycle can be mitigated by waste-reduction efforts, which fall broadly into four main categories: source reduction, reuse, recycling, and waste-to-energy.[47] The U.S. Environmental Protection Agency estimated that in 2017 569 million tons (U.S. short tons) of construction and demolition (C&D) debris were generated in the United States from construction, renovation, and demolition activities, which is more than two times the amount of municipal solid waste generated in the same year (268 million tons).[48] Construction and demolition debris can be reduced through more efficient use of

[43] Siegel, R.P. "Low-Carbon Concrete Can Fight Global Warming," *American Society of Mechanical Engineers*, February 18, 2020, https://www.asme.org/topics-resources/content/low-carbon-concrete-can-fight-global-warming.

[44] Ehrlich, Brent. "A New Standard for Replacing Cement with Recycled Glass," *GreenBuilding*, June 8, 2020, https://www.buildinggreen.com/newsbrief/new-standard-replacing-cement-recycled-glass; Kim et al. "Assessment of the CO2 Emission and Cost Reduction Performance of a Low-Carbon-Emission Concrete Mix Design Using an Optimal Mix Design System," *Renewable and Sustainably Energy Reviews*, vol. 25, September 2013, pp. 729-741, https://doi.org/10.1016/j.rser.2013.05.013.

[45] Kashef-Haghighi, Sormeh; Ghoshal, Subhasis. "CO2 Sequestration in Concrete through Accelerated Carbonation Curing in a Flow-Through Reactor," *Industrial and Engineering Chemistry Research*, vol. 49, no. 3, 2010, pp. 1143–1149, https://doi.org/10.1021/ie900703d.

[46] Jorge L. Contreras, Meghan Lewis, and Hannah Roth, "Toward a Rational Framework for Sustainable Building Materials Standards," *Standards Engineering* 63, no. 5 (September 2011), https://www.researchgate.net/profile/Jorge_Contreras12/publication/228311359_Toward_a_Rational_Framework_for_Sustainable_Building_Materials_Standards/links/576bdd1908aead4e3adcfd2c.pdf. See also "Programs and Activities of Selected Federal Agencies," below, for a discussion of some of the federal programs aimed at developing standards for, and facilitating the procurement of, environmentally-preferable materials.

[47] Waste-to-energy refers to the recovery of usable forms of energy from waste materials through processes such as combustion, gasification, and others. EPA ranks waste management strategies from most to least preferred as follows: source reduction and reuse, recycling/composting, energy recovery/waste-to-energy, and treatment and disposal (Environmental Protection Agency, "Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy," August 10, 2017, https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy).

[48] The estimate for construction and demolition debris accounted for waste generated from construction, renovation, and demolition of buildings, roads, and bridges. Municipal solid waste—commonly referred to as trash—can include waste packaging, food, yard trimmings, electronics, and large bulk items such as furniture and appliances. See Environmental Protection Agency (EPA), *Advancing Sustainable Materials Management: 2017 Fact Sheet: Assessing Trends in Material Generation, Recycling, Composting, Combustion with Energy Recovery and Landfilling in the United States*, November 2019, https://www.epa.gov/sites/production/files/2019-11/documents/

materials (source reduction) and recycling or reuse of waste products.[49] In addition to construction, renovation, and demolition activities, buildings also can generate waste during normal operations and maintenance. Some options to reduce waste generated during operations and maintenance can be pursued during the design and construction stage of a building while other options may require occupant engagement and participation. For example, landscaping can be designed to recycle waste such as lawn clippings through mulching and composting and to reduce or eliminate applied chemicals for grounds maintenance. The installation of high-efficiency boilers and furnaces can reduce the emission of atmospheric pollutants. Building owners also could engage occupants in waste diversion efforts through programs to encourage recycling, composting, or otherwise reducing waste generation.

Health

Several factors can influence the health impacts of buildings. For some, the health effects are obvious, such as the presence of indoor air pollutants like mold, radon, carbon monoxide, asbestos, and VOCs. Indoor air quality (IAQ) can have a significant impact on occupant health, given that people spend a large amount of their time indoors.[50] Primary techniques for maintaining high IAQ include ensuring adequate ventilation; providing air filtration; and using materials without heavy metals, VOCs, asbestos,[51] or other potentially toxic substances. Beyond IAQ, the overall indoor environmental quality (IEQ) may also have significant impacts on the health of building occupants.[52]

In light of the COVID-19 pandemic, there is increased interest in the interconnections between building ventilation and public health. According to the Centers for Disease Control and Prevention, most infections of SARS-CoV-2 (the coronavirus that causes COVID-19) are spread through close contact, not airborne transmission; however, circumstances under which airborne transmission of the coronavirus appears to have occurred include enclosed spaces, prolonged exposure to respiratory particles, and inadequate ventilation or air handling.[53] Poor ventilation in buildings, including a lack of sufficient fresh outdoor air, has been linked with transmission of the virus.[54] Increasing outdoor air ventilation may decrease transmission rates of airborne illnesses like COVID-19; however, this should be weighed against other potential risks in areas with high concentrations of air pollution.[55]

2017_facts_and_figures_fact_sheet_final.pdf.

[49] Environmental Protection Agency, "Sustainable Management of Construction and Demolition Materials," June 30, 2017, https://www.epa.gov/smm/sustainable-management-construction-and-demolition-materials.

[50] EPA defines IAQ as the air quality within and around buildings and structures, as it relates to the health and comfort of occupants. For more information, see Environmental Protection Agency, "Introduction to Indoor Air Quality," 2020, https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality.

[51] Asbestos is present in many older buildings and is still used in some construction materials (Environmental Protection Agency, "Learn About Asbestos," December 19, 2016, https://www.epa.gov/asbestos/learn-about-asbestos).

[52] GSA defines IEQ, very simply, as the conditions within a building. Most often, this usually includes factors such as IAQ, lighting, acoustics, temperature and humidity, and amount of open space. For more information on IEQ, visit General Services Administration, Sustainable Facilities Tool, "Indoor Environmental Quality (IEQ)," 2017, https://sftool.gov/learn/about/1/indoor-environmental-quality-ieq.

[53] Centers for Disease Control and Prevention (CDC), "Scientific Brief: SARS-CoV-2 and Potential Airborne Transmission," October 5, 2020, https://www.cdc.gov/coronavirus/2019-ncov/more/scientific-brief-sars-cov-2.html.

[54] Lu J, Gu J, Li K, et al. "COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020," *Emerging Infectious Diseases*, vol. 26, no. 7 (2020), pp. 1628-1631, doi:10.3201/eid2607.200764.

[55] L.D. Knibbs, L. Morawaska, S.C. Bell, P. Grzybowksi, "Room Ventilation and the Risk of Airborne Infection Transmission in 3 Health Care Settings Within a Large Teaching Hospital," *American Journal of Infection Control*,

Outsized emphasis on energy efficiency, without careful consideration of the potential effects on IAQ, has been shown to reduce ventilation rates in green buildings.[56] One of the most common methods for reducing energy costs is by sealing the building envelope to reduce the amount of heat loss or gain from the building. This practice of reducing air leaks stops indoor air from escaping the building and taking with it the energy used to maintain the temperature of the air. However, in doing this without also increasing ventilation, the air can become more stagnant and air pollutants can accumulate. Despite the potential risk of poorer IAQ, green buildings have shown the potential to outperform standard buildings in terms of IAQ and overall occupant health (see "Selected Studies: Health Performance" section for more information).

Siting

Where a building is situated can have significant effects on its environmental footprint.[57] For example, siting of buildings near transportation hubs can facilitate the use of public transportation and reduce impacts from private automobiles. Site selection may also take into account the ecological sensitivity of potential sites, to minimize adverse impacts on ecological services[58] and native species of plants and animals. The orientation of building and surface in relation to the sun and general wind direction, and the building's proximity to trees and other plantings, affect its heating and cooling requirements.

Climate-related risk factors may also be incorporated into siting decisions. Risks from sea-level rise, flooding, and extreme weather events, all of which may be affected by climate change, are of increasing concern to builders, particularly in coastal areas.[59] Resilience to these hazards can increase the useful life of a building and allow it to function when other public services like transportation and utilities are not available. For this reason, the Government Accountability Office (GAO) recommended in 2016 that there should be a government wide effort to "provide the best available forward-looking climate information to standards-developing organizations for their consideration in the development of design standards, building codes, and voluntary

vol. 39, no. 10 (2011), pp. 866-872, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7115323/; G. Buonanno, L. Stabile, and L. Morawska, "Estimation of Airborne Viral Emission: Quanta Emission Rate of SARS-CoV-2 for Infection Risk Assessment," *Environment International*, vol. 141 (2020), 105794. https://doi.org/10.1016/j.envint.2020.105794; T. Ruan, D. Rim, "Indoor Air Pollution in Office Buildings in Mega-Cities: Effects of Filtration Efficiency and Outdoor Air Ventilation Rates," *Sustainable Cities and Society*, vol. 49 (2019), 101609.

[56] A.P. Patton, L. Calferon, Y. Xiong, Z. Wang, et al., "Airborne Particulate Matter in Two Multi-Family Green Buildings: Concentrations and Effect of Ventilation and Occupant Behavior," *International Journal of Environmental Research and Public Health*, vol. 13, no. 1 (2016), p. 144, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4730535/. See also the NIST Report, Dusting Poppendieck et al., "Long Term Air Quality Monitoring in a Net-Zero Energy Residence Designed with Low Emitting Interior Products," *Building and Environment*, vol. 94 part 1 (December 2015), pp. 33-42, https://doi.org/10.1016/j.buildenv.2015.07.001.

[57] The WBDG Sustainable Committee, "Optimize Site Potential," *Whole Building Design Guide*, May 18, 2017, http://www.wbdg.org/design-objectives/sustainable/optimize-site-potential.

[58] *Ecological services* refer to services that natural sites in their undeveloped state may provide such as air and water purification, erosion control, recreation, and habitat for beneficial plants, animals, and microorganisms. Site development using standard design and construction practices can severely reduce such services.

[59] For a discussion of how sea-level rise impacts coastal development, see CRS Report R44632, *Sea-Level Rise and U.S. Coasts: Science and Policy Considerations*, by Peter Folger and Nicole T. Carter. For a discussion of coastal resilience to flooding, see CRS In Focus IF10225, *Coastal Flood Resilience: Policy, Roles, and Funds*, by Nicole T. Carter, Harold F. Upton, and Francis X. McCarthy. For a discussion of climate-change science and impacts, see CRS Report R43229, *Climate Change Science: Key Points*, by Jane A. Leggett.

certifications."[60] Approaches to resilience include such practices as resistant construction;[61] locating critical mechanical components on upper levels away from potential flood waters; on-site backup power generation, such as through solar panels and wind turbines; connection with a microgrid;[62] rainwater harvesting; and water recycling capabilities.

According to the Centers for Disease Control and Prevention, climate change is projected to increase the duration, severity, and frequency of heat waves in the United States.[63] Siting decisions that preserve pre-development vegetation and add to green spaces around buildings can improve the surface temperatures of the immediate built environment, which could reduce cooling-related energy consumption and the energy-associated GHG emissions.[64] In addition to energy, water, and climate related benefits, several studies have found a link between the presence of vegetation surrounding a building and occupants' overall health.[65]

Serviceability

A building that is not useful to its occupants is unlikely to be worth its cost, no matter how small the environmental footprint. Therefore, productivity and other measures of utility comprise an important element of green building that is not always discussed. A large percentage of U.S. workers spend their days in offices, and studies have suggested that IEQ strongly influences worker comfort and productivity.[66]

There is some evidence that green buildings can lead to improved productivity among occupants.[67] However, that is not always the case. For example, poor acoustic performance has been repeatedly observed in certified green buildings, suggesting that trade-offs do sometimes

[60] "Improved Federal Coordination Could Facilitate Use of Forward-Looking Climate Information in Design Standards, Building Codes, and Certifications," *Government Accountability Office*, GAO-17-3, February 2016, https://www.gao.gov/assets/690/681300.pdf.

[61] "Resistant construction" often refers to the construction of buildings that can withstand the forces imposed on them during seismic events; it can more generally refer to construction practices that resist failure from hazards such as earthquakes, hurricanes, flooding, subsidence, and wildfires.

[62] A microgrid is a localized energy grid that can provide energy to communities without being connected to the larger grid system.

[63] "Climate Change and Extreme Heat Events," Centers for Disease Control and Prevention, pp. 8-9, https://www.cdc.gov/climateandhealth/pubs/ClimateChangeandExtremeHeatEvents.pdf.

[64] Xu et al., "Quantifying the Direct Benefits of Cool Roofs in an Urban Setting: Reduced Cooling Energy Use and Lowered Greenhouse Gas Emissions," *Building and Environment*, vol. 48, February 2012, pp. 1-6, https://doi.org/10.1016/j.buildenv.2011.08.011.

[65] Roe, J.J.; Thompson, C.W.; Aspinall, P.A.; Brewer, M.J.; Duff, E.I.; Miller, D.; Mitchell, R.; and Clow, A., "Green Space and Stress: Evidence from Cortisol Measures in Deprived Urban Communities,". *International Journal of Environmental Research and Public Health*, 2013, 10, 4086–4103; Vries, S.; Verheij, R.A.; Groenewegen, P.P.; and Spreeuwenberg, P., "Natural Environments—Healthy Environments? An Exploratory Analysis of the Relationship Between Greenspace and Health," *Environment and Planning A: Economy and Space*, 2003, 35, 1717–1731; Brown, S.C.; Perrino, T.; Lombard, J.; Wang, K.; Toro, M.; Rundek, T.; and Kardys, J., "Health Disparities in the Relationship of Neighborhood Greenness to Mental Health Outcomes in 249,405 US Medicare Beneficiaries," *International Journal of Environmental Research and Public Health*, 2018, 15, 430.

[66] Yousef Al Horr et al., "Occupant Productivity and Office Indoor Environment Quality: A Review of the Literature," *Building and Environment* 105 (August 2016): 369–89, doi:10.1016/j.buildenv.2016.06.001.

[67] Greg Kats et al., "The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force" (Sustainable Building Task Force, October 2003), http://evanmills.lbl.gov/pubs/pdf/green_buildings.pdf; and Piers MacNaughton et al., "The Impact of Working in a Green Certified Building on Cognitive Function and Health," *Building and Environment* 114 (March 1, 2017): 178–86, doi:10.1016/j.buildenv.2016.11.041.

occur between serviceability and other elements. While serviceability is not generally considered as a separate element in green-building design, it is explicitly identified as an objective for high-performance buildings and has received increasing attention in green certification systems.[68]

Integration

One of the most salient features of green building is integration. The green building approach considers integration across (1) elements, to improve performance in multiple impact areas, and (2) stages, to minimize environmental impacts throughout the building's lifecycle.[69] An integrated approach that focuses on the whole building can lead to better assessment of the overall environmental impact of a building. It also permits explicit assessment of and balance among potentially competing goals, and it allows planners to examine how different elements and stages interact and to develop an integrated strategy. Integration and performance with respect to several elements can be enhanced by the appropriate use of information technology in building operations.[70]

Balance Among Elements

A focus on one element at the expense of others can be counterproductive. For example, energy efficiency can be improved by sealing the building envelope to prevent conditioned air from escaping. But an absence of air exchange can result in increased concentration of pollutants in the building and can impede moisture control, fostering the development of mold and deterioration of building materials.[71] Addressing both energy efficiency and health requires either a compromise or technologies such as active ventilation with heat exchange. A green building approach reduces the risk of unanticipated problems by forcing an examination of how actions affecting each element impact others, so that an overall optimization can be achieved. Nevertheless, in some cases, such as many renovations, only one or a few factors might be feasible to address. In other cases, it may make sense to prioritize certain elements at the expense of others due to cost or feasibility constraints, local environmental factors, or occupant priorities.

Balance Across Stages

A focus on one stage in the life cycle of a building can lead to savings at that stage but losses at another. For example, in the absence of sufficient data on the environmental impacts of developing, manufacturing, installing, using, and eventually disposing of alternative building materials, a choice that appears to be environmentally sound may in fact not be. Use of concrete walls provides more insulation on average than use of wood, but has much higher net emissions of carbon dioxide over its life cycle.[72] Far more energy is used in operating a building than in

[68] See, for example, Taryn Holowka, "Indoor Environmental Quality and LEED V4," *U.S. Green Building Council*, August 15, 2017, https://www.usgbc.org/articles/indoor-environmental-quality-and-leed-v4.

[69] This is called a *cradle-to-grave* approach.

[70] One example of this is the use of interconnected "smart" devices that can communicate via sensors and perform data analytics without human-machine interfacing. See also, ASHRAE, "An Introduction to Building Information Modeling (BIM): A Guide for ASHRAE Members," November 3, 2009, http://cms.ashrae.biz/bim/pdf/BIMGuide_Rev_110309.pdf.

[71] See, for example, the documents available at Building Science Corporation, "Building Science Digests," 2017, https://buildingscience.com/document-search?term=&field_doc_topic_tid=All&type%5B%5D=7. Note that inadequate sealing of a building envelope may also permit external pollutants to enter a building and may compromise moisture control, depending on climate and other factors.

[72] Tables 1.6.2 and 1.6.3 in Department of Energy, "2011 Buildings Energy Data Book," March 2012,

constructing one;[73] however, choices made during construction may need to be balanced with planning for the postoccupancy stage. An integrated approach can reduce such problems by facilitating an assessment of the impact from actions at one stage on all the others.

Green Certifications and Standards

Over the last few decades, formal systems and tools were developed that set criteria for green and sustainable buildings. Methods were also developed for assessing whether new construction or renovation projects meet those criteria. The systems and tools fall into one or more of three main categories: rating systems, certifications, and codes and standards. Rating and certification systems are voluntary and build upon the minimum requirements for building design and construction as defined through building codes and standards, which are adopted into law by state and local governments to ensure the safety of occupants and to optimize building performance.

Green Rating Systems and Certifications

Given the range and interconnections of elements involved, determining whether a building is green or sustainable is not straightforward—there is no simple metric for determining how well a building meets the desired criteria. To address this problem, in the 1990s, some professional organizations in the building sector developed rating and certification systems that helped to standardize and define green building practices and raised public awareness of them.

The term *rating system* is often used interchangeably with *certification system*, although they refer to somewhat different concepts. Rating systems assign points to buildings for meeting established criteria in various green building design categories. These points are summed for an overall score. Often, based on the overall score, the building is assigned to one of a number of ranked tiers indicating the level of rigor of the criteria this building attains (e.g., Bronze, Silver, Gold, Platinum). By contrast, certification has no point system, but provides validation that a building meets or exceeds specified design or performance requirements.

Both rating and certification systems are arguably most objective when an independent entity conducts the assessment and awards the certification. Such a *third party* must be independent of the builder, owner, contractor, and designer, as well as the organization that developed the rating system or standard.[74]

A handful of organizations currently offer rating and certification for green buildings. Different ratings systems emphasize different aspects of green building. Therefore, whether one or another is more appropriate may depend on local conditions and priorities. Systems also differ in the types of buildings for which they offer guidelines and certification; some focus primarily on new construction, while others are more geared toward existing buildings. Many systems combine both rating and certification into a single system.

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http://en.openei.org/doe-opendata/dataset/6aaf0248-bc4e-4a33-9735-2babe4aef2a5/resource/3edf59d2-32be-458b-bd4c-796b3e14bc65/download/2011bedb.pdf. The embodied energy also tends to be higher for concrete.

[73] National Institute of Standards and Technology, "Embedded Intelligence in Buildings Program," July 17, 2017, https://www.nist.gov/programs-projects/embedded-intelligence-buildings-program.

[74] Stephanie Vierra, "Green Building Standards and Certification Systems," Whole Building Design Guide, December 9, 2016, https://www.wbdg.org/resources/green-building-standards-and-certification-systems; Contreras, Lewis, and Roth, "Toward a Rational Framework for Sustainable Building Materials Standards."

Leadership in Energy and Environmental Design (LEED)

A handful of organizations currently offer rating and certification for green buildings. By far the most prevalent certification system within the United States is Leadership in Energy and Environmental Design (LEED), developed by the U.S. Green Building Council. When it launched in 1998, LEED was among the first voluntary, consensus-based certification systems in the United States. It quickly became widely recognized as a benchmark for green building design.[75] The number of LEED certifications has increased annually since the first certification was awarded in 2000.[76] As of November 2019, 100,000 commercial projects had been certified by LEED worldwide.[77]

USGBC has expanded the categories of building certifications offered. Building certification categories include new commercial construction, existing buildings, building interiors, homes, whole neighborhoods, and entire cities and communities. Some special-use buildings, such as schools, hospitals, and data centers,[78] pose unique challenges to green building in regards to resource-use patterns. As a result, different categories of special-use buildings require green-building design and construction that is tailored to fit their particular needs and priorities. In addition to certification for construction or renovation projects, certification also is available for operations and maintenance of existing buildings, with a three-year recertification cycle.[79] Such operations and maintenance certifications can apply to those buildings that received building certifications when newly constructed.

LEED focuses primarily on seven green building elements: location and transportation, sustainable sites, water, energy, materials and resources, indoor environmental quality, and integrative process.[80] It also has credit categories for innovation and for regional priority, which considers specific factors of importance to sustainability within a specified region.

To be LEED-certified, a building must meet a set of mandatory basic requirements for most elements and must also receive a designated number of the total points that can be earned within each element from optional items. A building's total score determines its level of certification: Certified, Silver, Gold, or Platinum. While a "checklist" approach allows building owners to selectively accumulate points, the points do not necessarily translate into improvements in building energy performance.[81] However, it permits an assessment of compliance and can

[75] Jenny Richards, "Green Building: A Retrospective History of LEED Certification" (Institute for Environmental Entrepreneurship, November 2012), http://enviroinstitute.org/wp-content/uploads/2012/09/GREEN-BUILDING-A-Retrospective-History-of-LEED-Certification-November-2012.pdf.

[76] U.S. Green Building Council, "About LEED," July 2017, https://www.usgbc.org/articles/about-leed.

[77] U.S. Green Building Council, "LEED Reaches New Milestone, Surpasses 100,000 Commercial Green Building Projects," November 7, 2019, https://www.usgbc.org/articles/leed-reaches-new-milestone-surpasses-100000-commercial-green-building-projects.

[78] Data centers are facilities—buildings or parts of buildings—used to store, manage, and disseminate electronic information for a computer network. Data centers house servers, which are computers used to perform network-management functions such as data storage and processing, and communications equipment and devices to connect the servers with the network. These facilities may range in size from small rooms called server closets, or even parts of rooms, within a conventional building, to large dedicated buildings called enterprise-class data centers. Larger centers may be purpose-built or retrofitted.

[79] U.S. Green Building Council, "USGBC Now Offers Recertification for All LEED Projects," November 15, 2018, https://www.usgbc.org/articles/usgbc-now-offers-recertification-all-leed-projects.

[80] Benjamin, Heather, "Green Building 101: What Is LEED?" (U.S. Green Building Council, September 2017), https://www.usgbc.org/articles/green-building-101-what-leed.

[81] See, for example, Andrew J. Nelson and Ari Frankel, "Building Labels vs. Environmental Performance Metrics: Measuring What's Important about Building Sustainability" (RREEF Real Estate, October 2012),

facilitate the kind of integrated consideration of elements that many observers regard as a hallmark of green building. Another criticism of LEED is that the new certification is based on data from modeling the proposed design and not on post-occupancy energy use data or other metrics.[82] Some LEED-certified buildings have been shown to underperform relative to the models when analyzing post-occupancy energy data, and some perform better than similar non-LEED-certified buildings.[83]

The LEED rating system is updated periodically; the most recent version, LEED v4.1, was released in January of 2019.[84] Also in 2019, USGBC launched a campaign called the Living Standard in an effort to go beyond building certification and standards and to redefine green building to include a more community-based approach.[85]

Building Research Establishment Environmental Assessment Method (BREEAM)

The Building Research Establishment Environmental Assessment Method (BREEAM) is a British system developed in 1990. Though BREEAM rating systems have been used internationally since then, only the BREEAM In-Use certification has been introduced in the United States, beginning in 2017. BREEAM In-Use is an online rating system for existing commercial building performance. Unlike LEED, BREEAM In-Use has no prerequisites; any existing building can use it to benchmark performance and certify subsequent improvements. BREEAM ratings are Acceptable, Pass, Good, Very Good, Excellent, and Outstanding, which are signified by between one and six stars. Rating levels are based on a building's score across nine impact categories: management, health and well-being, energy, transport, water, materials, waste, land use, and ecology and pollution.[86] To remain valid, certifications must be renewed annually.

Green Globes

Green Globes was developed in Canada by the Green Building Initiative. It is based on BREEAM, and has an associated standard (see "Green Building Codes and Standards"). A building may earn between one and four Globes based on the number of points earned out of a possible total of 1,000. Points are distributed across five elements—site, energy, water efficiency, materials, and indoor environment—plus project management.[87] Like BREEAM In-Use, Green

http://realestate.deutscheam.com/content/_media/Research_Sustainability_Metrics_in_the_Real_Estate_Sector-Oct_2012.pdf.

[82] Barth, Brian. "Is LEED Tough Enough for the Climate-Change Era?" *Bloomberg*, June 5, 2018, https://www.bloomberg.com/news/articles/2018-06-05/reconsidering-leed-buildings-in-the-era-of-climate-change.

[83] Scofield, John H. "Efficacy of LEED-Certification in Reducing Energy Consumption and Greenhouse Gas Emission for Large New York City Office Buildings," *Energy and Buildings*, vol. 67, December 2013, pp. 517-524, https://doi.org/10.1016/j.enbuild.2013.08.032.

[84] Stanley, Sarah. "USGBC Opens Registration for LEED v4.1 for New Construction and Interior Spaces" (U.S. Green Building Council, January 2019).

[85] For more information on Greenbuild's Living Standard, visit https://livingstandard.org/.

[86] For more information on the impact categories and the Building Research Establishment Environmental Assessment Method (BREEAM) In-Use, Version 6, see https://www.breeam.com/discover/technical-standards/breeam-in-use/.

[87] Green Globe has several different standards for categories including new construction, core and shell, and existing buildings. For more information on the elements and point allocation for Green Globe New Construction 2019, see https://thegbi.org/green-globes-certification/how-to-certify/new-construction/.

Globes has no mandatory provisions or prerequisites that must be met before certification can be considered; certification and rating level are based solely on the number of points earned.

Living Building Challenge

The International Living Future Institute's Living Building Challenge offers three certifications: Living Building Certification, Petal Certification, and Zero Energy Building Certification. Criteria for certification fall into seven performance areas, referred to as "Petals": place, water, energy, health and happiness, materials, equity, and beauty. Living Building Certification requires a building to meet requirements in all seven performance areas. Petal Certification requires compliance with no fewer than three of the seven Petals, one of which must be water, energy, or materials.[88] Zero Energy Certification requires a building to generate all of its energy needs on site without using combustion. Unlike new-building certification under the other rating systems, which occurs upon completion of construction, certification under the Living Building Challenge also requires a 12-month assessment of actual building performance.

Building Owners and Managers Association (BOMA) BEST

BOMA BEST is a Canadian certification system for the environmental performance and management of existing buildings. In the newest version of BOMA BEST Sustainable Buildings 3.0, there are 10 key areas that are assessed to obtain certification: Energy, Water, Air, Comfort, Health and Wellness, Custodial, Purchasing, Waste, Site, and Stakeholder Engagement. Building owners, managers, and operators answer a survey-based assessment of their building, and based on those results can qualify for any of the five levels of certification: Certified (19% on the assessment), Bronze (20-49%), Silver (50-79%), Gold (80-89%), or Platinum (90-100%). All buildings must meet certain minimum BEST Practices (or requirements) before being considered for a certification and all assessment is verified by a third party to ensure validity.

Element-Focused Programs

In addition to the comprehensive green certification systems discussed above, some programs certify that a building has taken steps to improve environmental performance for a single element or a limited number of performance areas. One of the most recognized single element programs is ENERGY STAR, a voluntary labeling program that focuses on energy efficiency, which is discussed below in "ENERGY STAR." Another certification, the DOE's Zero Energy Ready Homes program, addresses energy and energy efficiency specifically for homes. Homes certified under this program are certified by a third party organization to be at least 40%-50% more energy efficient than a typical new home.[89]

Single element programs can address elements other than energy efficiency. WaterSense is a similar voluntary labelling program for water-efficient products administered by the U.S. Environmental Protection Agency (EPA). WaterSense products are verified to be at least 20% more water-efficient than the average product on the market by an independent third-party certifier.[90] Another voluntary program administered by EPA is Indoor airPLUS,[91] which builds

[88] For more information on the Living Building Challenge 4.0 and Petals, see https://living-future.org/lbc/basics4-0/.

[89] Department of Energy, "Guidelines for Participating in the DOE Zero Energy Ready Home Program," 2020, https://www.energy.gov/eere/buildings/guidelines-participating-doe-zero-energy-ready-home-program.

[90] Environmental Protection Agency, "WaterSense," July 24, 2017, https://www.epa.gov/watersense. For more information WaterSense, see CRS In Focus IF11128, *WaterSense® Program: Congressional Authorization*, by Elena H. Humphreys.

[91] Environmental Protection Agency, "Indoor AirPLUS," June 9, 2017, https://www.epa.gov/indoorairplus.

upon ENERGY STAR requirements and provides additional specifications to protect indoor air quality. Indoor airPLUS certification requires homes to install moisture control systems; heating, ventilating, and air-conditioning (HVAC) systems; combustion-venting systems; radon resistant construction; and low-emitting building materials to meet EPA indoor air quality standards.

Other certification programs emphasize a few elements in combination. For example, Passive House/PHIUS+ focuses on certifying new home construction that reduces the energy consumption of a house but does not necessarily offset the consumption with on-site renewable energy generation.[92] As of 2015, PHIUS+ certification automatically earns the project EPA's indoor airPLUS and DOE's Zero Energy Ready Home certifications.[93] Another example is the International WELL Building Institute's (IWBI's) WELL standard, which emphasizes human health and wellness.[94] WELL focuses on 11 features ranging from water and air quality to accessibility issues. Many of the programs overlap and partner with each other for a more holistic approach to building.

ENERGY STAR[95]

ENERGY STAR is an internationally recognized voluntary labeling program for energy-efficient products, homes, buildings, and manufacturing plants.[96] It is jointly managed by the EPA and DOE. The program's portfolio has expanded over time. In 1995, ENERGY STAR was expanded to include labeling for buildings and new homes.[97]

ENERGY STAR provides several programs that are relevant to homes and residential buildings. EPA and DOE work with manufacturers to identify appliances and other products used by consumers in the home that are cost-effective and energy efficient. Those products that meet certain criteria can receive an ENERGY STAR label. Among the product categories included are office equipment; home electronics; HVAC; appliances; lighting; and windows. ENERGY STAR has also partnered with home builders to create ENERGY STAR-qualified homes. If they meet certain requirements, several residence types can qualify for a certification with ENERGY STAR including any single-family home, townhome, or duplex new construction, manufactured and multifamily housing, and homes that are undergoing gut rehabilitation.[98] Additionally, ENERGY STAR works with lenders to encourage the use of Energy-Efficient Mortgages and "green loans" to promote energy-efficient housing.[99]

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[92] Visit https://www.phius.org/home-page for more information about PHIUS+.

[93] Passive House Alliance, "PHIUS+ 2015: Passive Building Standard—North America," 2020, https://www.phius.org/phius-2015-new-passive-building-standard-summary.

[94] "WELL v2 Overview," International WELL Building Institute, 2018, http://www.wellcertified.com/certification/v2/.

[95] This section focuses on ENERGY STAR as it pertains to homes and buildings. For more information on the overall program, see CRS In Focus IF10753, *ENERGY STAR Program*, by Corrie E. Clark.

[96] ENERGY STAR, "Buildings and Plants," 2017, https://www.energystar.gov/buildings.

[97] Other program additions that are relevant to buildings include manufacturing facilities in 2006 and manufactured homes in 2007.

[98] Manufactured homes are defined as homes built in a factory that are subject to the federal Manufactured Home Construction and Safety Standards (also known as the HUD Code). For more information on ENERGY STAR programs related to new homes and other residential types, visit https://www.energystar.gov/newhomes?s=mega.

[99] An energy-efficient mortgage (EEM) can be used to purchase or refinance an energy-efficient home or to finance energy-efficient improvements to an existing home. The EEM accounts for cost savings from the lower utility bills of an energy-efficient home. This can be used by a lender to offer more favorable financing terms to a borrower. For more information, see ENERGY STAR, "Energy Efficient Mortgages," https://www.energystar.gov/newhomes/mortgage_lending_programs/energy_efficient_mortgages.

ENERGY STAR developed a tool for commercial building owners or managers called Portfolio Manager. Portfolio Manager allows owners and managers to track energy and water usage, normalize consumption for their specific business activity (accounting for hours, workers, and the climate), and compare their performance to typical commercial building performances.[100] In addition, EPA offers partnerships to businesses and other organizations that make top-level managerial commitments to adopt superior energy management. Partners commit to assess energy use within their organizations and use an integrated approach in upgrading buildings. The Portfolio Manager can be used to calculate an ENERGY STAR score from 1 to 100 to compare a building's performance with similar buildings nationwide. A score of 50 is the median energy performance of buildings, while a score of 75 or better indicates that a building may be eligible for ENERGY STAR certification.[101]

In addition to benchmarking for building owners, ENERGY STAR developed a program for commercial building tenants that voluntarily achieve high levels of energy efficiency. This program, called ENERGY STAR Tenant Space, launched in 2020. Tenants interested in being recognized must commit to metering energy use and meeting certain lighting and equipment efficiency standards, among other requirements. The tenant space must be either a general administrative office, financial office, or a non-diagnostic medical office.[102]

Federal Government Use of Certification Systems

Several federal statutes and policies impose green building requirements on federal offices and agencies,[103] and some agencies have been using third-party green building certification systems since the late 1990s. While no certification system meets all of the federal requirements for green buildings, the General Services Administration (GSA) has recommended that agencies use third-party green certification systems,[104] and some federal agencies have found the use of third-party certification systems to have benefits that include simplifying compliance with federal guidelines, reducing the need for additional staff, and providing a recognizable label to communicate sustainability efforts within the agency and to the public.[105] Several agencies have elected to establish internal policies on certification under one of the available rating systems.[106]

EISA required the Secretary of Energy, in consultation with GSA and the Department of Defense (DOD), to identify a third-party certification system and level that the Secretary "determines to be

[100] "Typical" commercial building performance is based upon the Energy Information Administration's Commercial Buildings Energy Consumption Survey.

[101] ENERGY STAR, "How the 1-100 ENERGY STAR Score Is Calculated," https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/understand-metrics/how-1-100.

[102] Examples of non-diagnostic medical offices include a doctor's office or dentist's office without diagnostic equipment. For more information on ENERGY STAR Tenant Space, see https://www.energystar.gov/buildings/tenants/about_tenant_space.

[103] See the section on "Legislative and Policy Framework."

[104] Dan Tangherlini, Administrator, General Services Administration, "Letter to Ernest Moniz, Secretary of Energy," October 25, 2013, https://www.gsa.gov/portal/getMediaData?mediaId=180467.

[105] Government Accountability Office, "Federal Green Building: Federal Efforts and Third-Party Certification Help Agencies Implement Key Requirements, but Challenges Remain," GAO-15-667 (July 2015), http://www.gao.gov/assets/680/671618.pdf.

[106] Agencies that have adopted a green rating system include the Department of Defense, DOE, GSA, the Department of Veterans Affairs, the U.S. Department of Agriculture, and EPA. Ibid.; and U.S. Department of Agriculture, "2016 Strategic Sustainability Performance Plan," June 30, 2016, https://www.dm.usda.gov/emd/docs/USDA%202016%20Strategic%20Sustainability%20Performance%20Plan-updated.pdf.

the most likely to encourage a comprehensive and environmentally-sound approach to certification of green buildings" (42 U.S.C. §6834(a)(3)(D)(i)(III)). The Secretary's recommendation is to be reviewed and updated every five years, taking into account the results of a study to be conducted by the Director of GSA's Office of Federal High-Performance Green Buildings, which was also established by EISA (42 U.S.C. §17092). As of 2019, GSA has expanded the certifying organizations it recommends to federal agencies to include LEED, Green Globes, Living Building Challenge, BOMA BEST, and BREEAM for existing federal buildings.[107] For major renovation or new construction federal buildings, GSA recommends that LEED version 4.0 or Green Globes be used as they both fit DOE requirements.[108]

Instead of specifying a particular rating system, the 2014 Department of Energy rulemaking on green building certification sets out minimum criteria for a rating system to be eligible for use by federal agencies. Those agencies choosing to pursue third-party certification must choose a system that meets those criteria.[109]

Many states also require green building certification or the equivalent for government buildings, and many cities or counties have such requirements for buildings in the commercial sector. Some jurisdictions also provide grants or tax incentives for some green building certifications.[110] While rating and certification systems are not necessarily mandatory, they can serve as testbeds for objectives and practices that have subsequently been incorporated into mandatory building codes and standards.

Green Building Codes and Standards

Building codes specify minimum design and construction requirements for new construction and major renovation buildings. Historically, they have focused primarily on health and safety, but they can cover many other aspects of a building's design or construction, from aesthetics to resource use. Beyond certain federally mandated minimum requirements, it is left to state and local governments to determine the contents of the codes that regulate buildings within their jurisdictions.[111] This allows flexibility with the codes to meet the priorities of a specific region. For instance, California jurisdictions may apply stricter seismic codes as that area is more prone to earthquakes than other areas of the country. Rather than create and revise their own codes, however, many state and local jurisdictions adopt or modify national model codes generated by code development organizations such as the International Code Council (ICC). ICC is a nonprofit association that develops model codes and standards for buildings and structures. These model codes, if adopted by governments, can serve as minimum performance standards for buildings. ICC is responsible for the development of a comprehensive family of integrated International

[107] Murphy, Emily. "GSA High-Performance Building Certification System Review Letter to Sec Energy," General Services Administration, September 16, 2019, https://www.gsa.gov/cdnstatic/DOE%20Letter%20(Final%20-%20signed%202019).pdf.

[108] Ibid.

[109] 10 C.F.R. §433.300.

[110] Daniel C. Matisoff, Douglas S. Noonan, and Mallory E. Flowers, "Policy Monitor—Green Buildings: Economics and Policies," *Review of Environmental Economics and Policy*, vol. 10, no. 2 (July 2016): 329–46, doi:10.1093/reep/rew009.

[111] The Energy Policy Act of 1992 (EPACT 1992, P.L. 102-486) established a baseline for energy efficiency in building codes. For a history of the development of ASHRAE energy efficiency standards and their inclusion in U.S. law, see Gordon Holness, "Achieving Energy Performance—Going Beyond Codes and Standards," April 4, 2011, http://newbuildings.org/sites/default/files/Holness_Beyond_codes.pdf.

Codes, covering a number of building sectors.[112] The ICC International Building Code (IBC) and the International Residential Code (IRC) are widely used in the United States. Federal agencies are required by law to comply with one of the nationally recognized model building codes and other nationally recognized codes to the maximum extent feasible.[113] Model building codes are updated every three years, so if the code is updated to a higher efficiency measure, the federal agencies' standard also must be adjusted accordingly. In addition, Congress has directed the Secretary of the DOE to establish federal building energy standards by rule.[114]

Both model codes and mandatory building codes often incorporate technical standards for specific components or features. Those standards are created by recognized standards development organizations (SDOs); a standard can be considered as "a set of guidelines and criteria against which a product can be judged."[115] Just as a building may be certified under a rating system, a building that has achieved a given standard may be certified as having met the criteria of that standard. While most standards are not themselves mandatory, they, along with model codes,[116] may be incorporated into mandatory codes or laws.[117] This section discusses comprehensive green building codes and standards that address multiple green building elements. Codes and standards may also address single elements; for example, building energy codes and standards pertain to energy efficiency.[118]

DOE's Building Energy Codes Program (BECP)

DOE's BECP engages with national model building energy codes in several ways.[119] The program submits code change proposals for the International Energy Conservation Code (IECC)[120] and ASHRAE Standard 90.1.[121] It also

[112] ICC develops building codes through the ICC Governmental Consensus Process, which includes regulators in the code-development process. See International Code Council, "CP28-05—Code Development," December 11, 2015, https://cdn-web.iccsafe.org/wp-content/uploads/CP28-05.pdf.

[113] Requirements for federal agencies to comply with nationally recognized model building codes are found in 40 U.S.C. §3312 as authorized in §3312 of an act to revise, codify, and enact without substantive change certain general and permanent laws, related to public buildings, property, and works, as title 40, United States Code, "Public Buildings, Property, and Works" (P.L. 107-217).

[114] The Secretary of the DOE is directed to establish federal building energy standards under the Energy Conservation and Production Act (EPCA, P.L. 94-385, 42 U.S.C. §6834).

[115] Dan Prowler and Stephanie Vierra, "Whole Building Design," *Whole Building Design Guide*, August 17, 2017, http://www.wbdg.org/resources/whole-building-design. See text box "Whole Building Design Guide," below, for further information.

[116] Model codes are building codes prepared by groups of experts that have no legislative or rulemaking authority. Model codes gain the force of law when they are adopted as requirements by a jurisdiction (Melvyn Green, *Building Codes for Existing and Historic Buildings* [Hoboken, N.J: Wiley, 2012]).

[117] For example, the mandatory building code of the District of Columbia for construction, alteration, maintenance, and so forth includes by reference the International Building Code, a model code created by the International Code Council, and technical standards developed by organizations such as the American Society of Mechanical Engineers. See District of Columbia Government, "District of Columbia Construction Codes Supplement of 2013," May 2014, https://dcra.dc.gov/sites/default/files/dc/sites/dcra/publication/attachments/DCMR%2012_ConstructionCodes_2013.pdf.

[118] DOE has a role in the development, adoption, and compliance of building energy codes as discussed in the textbox "DOE's Building Energy Codes Program (BECP)."

[119] DOE, Building Energy Codes Program, https://www.energycodes.gov/.

[120] The IECC is a model code developed by ICC that is very often adopted by state and local governments for minimum building energy efficiency requirements. For more information about BECP and the 2018 IECC, see the BECP presentation "2018 IECC Commercial Scope and Envelope Requirements" at https://www.energycodes.gov/sites/default/files/becu/2018_IECC_commercial_requirements_envelope.pdf.

[121] Standard 90.1 is the energy efficiency standard of the standard-developing organization ASHRAE for buildings

conducts analysis of building energy efficiency and cost savings, and formulates underlying evaluation methodologies. Under the Energy Conservation and Production Act (ECPA, P.L. 94-385), after a new version of the IECC or ASHRAE Standard 90.1 is issued, DOE is directed to assess and make a determination of whether the energy savings from each updated version will improve energy efficiency in buildings. If this determination is positive, each state must certify that they have reviewed their commercial and residential codes. In the case of residential buildings codes, the state only needs to review them to determine whether it is appropriate to revise them to meet or exceed the elements of the updated model code. But for commercial building codes, the state must update them after review in accordance with the revised standard and demonstrate that these updated commercial codes meet or exceed the standard. The program provides technical assistance for the adoption of these new code changes. DOE does not have the authority to enforce the adoption of any model energy building codes. This authority lies with the states and localities. BECP provides resources and training on code changes, which can aid builders, architects, engineers, and contractors in complying with newly adopted mandatory building codes in their state and locality. BECP has created two compliance software packages called REScheck and COMcheck, which allow builders to quickly determine whether new homes, additions, and alterations or new commercial buildings and high-rise residential buildings meet the requirements of the IECC and ASHRAE Standard 90.1, as well as several state-specific codes.

Green building codes specify additional requirements for environmental design and performance that go beyond, and, in some cases, can be layered on top of existing building codes. They are occasionally referred to as "beyond-code" or "above-code" options, because they exceed minimum building code requirements. Governments adopting green building model codes can choose to make them mandatory or treat them as voluntary measures for meeting green building objectives.

For both green building codes and standards, specific requirements may be achievable by multiple pathways. Prescriptive pathways specify the precise method of achieving a given requirement, whereas performance pathways allow designers flexibility in their methods provided that the projected or modelled end results meet the necessary requirements. A newer option is outcome-based requirements, which establish a performance target that must be met and verified through measurement and reporting after construction ends.

Green building standards are sometimes described as code-intended, indicating that they are written in mandatory, code-enforceable language. In this manner, they may be adopted by jurisdictions, either as they are written or with modifications made by the adopting entity. Both codes and standards are developed through a consensus process that involves multiple stakeholders,[122] but SDOs typically require accreditation by a body such as the American National Standards Institute (ANSI), ensuring that their development process adheres to a set of approved procedures.[123] ANSI standards also require that certification be performed by a third party.

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except for low-rise residential buildings. For an online, read-only version of the Standard, visit https://ashrae.iwrapper.com/ViewOnline/Standard_90.1-2019

[122] The number and types of stakeholders involved in the consensus process differs between code developing organizations and standards setting organizations.

[123] American National Standards Institute, "ANSI Essential Requirements: Due Process Requirements for American National Standards," January 2020, https://share.ansi.org/Shared%20Documents/Standards%20Activities/American%20National%20Standards/Procedures,%20Guides,%20and%20Forms/2020_ANSI_Essential_Requirements.pdf.

The Whole Building Design Guide (WBDG) is a web-based portal providing information on an integrated approach to the design, construction, and operation of buildings. It is a collaboration among federal agencies and many private-sector and nonprofit organizations. It is hosted by the National Institute of Building Sciences.[124]

The WBDG describes its goals as follows: "Whole Building Design provides the strategies to achieve a true high-performance building: one that is cost-effective over its entire life cycle, safe, secure, accessible, flexible, aesthetic, productive, and sustainable."[125] The most relevant goal for green building is the sustainability goal. The guide provides design guidance to federal agencies for all seven goals, as well as a broad range of information and resources to the federal government, the building industry, and the public.

This whole-building approach involves not only integrated design but also integration of the teams of people involved, including architects, owners, contractors, operators, community members, and other stakeholders. The portal provides tools and other resources to promote and facilitate such integration.

In addition to developing model building codes and standards, ICC and ASHRAE are also the two main developers of national green building model codes and standards in the United States.[126] Their efforts are discussed below.

In 2012 the ICC released the International Green Construction Code (IgCC),[127] self-described as "the first model code to include sustainability measures for the entire construction project and its site."[128] The IgCC functions as an overlay code, meaning that it is compatible, and can be adopted in conjunction with, other ICC codes governing building safety and other features. The most recent revision was released in 2018.[129] Municipalities choosing to adopt the IgCC as an overlay may choose from among various compliance pathways and options in order to make the mandated requirements more or less strict, as well as to account for local climate and other pertinent factors.

The IgCC covers most building types, with the exception of low-rise residential buildings. The IgCC refers low-rise residential builders to the ICC 700 National Green Building Standard (NGBS), an ANSI standard developed in partnership with ASHRAE and the National Association of Homebuilders (NAHB). The NGBS is structured as a rating system, much like LEED, but can be adopted by ordinance, much like a model code.[130]

ASHRAE, USGBC, and the Illuminating Engineering Society of North America (IES) jointly released Standard 189.1, a high-performance green building standard for nonresidential buildings and residential buildings of more than three stories.[131] Standard 189.1 functions as a code-

[124] Whole Building Design Guide website: https://www.wbdg.org/.

[125] Dan Prowler and Stephanie Vierra, "Whole Building Design," Whole Building Design Guide, August 17, 2017, http://www.wbdg.org/resources/whole-building-design.

[126] Melissa A. Beutler et al., eds., *Green Building and the Construction Lawyer: A Practical Guide to Transactional and Litigation Issues* (Chicago, Illinois: Forum on Construction Law, 2014). ASHRAE was formerly known as the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

[127] IgCC is developed in cooperation with the American Institute of Architects, ASTM International, ASHRAE, the Illuminating Engineering Society, and USGBC. The ICC has also developed the International Energy Conservation Code focused primarily on encouraging building energy efficiency.

[128] International Code Council, "Overview of the IgCC," 2017, https://www.iccsafe.org/codes-tech-support/codes/2015-i-codes/igcc/.

[129] "International Green Conservation Code," Sept 2018, https://codes.iccsafe.org/content/IGCC2018/chapter-1-scope-and-administration.

[130] National Association of Home Builders, "ICC 700 National Green Building Standard," 2020, https://www.nahb.org/Advocacy/Industry-Issues/Sustainability-and-Green-Building/ICC-700-National-Green-Building-Standard.

[131] ASHRAE, "Standard 189.1-2014—Standard for the Design of High-Performance Green Buildings," 2014, http://www.techstreet.com/ashrae/standards/ashrae-189-1-2014?product_id=1886477.

intended standard and is offered as a compliance option under the IgCC. The standard contains requirements in the following areas: site sustainability; energy efficiency and renewable energy; water-use efficiency; indoor environmental quality; and building impacts on the atmosphere, materials, and resources. Elements of Standard 189.1 have been incorporated into the building requirements for Department of Defense properties.[132]

In 2018, the ICC and ASHRAE fully integrated Standard 189.1 to serve as the technical content of the new version of the IgCC. Called "IgCC powered by 189.1," the new code also aligns with the LEED rating system, providing the market with a streamlined set of beyond-code tools.[133] In addition to such national efforts, several state, local, and tribal authorities have developed their own green building codes.

Legislative and Policy Framework

Several federal laws, executive orders, and other policy instruments have provisions relating to green building. Selected relevant policies are listed in **Table 1**, and selected requirements by topic (i.e., green building, renewable energy, and energy efficiency) are described below. The list of laws presented in this report is not exhaustive. For example, the Resource Conservation and Recovery Act of 1976 (RCRA), as amended (42 U.S.C. §6901 et seq.), requires agencies to procure products with recycled content. This report also does not include discussion of state and local policies, which have substantial influence on green building efforts within those jurisdictions.

Table 1. Selected Policies Related to Green Building

Title	Public Law (P.L.) or Executive Order (E.O.)
Energy Policy Act of 1992 (EPACT 1992)	P.L. 102-486
Energy Policy Act of 2005 (EPACT 2005)	P.L. 109-58
Energy Independence and Security Act of 2007 (EISA)	P.L. 110-140
American Recovery and Reinvestment Act of 2009 (ARRA)	P.L. 111-5
Energy Efficiency Improvement Act of 2015	P.L. 114-11
Energy Act of 2020 (Division Z of the Consolidated Appropriations Act, 2021)	P.L. 116-260
Efficient Federal Operations[a]	E.O. 13834
Protecting Public Health and the Environment and Restoring Science To Tackle the Climate Crisis	E.O. 13990
Tackling the Climate Crisis at Home and Abroad	E.O. 14008

Source: CRS.

a. E.O. 13834, *Efficient Federal Operations*, was partially revoked by E.O. 13990, *Protecting Public Health and the Environment and Restoring Science To Tackle the Climate Crisis*, on January 20, 2021.

[132] Department of Defense, "United Facilities Criteria: High Performance and Sustainable Building Requirements," UFC 1-200-02, (December 1, 2016), http://www.wbdg.org/FFC/DOD/UFC/ufc_1_200_02_2016.pdf.

[133] U.S. Green Building Council, "Streamlining for Building Code Makes It Easier to Achieve Green Projects: Building Professionals Move Toward a Unified Green Code by Streamlining and Simplifying the Code Enigma," https://www.iccsafe.org/products-and-services/i-codes/2018-i-codes/igcc/.

Green Building Requirements

The Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) provided both a general legislative framework for federal green building efforts, including a definition of high-performance green building,[134] and specific actions and requirements. For federal buildings, EISA increased the building energy efficiency goal for federal agencies, such that each agency would be required to reduce their total energy consumption from federal buildings to 30% (relative to 2003) by 2015.[135] EISA also set more stringent energy goals for new construction and major renovations, requiring these buildings to reach an 80% reduction in fossil fuel-generated energy by 2020, and zero-net fossil fuel-generated energy use by 2030. EISA also set general water-conservation guidelines and stormwater runoff requirements for federal property development. EISA directed the General Services Administration to establish an Office of Federal High-Performance Green Buildings to recommend to the Secretary of Energy rating and certification systems that could be used by agencies for meeting federal green building requirements.

The American Recovery and Reinvestment Act of 2009 (ARRA, P.L. 111-5) provided $4.5 billion to convert GSA facilities to high-performance green buildings.[136] It also provided $250 million to the Department of Housing and Urban Development (HUD) for green retrofits of multifamily housing. In addition, of the $4 billion that ARRA provided to HUD for public housing, HUD directed $600 million for the "Creation of Energy Efficient, Green Communities."[137]

The Energy Efficiency Improvement Act of 2015 (P.L. 114-11) directed GSA to develop model leasing provisions to encourage the implementation of energy and water efficiency measures by tenants in commercial buildings. GSA may use those provisions for leases involving federal agencies, and it must make them available to state and local governments for their own use.

On January 27, 2021, President Biden issued Executive Order (E.O.) 14008, *Tackling the Climate Crisis at Home and Abroad*.[138] Among other provisions, E.O. 14008 established a national climate task force. One of the task force's responsibilities is to develop a plan to leverage federal procurement authorities to facilitate a carbon pollution-free electricity sector no later than 2035. E.O. 14008 also directs the Chair of the Council on Environmental Quality and the Director of the Office of Management and Budget to ensure that investments in federal infrastructure reduce climate pollution and that federal permitting decisions consider the effects of greenhouse gas emissions and climate change.

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[134] The Energy Policy Act of 2005 (EPACT 2005) defined a high-performance building as "a building that integrates and optimizes all major high-performance building attributes, including energy efficiency, durability, life-cycle performance, and occupant productivity" (§914(a)). EISA 2007 built upon that definition for "high-performance green building," as discussed in the section "What Is Green Building?"

[135] See EISA, sec. 431.

[136] ARRA provided almost $800 billion through extensive discretionary spending, mandatory spending, and revenue provisions for existing and some new programs in the 15 Cabinet-level departments and 11 independent agencies. For more on ARRA, see CRS Report R40537, *American Recovery and Reinvestment Act of 2009 (P.L. 111-5): Summary and Legislative History*, by Clinton T. Brass et al.

[137] Of the $4 billion, $3 billion was directed for formula grants and $1 billion for competitive grants. Department of Housing and Urban Development (HUD), "HUD's Fiscal Year (FY) 2009 Notice of Funding Availability (NOFA) for the Capital Fund Recovery Competition Grants; Revised to Incorporate Changes, Corrections, and Clarifications," June 3, 2009, https://www.hud.gov/sites/documents/DOC_9756.pdf, p. 20.

[138] Executive Order E.O. 14008, "Tackling the Climate Crisis at Home and Abroad," 86 *Federal Register* 7619, February 1, 2021, https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad.

Guiding Principles for Federal Leadership in High Performance Sustainable Buildings

In 2006, representatives of 19 federal agencies and offices[139] signed a memorandum of understanding (MOU) titled "Federal Leadership in High Performance and Sustainable Buildings."[140] The MOU was developed concurrently with the enactment of EPACT 2005 and contained the first set of five core Guiding Principles for federal high performance and sustainable buildings: employ integrated design principles, optimize energy performance, protect and conserve water, enhance indoor environmental quality, and reduce environmental impact of materials. Subsequent revisions of the Guiding Principles were issued in 2008 and, most recently, in 2020[141] to reflect progress in green building design and to address a broader set of issue areas, including the health and productivity of building occupants. The revision in 2016 added a sixth overarching principle to the list: assess and consider climate change risks.[142] The revision in 2020 modified this principle to assess and consider building resilience.

[139] Those agencies were the Departments of Agriculture, Commerce, Defense, Energy, the Interior, Health and Human Services, Homeland Security, Housing and Urban Development, Justice, Labor, State, Transportation, and Veterans Affairs; and the Council on Environmental Quality, the Environmental Protection Agency, the General Services Administration, the National Aeronautics and Space Administration, the Office of Personnel Management, and the Tennessee Valley Authority.

[140] Department of Defense et al., "Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding," 2006, http://wbdg.org/FFC/FED/HPSB-MOU.pdf.

[141] Council on Environmental Quality, "Guiding Principles for Sustainable Federal Buildings and Associated Instructions," December 2020, https://www.sustainability.gov/pdfs/guiding_principles_for_sustainable_federal_buildings.pdf.

[142] Council on Environmental Quality, "Guiding Principles for Sustainable Federal Buildings and Associated Instructions," February 2016, https://www.sustainability.gov/pdfs/guiding_principles_for_sustainable_federal_buildings-2016.pdf.

Guiding Principles[143]

The six Guiding Principles for Federal Leadership in High Performance Sustainable Building are

- **Employ Integrated Design Principles.** This principle includes use of a collaborative and integrated process for all stages from planning through operation for each building or modernization project, incorporation of design choices and operational components that improve environmental performance, consideration of the entire life cycle of the building, and the development of plans that accommodate temporary changes to operational conditions due to emergencies or other significant events.
- **Optimize Energy Performance.** This involves complying with federal building energy efficiency standards, establishing an energy performance goal for the entire building, including reduction in energy costs of 20%-30% below existing standards, and employing strategies to use life cycle cost-effective renewable electric and thermal renewable energy. It also includes installing building level meters to track and measure performance annually in comparison to ENERGY STAR benchmarks.
- **Protect and Conserve Water.** This involves minimizing the use and waste of indoor potable water, purchasing water conserving products and ensure optimized indoor water operations, installing building level water meters including leak detection, using water efficient landscaping and water efficient irrigation strategies to track and reduce potable outdoor water consumption, using drought-tolerant native landscaping where practicable, and maximizing the use of alternative sources of water to the extent practicable.
- **Enhance the Indoor Environment.** This principle requires meeting established standards for temperature, humidity, and ventilation; controlling moisture to prevent damage and mold; maximizing opportunities for daylight except where not appropriate; using appropriate lighting controls and task lighting; using low-emitting materials and products; taking other steps to protect air quality in the building; encouraging integrated pest management; and designing building features and integrating programs and initiatives to promote voluntary health and wellness opportunities for occupants.
- **Reduce the Environmental Impact of Materials.** This involves using materials with recycled and biobased (renewable and sustainable) content that is at or above recommended levels, complying with requirements for substitutes for ozone-depleting compounds, complying with hazardous waste management requirements during construction and operations, and reducing the landfilling of wastes by recovering, reusing, and recycling materials.
- **Assess and Consider Building Resilience.** This principle involves identifying and assessing current and future potential regional risks to ensure resilient building design and operations and reduce potential vulnerabilities; incorporating resilient design and operational adaptation strategies; avoiding or mitigating the short- and long-term adverse impacts associated with projected climate changes and acute weather events, including storms, wildfires, droughts and floods; and balancing options to address risks against mission criticality, cost, and security needs over the building's intended service life.

Renewable Energy Goal

The Energy Policy Act of 2005 (EPACT 2005, P.L. 109-58), among other provisions, established a renewable electricity goal for the federal government. Of the total electric energy consumed by the federal government, 7.5% was required to be from a renewable energy source by FY2013 under EPACT 2005 (see 42 U.S.C. §15852).[144] EPACT 2005 allows the amount of renewable energy to be considered as doubled if it is produced and consumed on-site, or produced on federal lands or Indian lands and consumed at a federal facility.[145]

[143] Council on Environmental Quality, "Guiding Principles for Sustainable Federal Buildings and Associated Instructions," December 2020, https://www.sustainability.gov/pdfs/guiding_principles_for_sustainable_federal_buildings.pdf.

[144] For a discussion of progress on this goal, see section "Progress Toward Federal Goals" in this report.

[145] While EPACT 2005 section 203 does not mention "renewable energy certificates" or RECs, federal agencies use RECs to guarantee that an amount of electricity purchased comes from renewable sources. A REC is a tradable commodity equivalent to 1 megawatt-hour (MWh) of electricity generated by renewable energy. For more information, see Council on Environmental Quality (CEQ), Office of Federal Sustainability, "Implementing Instructions for

Energy Efficiency Provisions

Congress has introduced and amended energy efficiency requirements over time. Many of these requirements pertain to federal, commercial, and residential buildings. The Energy Policy Act of 1992 (P.L. 102-486) contained various incentives and requirements relating to the efficient use of energy and water in buildings. It included provisions related to energy efficiency in federal buildings and public housing, a pilot program for mortgages for energy-efficient housing, the development of energy-efficient technologies, and energy and water efficiency requirements for appliances, plumbing fixtures, and building materials. EPACT 1992 reauthorized programs for state energy conservation and weatherization assistance, and it also contained provisions relating to state building energy codes.[146]

The Energy Policy Act of 2005 (EPACT 2005, P.L. 109-58) built upon EPACT 1992. EPACT 2005 set energy and water conservation standards for various specific products. It also formally codified the ENERGY STAR labeling program as a joint program of DOE and EPA,[147] and established public information and education programs relating to energy conservation. The act requires federal agencies to purchase products that either have an ENERGY STAR label or are designated as energy-efficient by the Department of Energy.[148] EPACT 2005 set energy efficiency standards for public housing and directed the Department of Housing and Urban Development to develop a strategy for energy conservation and efficiency. It also authorized funding for states to administer rebate programs for residential energy-efficient appliances, to assist local governments in improving energy efficiency in public buildings, and for other state activities, including incentives to states to establish building energy efficiency codes that meet or exceed established standards.

EISA further built upon existing energy and water conservation standards. Title III set efficiency standards for electric lighting and various appliances and equipment. Appliance and equipment standards include those for residential refrigerators, freezers, refrigerator-freezers, metal halide lamps, and commercial walk-in coolers and freezers.[149] Title V focused on energy efficiency in government and public institutions and established the Energy Efficiency and Conservation Block Grant (EECBG) program, among other provisions. The EECBG was authorized to help reduce energy use and carbon emissions at the local and regional level. ARRA provided $3.2 billion in funding for the EECBG in addition to other funding provisions such as funding for state energy programs ($3.1 billion) and weatherization assistance ($5 billion).

Executive Order 13834 Efficient Federal Operations," April 2019, https://www.sustainability.gov/pdfs/eo13834_instructions.pdf ; CEQ, Office of Federal Sustainability, "Federal Renewable Energy Certificate Guide," June 2016, https://www.sustainability.gov/pdfs/federal_rec_guide.pdf.

[146] For a summary, see "National Legislation on Building Energy Codes," Table 7.3.5 in Department of Energy, "2008 Buildings Energy Data Book," November 2008, http://web.archive.org/web/20130215004243/http://buildingsdatabook.eren.doe.gov/docs/DataBooks/2008_BEDB_Updated.pdf. Most states now have energy codes, although specific requirements vary.

[147] EPA established the program in 1992 using its statutory authority under the Clean Air Act. For more information, see CRS In Focus IF10753, *ENERGY STAR Program*, by Corrie E. Clark.

[148] The Department of Agriculture also administers a labeling and procurement program, for biobased products. The program was established in the Farm Security and Rural Investment Act of 2002 (P.L. 107-171) and most recently revised in the Agriculture Improvement Act of 2018 (P.L. 115-334), also known as the 2018 Farm Bill. The two main purposes of the program are to aid in the mandatory purchasing requirements for federal agencies and their contractors and to serve as a voluntary labeling initiative for biobased products. For more information on this program, visit https://www.biopreferred.gov/BioPreferred/.

[149] CRS In Focus IF11354, *Department of Energy Appliance and Equipment Standards Program*, by Corrie E. Clark.

The Energy Efficiency Improvement Act of 2015 (P.L. 114-11) addressed energy and water conservation standards and building energy efficiency. It established energy conservation standards for grid-enabled water heaters used as energy storage or demand-response assets, among other provisions. The act also amended EISA to add provisions regarding improving energy efficiency in tenant spaces. These include directing DOE to study the feasibility of improving energy efficiency in commercial buildings through the implementation of energy efficiency measures in discreet spaces within those buildings; directing the DOE's Energy Information Administration (EIA) to collect additional occupant energy-use information as part of its Commercial Buildings Energy Consumption Surveys; and directing EPA to develop a Tenant Star recognition label as a part of the ENERGY STAR program.[150]

Title I of the Energy Act of 2020 (Division Z of P.L. 116-260) addressed several building energy efficiency issues. It designates DOE as the lead federal agency to coordinate and provide information on existing federal programs that could assist states, local educational agencies, and schools in initiating, developing, and financing energy efficiency, renewable energy, and energy retrofitting projects for schools. It directs the Secretary of Energy and the Director of the Office of Management and Budget (OMB) to develop a utilization metric for data center energy efficiency and to establish performance goals related to the energy use of information technology used by federal agencies. In addition each agency is to develop an implementation strategy for the maintenance, purchase, and use of energy-efficient and energy-saving information technologies at federal facilities. Title I of the act also established a smart building accelerator program, created a smart energy and water efficiency pilot program, and authorized the Federal Energy Management Program. Among other energy efficiency provisions, Title I of the act also amended and reauthorized the weatherization assistance program; the act clarified that renewable energy technologies are included in the definition of weatherization materials and authorized DOE to account for the non-energy benefits of weatherization improvements—such as improvements to health and safety—when determining appropriate standards and procedure.

Programs and Activities of Selected Federal Agencies

The federal government owns or leases about 3 billion square feet of floorspace in the United States, consuming 353 trillion British thermal units (Btus) and costing $6.3 billion in energy bills.[151] The Department of Defense has the largest percentage of floorspace of federal agencies (see **Table 2**). EISA and other policy instruments require all federal agencies to implement green building practices for buildings they control. Several federal offices provide guidance and support for the implementation of those requirements.[152]

[150] While the Energy Efficiency Improvement Act of 2015 refers to the program as "Tenant Star," in practice, the program is referred to as ENERGY STAR Tenant Space, as discussed in the section "ENERGY STAR."

[151] Gross square footage, energy consumption, and energy spending data are all found in DOE's Comprehensive Annual Energy Data and Sustainability Performance for FY2019. Agencies are required to report this data to satisfy energy management requirements in National Energy Conservation Policy Act (42 U.S.C. §8253-8258), EPACT 2005, and EISA. For the full dataset for FY2019, visit https://ctsedwweb.ee.doe.gov/Annual/Report/Report.aspx. The data presented are for all buildings; however, only goal-subject buildings are required to comply with federal sustainability goals. The number of buildings was approximately 250,000 in FY2016, according to GSA. FY2016 was the last year that GSA reported both civilian non-civilian real property data (GSA, "FY2016 Federal Real Property Profile Open Data Set," https://www.gsa.gov/portal/content/102880.)

[152] These include the Council on Environmental Quality (CEQ), DOE, EPA, GSA, and OMB. See the appendices in

Table 2. Percentages of Total Federal Building Floorspace Owned or Leased Under the Jurisdiction of Selected Agencies, 2016

Agency	Percent of Total
Department of Defense	57
General Services Administration	16
Department of Veterans Affairs	7
Department of Energy	4
Department of the Interior	4
Other	13

Source: GSA, "FY2016 Federal Real Property Profile Open Data Set," https://www.gsa.gov/portal/content/102880.

Notes: Percentages do not sum to 100 due to rounding. Although the Federal Real Property Profile data that is compiled by GSA is typically considered the authoritative source for federal property data, beginning in FY2017, the open data set only provides information for civilian agencies (see GSA, "FY2017 Federal Real Property Profile Open Data Set"). In addition, it is acknowledged to have outstanding issues with reliability and data collection. See GAO, "High Risk: Managing Federal Real Property," accessed July 25, 2017, http://www.gao.gov/highrisk/managing_federal_property/why_did_study.

Select Green Building-Related Programs at Federal Agencies

Several agencies have programs and activities that have a broader focus than reducing the environmental impacts of the facilities of that agency. Descriptions of selected examples are included below.[153] This report does not discuss green building within individual agencies, although such efforts may be significant. For descriptions of selected programs, see **Appendix**.

General Services Administration[154]

Green Proving Ground	Conducts evaluations of next-generation building technologies. Recommends those technologies that meet agency standards for deployment throughout GSA's property holdings.
Facility Management Institute	Assists agencies in improving the operations and management of federal buildings.

Department of Energy[155]

Building America	Partners with the building industry on research and development that focuses on a whole-building, integrated approach to improving energy savings in residential buildings.

Government Accountability Office, "Federal Green Building: Federal Efforts and Third-Party Certification Help Agencies Implement Key Requirements, but Challenges Remain."

[153] Selection was based on the perceived prominence and influence of those programs on the implementation of green building.

[154] GSA, "About GSA's Green Proving Ground (GPG) Program," https://www.gsa.gov/governmentwide-initiatives/sustainability/emerging-building-technologies/about-gsas-proving-ground-gpg; GSA, "Facility Management Institute," July 24, 2020, https://www.gsa.gov/portal/content/160715.

[155] DOE, "Building Performance Database," https://www.energy.gov/eere/buildings/building-performance-database-bpd; DOE, "Federal Energy Management Program," 2020, https://energy.gov/eere/femp/federalenergy-management-program; DOE, Better Buildings Initiative, "About the Better Buildings Alliance," https://betterbuildingssolutioncenter.energy.gov/alliance/about; DOE, "Commercial Buildings Integration," July 24, 2020, https://www.energy.gov/eere/buildings/commercial-buildings-integration; DOE, "Building America: Bringing

Better Buildings Alliance	Promotes energy efficiency in commercial buildings through collaboration with members of the U.S. commercial building community.
Building Performance Dataset Project	Provides public access to data on the energy performance of commercial buildings.
Commercial Buildings Integration program	Implements initiatives related to energy savings in commercial buildings.
Federal Energy Management Program	Assists federal agencies in implementing energy savings and other goals and statutory requirements. Provides training and guidance to facilitate procurement, construction, operations, and maintenance of energy projects.

Environmental Protection Agency[156]

Environmentally Preferable Purchasing Program	Assists federal agencies in meeting green purchasing requirements.
Green Infrastructure Collaborative	Assists communities through a public-private partnership to implement green infrastructure. Builds and shares knowledge on emerging green infrastructure technologies and policy issues.
Smart Location Database Program	Collects nationwide geographic data. Measures neighborhood characteristics such as housing density, neighborhood design, and transit accessibility to produce a measurement of a location's siting efficiency.
Sustainable Materials Management Program	Provides resources for governments and businesses on assessing and reducing material use, purchasing recycled materials, and increasing recycling and reuse of construction and demolition materials.

Department of Defense[157]

Unified Facilities Criteria program	Provides planning, design, construction, sustainment, restoration, and modernization criteria in accordance with DOD Directive 4270.5, Military Construction.

Department of Housing and Urban Development[158]

Better Buildings Challenge Management Add-on Fee	Provides a financial incentive to HUD-insured or HUD-assisted properties to encourage portfolio-wide utility benchmarking and implementation of energy efficiency measures.

Building Innovations to Market," https://energy.gov/eere/buildings/building-america-bringing-building-innovations-market.

[156] EPA, "Green Infrastructure Collaborative," https://www.epa.gov/green-infrastructure/green-infrastructure-collaborative; EPA, "Sustainable Materials Management," https://www.epa.gov/smm; EPA, "About the Environmentally Preferable Purchasing Program," https://www.epa.gov/greenerproducts/about-environmentally-preferable-purchasing-program; EPA, "Smart Location Mapping," https://www.epa.gov/smartgrowth/smart-location-mapping.

[157] Whole Building Design Guide, "Department of Defense: Unified Facilities Criteria Program," https://www.wbdg.org/ffc/dod.

[158] HUD, "Mark-to-Market," https://www.hud.gov/program_offices/housing/mfh/presrv/presmfh/aboutm2m; HUD, "Energy Efficient Mortgage Program," https://portal.hud.gov/hudportal/HUD?src=/program_offices/housing/sfh/eem/energy-r; HUD, "Office of Lead Hazard Control and Healthy Homes (OLHCHH)," https://portal.hud.gov/hudportal/HUD?src=/program_offices/healthy_homes.

Energy Efficient Mortgage Program	Provides resources for governments and businesses on assessing and reducing material use, purchasing recycled materials, and increasing recycling and reuse of construction and demolition materials.
Environmentally Preferable Purchasing Program	Enables homeowners and buyers to finance the cost of energy efficiency improvements through their Federal Housing Administration-insured mortgage.
Healthy Homes and Weatherization Cooperation Demonstration	Provides grants as a pilot program within the Healthy Homes Initiative to demonstrate whether the coordination of remediation activities with weatherization activities achieves cost savings and improved outcomes for the safety and quality of homes.

National Institute of Science and Technology (NIST)[159]

Net-Zero Energy High-Performance Buildings Program	Focuses on developing building metrics for overall building sustainability and reducing building energy usage through improvements in specific component areas.
Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure Program	Focuses on improvements in measurement science and data relating especially to intelligent building systems, sustainably engineered materials, and achieving net-zero energy buildings with high indoor air quality.

Council on Environmental Quality (CEQ)[160]

Office of Federal Sustainability	Coordinates policy to promote energy and environmental sustainability across all agencies.

Assessing Green Building Efforts

The rise in prominence of green building since the 1990s has raised questions about its impacts. Those questions cover a broad range of issues, including market penetration, cost, actual building performance, the underlying measurement science, the extent to which legislative goals are being met, and the general approach and implementation of green building. Those issues are discussed below.

Market Penetration

The building industry is a substantial component of the U.S. economy. In 2019, the total value of construction and renovation work in the United States exceeded $1.3 trillion and accounted for more than 6% of U.S. gross domestic product (GDP).[161] The percentage of the overall construction market devoted to green building has grown substantially in recent years, spurred by a variety of factors, from government requirements to the prospect of attractive investment returns to increasing concerns about environmental degradation and quality of life. In 2005,

[159] NIST, "Net-Zero Energy, High-Performance Buildings Program," https://www.nist.gov/programs-projects/net-zero-energy-high-performance-buildings-program; NIST, "Strategic Goal: Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure," https://www.nist.gov/el/goals-programs/sustainable-and-energy-efficient-manufacturing-materials-and-infrastructure.

[160] CEQ, "The Office of Federal Sustainability," https://sustainability.gov/home.html.

[161] U.S. Census Bureau, "US Census Bureau Construction Spending Survey," June 2019, https://www.census.gov/construction/c30/c30index.html.

according to one analysis, 5% of commercial office square footage in 30 markets in the United States was certified "green" or "efficient." By 2019, the percentage had increased to 42%.[162]

Prior to the COVID-19 pandemic, green construction spending in the United States had been growing faster than general construction spending as a whole.[163] Spending on green construction more than tripled from $39 billion in 2008 to $129 billion in 2014.[164] One analysis projected that green building activities would generate $303.4 billion in GDP between 2015 and 2018.[165] The COVID-19 pandemic negatively affected the green construction industry among other industrial sectors. Reportedly, both nonresidential green construction spending and residential green construction globally are expected to decline from 2019 to 2020 and to recover by 2023.[166] Many expect new institutional construction to be a large future driver of green building growth in the United States, primarily due to certification requirements for public buildings and schools.[167]

At the same time, there remains a large portion of the U.S. residential and commercial building stock that was not constructed according to green building criteria and for which rapid retrofitting or replacement to meet those criteria does not seem feasible.[168]

Cost

Green building efforts can impact the financial performance of a building by affecting initial construction costs, operating expenses, rental rates, and property values, among other factors. Actual and perceived costs of implementing green building measures have a strong bearing on design and construction decisions. However, information on true costs is not always easy to

[162] CBRE, "U.S. Green Building Adoption Index for Office Buildings," 2019, https://www.cbre.us/research-and-reports/US-Green-Building-Adoption-Index-for-Office-Buildings—2019.

[163] Booz Allen Hamilton, "Green Building Economic Impact Study" (U.S. Green Building Council, September 2015), https://kapost-files-prod.s3.amazonaws.com/published/56438d353dab34e8a1000061/green-building-economic-impact-study.pdf?kui=ntZxSELuij0YNSwkwEO_Kw.

[164] Ibid.

[165] Ibid.

[166] For the nonresidential green construction, spending was expected to decline from $85.1 billion in 2019 to $79.1 billion in 2020 and to recover to an estimated $103.1 billion in 2023. For the single-family residential green building market, which includes construction, sales, and maintenance, spending was expected to decline from $119.6 billion in 2019 to $116.5 billion in 2020 and to recover to an estimated $151.0 billion in 2023. See "Global Single-Family Housing Green Buildings Market 2020-2030: Growth and Change Amid COVID-19—ResearchAndMarkets.com," *BusinessWire,* (August 19, 2020), https://www.businesswire.com/news/home/20200819005525/en/Global-Single-Family-Housing-Green-Buildings-Market-2020-2030-Growth-and-Change-Amid-COVID-19—ResearchAndMarkets.com; "Single-Family Housing Green Buildings Global Market Report 2020-30: Covid 19 Growth and Change," *Globe Newswire* (July 24, 2020), https://www.globenewswire.com/news-release/2020/07/24/2067374/0/en/Single-Family-Housing-Green-Buildings-Global-Market-Report-2020-30-Covid-19-Growth-and-Change.html.

[167] Dodge Data and Analytics, "World Green Building Trends 2016: Developing Markets Accelerate Global Green Growth," SmartMarket Report (2016), http://images.marketing.construction.com/Web/McGrawHillConstruction/%7B9cae5ab2-4ea8-429d-915d-49bc72212ebc%7D_World_Green_Building_Trends_2016_SmartMarket_Report_FINAL.PDF.

[168] According to one 2008 estimate, about 3% of the building stock (more than 300 billion square feet) in the United States is built new or renovated each year, with a growth rate in the stock of about 1% per year, and a projection that about three-quarters of the stock will be new or renovated by 2035 (Steven Winter, "Green Residential Building in North America: A Perspective from the United States," Background Paper [Commission for Environmental Cooperation, 2008], http://www3.cec.org/islandora/en/item/2333-paper-4b-residential-green-building-in-north-america-en.pdf). In 2012, commercial buildings had a median age of 32 years. Approximately half of such buildings had been built before 1980, and 12% since 2003 (EIA, "A Look at the U.S. Commercial Building Stock: Results from EIA's 2012 Commercial Buildings Energy Consumption Survey (CBECS)," March 4, 2015, https://www.eia.gov/consumption/commercial/reports/2012/buildstock/).

obtain, and such informational barriers can distort perceptions about the economic costs and benefits of green building. Moreover, researchers have noted that the flexibility inherent in designing individual green buildings makes generalizing about the cost performance of the market segment as a whole difficult.[169] As a result, empirical evidence of the financial performance of green building investments is limited.

It is widely believed that the initial costs of green buildings are higher than for conventional buildings. A survey of construction industry professionals found that higher perceived initial cost was among the top three obstacles for green building in the United States.[170] Such higher costs can result from several sources. Not only can many features, such as high-efficiency appliances and high-performance windows, be more expensive than conventional approaches, but design costs may be higher, and if the building is to be certified, the process may be time-consuming and expensive in its own right.

There is some indication, however, that the costs for constructing green buildings are not substantially higher than those of standard construction. A DOE review of the existing literature on green-certified buildings concluded that the available research shows construction costs for green buildings to be comparable to those of conventional buildings.[171] The use of integrated design may also result in some reductions in initial costs,[172] and some studies support that claim.[173]

Proponents of green building assert that operational cost savings will eventually recoup any initially higher investment. One way green buildings can create operational cost savings is by reducing usage of utility resources, and, in some cases, through selling site-generated renewable energy back to the grid. GSA, for instance, claims to have saved over $340 million in energy and water costs between FY2008 and FY2015 from efficiency improvements.[174] More than two dozen studies support the contention that green certification is associated with reduced utility expenses.[175] However, utility costs, such as electricity, gas, and water and sewerage bills, make up approximately 19% of a commercial building's operating costs,[176] and evidence is mixed on

[169] Daniel C. Matisoff, Douglas S. Noonan, and Mallory E. Flowers, "Policy Monitor—Green Buildings: Economics and Policies," *Review of Environmental Economics and Policy* 10, no. 2 (July 2016): 329–46, doi:10.1093/reep/rew009.

[170] Dodge Data and Analytics, "World Green Building Trends 2016: Developing Markets Accelerate Global Green Growth."

[171] Waypoint and JDM Associates, "Energy Efficiency and Financial Performance: A Review of Studies in the Market" (Department of Energy, December 2015), https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Energy%20Efficiency%20and%20Financial%20Performance_12_2015.pdf.

[172] Robert Cassidy, ed., "White Paper on Sustainability," *Building Design and Construction* Supplement, November 2003, 48 p., https://www.bdcnetwork.com/sites/default/files/BD%2BC%202003%20White%20Paper%20on%20Sustainability.pdf.

[173] Greg Kats et al., "The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force" (Sustainable Building Task Force, October 2003), http://evanmills.lbl.gov/pubs/pdf/green_buildings.pdf.

[174] GAO, *2016 Strategic Sustainability Performance Plan*, June 30, 2016), https://www.gsa.gov/cdnstatic/GSA_FY_2016_SSPP_Final_Cleared_508.pdf.

[175] Waypoint and JDM Associates, "Energy Efficiency and Financial Performance: A Review of Studies in the Market" (Department of Energy, December 2015), https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Energy%20Efficiency%20and%20Financial%20Performance_12_2015.pdf.

[176] Alex Herceg and Aditya Ranade, "Cash Is King: Assessing the Financial Performance of Green Buildings," ACEEE Summer Study on Energy Efficiency in Industry (July 14, 2015), http://aceee.org/files/proceedings/2015/data/papers/2-138.pdf.

whether green certification reduces overall operating expenses.[177] There are also some studies that suggest green-labeled buildings command price premiums on the real estate market, both in the amount that renters are willing to pay to use the space, and in terms of overall market value.[178] However, there are more studies suggesting that willingness to pay to rent a green residential space is not as straightforward. Even with perceived IEQ benefits compared to conventional residential spaces, some potential renters are not willing to pay extra to work or live in a green building.[179]

Some features of real estate markets can reduce incentives for investments in green building. For example, building owners, especially homeowners, often move after a few years,[180] reducing the time for a return on their initial investment through potential utility savings. The effect can be exacerbated if the building is rented or leased. The financial return on green building investments made by owners would depend on the premium they could charge current or new tenants. The return for investments by tenants would depend on the length of their tenure—only long-term tenants would be likely to benefit from making such an investment.[181] This is sometimes called the principal/agent or split-incentive problem.[182]

Many potential beneficiaries of green building renovations may be limited by constraints on the availability of capital for such investments, even outside the residential sector. Such constraints are reported with respect to such significant users of energy as educational institutions, hospitals, and municipalities.[183]

Cost barriers to increase the adoption of green building may continue to decrease as the practice becomes more widespread and economies of scale lower the initial cost differential. Also, financial incentives, offered by some states and municipalities, may help to defray higher initial costs, making green building investments more financially attractive. Some observers argue that costs beyond simple monetary expenditures should be considered. Such thinking has led to the use of concepts such as the "triple bottom line"[184] in literature on green building. The term refers to the inclusion of social and environmental returns, in addition to financial ones, in assessing business performance.

[177] Waypoint and JDM Associates, "Energy Efficiency and Financial Performance: A Review of Studies in the Market" (Department of Energy, December 2015), https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Energy%20Efficiency%20and%20Financial%20Performance_12_2015.pdf.

[178] Ibid.

[179] Maryam Golbazi et al., "Willingness to Pay for Green Buildings: A Survey on Students' Perception in Higher Education," *Energy and Buildings*, vol. 216 (June 2020), https://doi.org/10.1016/j.enbuild.2020.109956.

[180] Between 11% and 13% of Americans move every year. (U.S. Census Bureau, "U.S. Mover Rate Remains Stable at About 12 Percent Since 2008," *The United States Census Bureau*, March 18, 2015, https://www.census.gov/newsroom/press-releases/2015/cb15-47.html).

[181] Such arguments about cost problems are often cited as a barrier to wider implementation of green building. See, for example, DOE, Building Technologies Office, "Multi-Year Program Plan."

[182] Florian Bressard et al., "Curbing Global Energy Demand Growth: The Energy Productivity Opportunity" (McKinsey Global Institute, May 2007), http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/curbing-global-energy-demand-growth.

[183] Ibid.

[184] John Elkington, *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*, Conscientious Commerce (Gabriola Island, BC: New Society Publishers, 1998).

Performance

Although many consider green building to be a positive development, other observers have expressed concerns about the approach. Some of those criticisms have been directed at rating and certification systems. The certification process is more rigorous for some systems than for others, and critics have pointed out that many systems do not set caps on performance metrics such as energy use, making claims to sustainability relative. Some argue that the design criteria are not sufficiently integrative—they do not provide sufficient integration across elements or stages in the building's life cycle—or that they are too incremental in scope.[185] Others have argued that mere mitigation of environmental impacts is not sustainable, and that new approaches are preferable, for example based on maintenance or even enhancement of ecosystem services.[186] Such approaches would arguably need to go beyond individual buildings and include other components of the built environment.[187] Such issues can be compounded by differences in goals and perspectives among different stakeholders.[188] Identifying objective, rather than subjective, criteria and approaches may also be difficult, especially for elements of green building, such as siting, that are not as amenable to quantitative evaluation as others, such as energy.

In evaluating the efficacy of green building efforts, how the new green building construction or retrofit performs over time must be discussed. Much of the focus of green building, including rating systems such as LEED, has primarily been on design and construction specifications. Historically, actual environmental performance of green buildings was not incorporated into certification requirements for most rating systems. However, LEED has included an Operations and Maintenance (O&M) certification for existing buildings since 2008 that requires building owners to submit energy performance data that demonstrate they meet the criteria. In LEED v4, buildings must submit 12 months of continuous energy data which shows they're in the 75th percentile or above in terms of energy efficiency of the national average for their building type.[189]

Factors Affecting Performance

There are many factors that can affect operations and potentially degrade the performance of a building after it has received its green rating. Such factors include inadequate maintenance of systems, alterations to prescribed building controls, and unintended changes in building use and occupancy. Consequently, it is not certain that a nominally green building, even one for which the design and construction are certified, will perform in a manner that is significantly better or worse than a conventional building. Some examples of certified green buildings have been shown to be

[185] Anya Kamenetz, "The Green Standard?," Fast Company, December 19, 2007, http://www.fastcompany.com/magazine/119/the-green-standard.html; and Andrew J. Nelson and Ari Frankel, "Building Labels vs. Environmental Performance Metrics: Measuring What's Important about Building Sustainability" (RREEF Real Estate, October 2012), http://realestate.deutscheam.com/content/_media/Research_Sustainability_Metrics_in_the_Real_Estate_Sector-Oct_2012.pdf.

[186] Sarah Nugent et al., "Living, Regenerative, and Adaptive Buildings," *Whole Building Design Guide*, August 5, 2016, https://www.wbdg.org/resources/living-regenerative-and-adaptive-buildings; Victor Olgyay and Julee Herdt, "The Application of Ecosystems Services Criteria for Green Building Assessment," *Solar Energy*, vol. 77, no. 4, (October 2004): 389–398.

[187] For example, LEED has developed a Neighborhood Development rating system to assess sustainability of the built environment at the neighborhood scale.

[188] For example, environmental groups are likely to have different goals and perspectives than builders or occupants.

[189] "LEED v4 for Building Operations and Maintenance," U.S. Green Building Council, Jan. 5, 2008, https://www.usgbc.org/resources/leed-v4-building-operations-and-maintenance-current-version.

extremely resource-intensive postoccupancy. Other studies have identified that changes in postoccupancy operations and maintenance can lead to reductions in anticipated benefits.[190]

Studies that have evaluated actual green building performance are discussed later in this section. However, even where greater resource-use efficiency can be demonstrated, savings may be offset by other factors. For example, green building efforts and related energy efficiency initiatives appear to have helped reduce energy-use intensity (see "Measurement," below) in U.S. homes built since 2000. Yet, because these homes have increased in size by 25% since the 1960s, they consume the same amount of energy as homes built in the 1960s.[191]

The energy performance of green buildings has received the most scrutiny. Researchers have shown that there is often a significant difference between the predicted or modeled energy use of a building and its measured performance.[192] This difference is sometimes referred to as a "performance gap." Closing that gap is of ongoing interest and concern to the construction industry.

In response to such concerns, rating system developers have placed increasing emphasis on postoccupancy performance assessment. LEED v4 sought to address critiques centered on the one-time assessment nature of certification by requiring installation of building-level energy and water meters, the data from which are to be compiled and reported to USGBC for the first five years following certification. Other systems, such as BREEAM In-Use and the Living Building Certification, explicitly include performance parameters within the criteria for certification (see "Green Certifications and Standards," above). Building codes are also moving toward incorporating performance outcomes into requirements: the 2015 IgCC included an outcome-based compliance pathway for energy usage, allowing builders to meet requirements through actual performance.[193]

Building systems may also be commissioned—that is, independently assessed to ensure they are designed, installed, tested, and capable of being operated as planned.[194] Available data appear to support the contention that commissioning improves environmental performance, especially for energy use.[195] The process can be used not only for new buildings, but also existing ones, either during retrofitting or continuing operations.

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[190] Richard Conniff, "Why Don't Green Buildings Live Up to Hype on Energy Efficiency?," Yale E360, August 25, 2017, http://e360.yale.edu/features/why-dont-green-buildings-live-up-to-hype-on-energy-efficiency; Sam Roudman, "Bank of America's Toxic Tower," *The New Republic*, July 29, 2013, https://newrepublic.com/article/113942/bank-america-tower-and-leed-ratings-racket.

[191] EIA, "Highlights from the 2015 RECS: Energy Consumption, Expenditures, and End-Use Modeling," July 31, 2018, p. 11, https://www.eia.gov/consumption/residential/webinar_slides/highlights_from_the_2015_RECS.pdf.

[192] Shi et. al, "Magnitude, Causes, and Solutions of the Performance

Gap of Buildings: A Review," *Sustainability*, February 2019, https://www.mdpi.com/2071-1050/11/3/937.

[193] Institute for Market Transformation, "Outcome-Based Pathway Is Voted into the 2015 IgCC" (press release, November 20, 2014), http://www.imt.org/news/the-current/outcome-based-pathway-is-voted-into-the-2015-igcc.

[194] Whole Building Design Guide, "Building Commissioning," November 12, 2016, http://www.wbdg.org/building-commissioning.

[195] See, for example, Evan Mills, "Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions in the United States," *Energy Efficiency* 4, no. 2 (May 1, 2011): 145–73, doi:10.1007/s12053-011-9116-8; Kramer, H., Lin, G., Curtin, C. et al., "Building Analytics and Monitoring-Based Commissioning: Industry Practice, Costs, and Savings," *Energy Efficiency* 13, 537–549 (2020). https://doi.org/10.1007/s12053-019-09790-2.

In addition to certification and commissioning, an organization can develop an environmental management system (EMS), for which international standards are available.[196] To be certified under the standards, an organization must have an explicit environmental policy that includes commitments to conform to relevant environmental requirements, continuously improve environmental performance, and prevent pollution, among other things. Such commitments are arguably far easier to meet if the EMS includes performance measurement.[197] Similarly, there are building energy management systems (BEMS) that optimize a building's energy use through the use of computer-based controls. In general, having a BEMS may lead to greater energy savings, depending on building type.[198]

Networked building monitoring and diagnostic tools are increasingly prevalent. Such tools can allow early fault detection in critical building equipment as well as providing resource use analytics, allowing building managers to more effectively respond to changing use patterns in real time. (See Smart Buildings subsection in "Issues for Congress.") For example, GSAlink, a GSA-developed building diagnostic tool, has been used to identify over 33,000 instances of sub-optimal equipment performance within GSA holdings alone.[199]

Selected Studies for Energy

Many studies have attempted to measure and evaluate green building performance. However, a lack of consensus on the criteria for defining green building, as well as on the outcomes to be measured, complicates comparisons between studies.[200] Generally, the evidence that green buildings perform significantly better than conventional buildings is mixed. Recent studies have shown green buildings to exhibit a wide range of measured energy performance, with some buildings performing far below design expectations.[201] In general, however, the studies seem to conclude that buildings with green certifications perform better than buildings without one. The selected studies discussed below primarily use LEED ratings as the criteria for inclusion. Because other rating systems are not as prevalent in the United States, little information is available on the performance of buildings constructed under those systems in the U.S. market.

A study of energy use by more than 100 LEED-certified buildings found that, on average, they performed 24% better than other buildings.[202] About one in seven performed worse than average.

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[196] The standard is ISO 14001. See International Organization for Standardization, "ISO 14001 Family—Environmental Management," August 21, 2017, https://www.iso.org/iso-14001-environmental-management.html. EPA has promoted testing and adoption of this standard by local governments and nonprofit organizations Environmental Protection Agency, "Frequent Questions About Environmental Management Systems," Overviews and Factsheets (January 23, 2017), https://www.epa.gov/ems/frequent-questions-about-environmental-managment-systems.

[197] For more information on ensuring buildings meet performance objectives, see WBDG Functional/Operational Committee, "Meet Performance Objectives," Whole Building Design Guide, October 25, 2016, http://wbdg.org/design-objectives/functional-operational/meet-performance-objectives.

[198] Lee, Dasheng, Cheng, Chin-Chi, "Energy Savings by Energy Management Systems: A Review," *Renewable and Sustainable Energy Reviews*, vol. 56, April 2016, pp. 760-77, https://doi.org/10.1016/j.rser.2015.11.067.

[199] GAO, *2016 Strategic Sustainability Performance Plan*, June 30, 2016, https://www.gsa.gov/cdnstatic/GSA_FY_2016_SSPP_Final_Cleared_508.pdf.

[200] Melissa A. Beutler et al., eds., *Green Building and the Construction Lawyer: A Practical Guide to Transactional and Litigation Issues* (Chicago, Illinois: Forum on Construction Law, 2014).

[201] New Buildings Institute, "High Performance Buildings Measured Performance and Key Performance Indicators," CEC-500-08-049 (March 2013), http://newbuildings.org/wp-content/uploads/2015/11/HPBldgsFinalResearchSummary1.pdf.

[202] Cathy Turner and Mark Frankel, "Energy Performance of LEED for New Construction Buildings" (New Building Institute, March 4, 2008), https://www.usgbc.org/ShowFile.aspx?DocumentID=3930.

Some criticized this study as misleading because of purported sample bias, inappropriate baselines for comparison, and other concerns.[203] A follow-up assessment using the same data concluded that primary energy savings from LEED certification were nonexistent for lower levels of certification and 13% better than average for Gold and Platinum-certified buildings.[204]

A longitudinal study of 16 low-income green residential buildings with 310 individual units tracked building energy and cost savings performance for over three years. All of the buildings in the study were located in the state of Virginia and all were EarthCraft-certified[205] green buildings. Data collected for building energy performance included monthly electricity use (kWh), construction type (new or renovated), occupant type (family or senior), technology level, climate, and conditioned floor area data. The study also collected voluntary behavioral surveys, and utility account data from individual units to compare with statewide average energy use for a cost savings analysis. The results of the study indicate a stable and consistent energy performance across the three-year period for the EarthCraft-certified multifamily residential buildings. The study also calculated an average annual cost savings per unit of $648, which translates to 26.6%-37.5% cost savings.

A GSA study of 22 green federal buildings, most of which had received LEED certification, found that, on average, the buildings studied performed better than the national average in all measured performance areas, including energy use, water use, operating costs, occupant satisfaction, and carbon emissions.[206] Some buildings performed worse than the national average in certain areas, however.

The performance gap of green buildings is supported by a literature review of over 900 papers on green building performance across the world that showed many green buildings saved less energy than expected.[207] Despite the performance gap, this literature review found that, except in rare occasions, green buildings performed better than conventional buildings. The review also found that, in the United States, occupants were generally unsatisfied with the thermal and acoustic performance of green buildings. Some have criticized this review article for not accounting for energy losses due to transmission of energy, redundancies in the datasets compared, and improper averaging of buildings' performances in some papers.[208] Taking these issues into account, the

[203] Joseph W. Lstiburek, "Prioritizing Green—It's the Energy Stupid," BSI-007, Insights (Building Science Corporation, November 2008), https://buildingscience.com/documents/insights/bsi-007-prioritizing-green-it-s-the-energy-stupid. Another report found discrepancies between LEED ratings and the results of modeling that examined impacts expected over the entire life of the building. (Chris W. Scheuer and Gregory A. Keoleian, "Evaluation of LEED Using Life Cycle Assessment Methods," NIST GCR 02-836 [National Institute of Standards and Technology, September 2002], http://www.fire.nist.gov/bfrlpubs/build02/PDF/b02170.pdf).

[204] John Scofield, "A Re-Examination of the NBI LEED Building Energy Consumption Study" (2009 International Energy Program Evaluation Conference, Portland, OR, 2009), https://www.researchgate.net/publication/267793718_A_Re-examination_of_the_NBI_LEED_Building_Energy_Consumption_Study.

[205] EarthCraft is a program that certifies above-code, high performance buildings. Their multifamily certification aligns closely with requirements for states' Qualified Allocation Plan (QAP) for Low Income Housing Tax Credit (LIHTC) projects. For more information, see http://earthcraft.org/wp-content/uploads/2020/01/ECMF-new-and-renovation-onesheet-final.pdf.

[206] General Services Administration, "Green Building Performance: A Post Occupancy Evaluation of 22 GSA Buildings," August 2011, https://www.gsa.gov/portal/getMediaData?mediaId=214295.

[207] Geng et al., "A Review of Operating Performance in Green Buildings: Energy Use, Indoor Environmental Quality and Occupant Satisfaction," *Energy and Buildings*, vol. 183, 15 January 2019, pp. 500-14, https://doi.org/10.1016/j.enbuild.2018.11.017.

[208] John Scofield, "Comment on 'A Review of Operating Performance in Green Buildings: Energy Use, Indoor Environmental Quality and Occupant Satisfaction' by Geng et al.," *Energy and Buildings*, vol. 194, 1 July 2019, pp. 369-71, https://doi.org/10.1016/j.enbuild.2019.04.025.

writer of the criticism argues that the review would conclude that green buildings perform no better than conventional buildings. The authors of the review paper disagreed with these technical critiques and posit that even taking into account some of the critic's suggested analysis, green buildings still perform better than conventional buildings, on average.[209]

As discussed, there is disagreement in the green building community about how effective LEED certifications are at reliably demonstrating superior energy performance. Depending on the level and type of certification, energy performance varies. However, sample sizes were small and may not be representative of the overall performance of green-certified buildings. Performance data is often proprietary and therefore inaccessible to researchers conducting evaluations. Greater access to building performance data is frequently cited as a prerequisite to more comprehensive performance assessments.[210]

Selected Studies: Health Performance

While energy performance is one key element of any green building, another element, occupant health, is becoming an increasingly important factor. The extent that a certified green building has improved IEQ and occupant health when compared to non-certified buildings is unclear. Two studies found that a LEED certified building did not necessarily indicate higher occupant satisfaction with IEQ.[211] It was also shown that there was no substantive increase in occupant satisfaction with IEQ with increased LEED rating (or total amount of LEED points).[212] Some studies on health impacts of green buildings rely on self-reported occupant health surveys, which are subjective. Other studies rely on direct data on occupant health, which can be more challenging to collect. One such study investigated the cognition of occupants in green office buildings and non-green office buildings.[213] The study found that the 69 workers that worked in LEED-certified high-performance buildings for a week scored 26.4% better on cognitive assessments than the 40 participants in high-performance office buildings without a LEED certification.[214] This study was in accordance with the former study by illustrating no significant differences in IEQ measurements like ventilation rates, VOC concentration, temperature, CO_2 concentrations, lighting, or noise between green and conventional high-performance buildings.

A study involving both subjective survey data and objective data provides evidence that green buildings positively impact IEQ measures. In the study, eight green and six conventional buildings were tested for IEQ measures such as lighting, temperature, humidity, particulate matter concentration, and the presence of fungi.[215] In addition, 367 occupants were surveyed about their

[209] Geng et al. "Response to the Commentary on 'A review of Operating Performance in Green Buildings: Energy Use, Indoor Environmental Quality and Occupant Satisfaction' by John H. Scofield," *Energy and Buildings*, vol. 194, 1 July 2019, pp. 366-68, https://doi.org/10.1016/j.enbuild.2019.04.024.

[210] John H. Scofield, "Do Green Buildings Really Save Energy? A Look at the Facts," Text, *GreenBiz* (September 21, 2016), https://www.greenbiz.com/article/do-green-buildings-really-save-energy-look-facts.

[211] Sergio Altomonte et al., "Indoor Environmental Quality and Occupant Satisfaction in Green-Certified Buildings," *Building Research and Information*, vol. 47 (November 2017), pp. 255-74, https://doi.org/10.1080/09613218.2018.1383715; Emily Oldham and Hyojin Kim, "IEQ Field Investigation in High-Performance, Urban Elementary Schools," *Atmosphere*, vol. 11, no. 1 (January 2020), p. 81, https://doi.org/10.3390/atmos11010081.

[212] Emily Oldham and Hyojin Kim, "IEQ Field Investigation in High-Performance, Urban Elementary Schools," *Atmosphere*, vol. 11, no. 1 (January 2020), https://doi.org/10.3390/atmos11010081.

[213] Piers MacNaughton et al., "The Impact of Working in a Green Certified Building on Cognitive Function and Health," *Building and Environment*, vol. 114 (March 2017), pp. 178-86, https://doi.org/10.1016/j.buildenv.2016.11.041.

[214] Ibid.

[215] Jang Young-Lee et al., "Indoor Environmental Quality, Occupant Satisfaction, and Acute Building-Related Health

perceived level of satisfaction in the buildings. The study found a lower concentration of fungi and particulate matter, and a higher consistency in temperature and humidity in the green buildings, as compared to the conventional buildings.[216] The survey found that occupants were more satisfied and had a reduction in headaches, fatigue, and skin irritation in green buildings.[217]

Another study investigated more specifically the environmental perceptions and how they affect occupants' health. The study followed 24 participants as they moved from one green office building to another one for six work days. As the building IEQ was purposefully changed from conventional, green, and green with increased ventilation, the researchers found that participants' perception of being in a green building more closely followed participants' actual health indicators than the conditions manipulated by the researchers.[218]

While the first two studies showed no correlation between occupants' perceptions of IEQ and occupancy in a green building, the last two suggest that green buildings do have an effect, perceived or otherwise, on the health of the building occupants. In summary, it seems that occupant health, whether in green or conventional buildings, is affected in part by not only the measurable environmental factors, but also the perception of the IEQ of a building.

Measurement

As the discussion above shows, performance measurement is important for ensuring that green buildings meet the environmental targets claimed for them and to assess ways to improve those targets. However, methods for measuring the performance of green buildings are not yet well-developed for most elements. Some, such as energy and water use, are comparatively easy to measure quantitatively, for example through metering. Others may be difficult to quantify and may be possible to evaluate only on the basis of the presence or absence of certain features or through other more qualitative measures.[219] Even for elements that are relatively simple to measure, such as energy usage, there may be disagreement about which of several possible metrics captures the most relevant information. For instance, energy use intensity (EUI), which is the primary metric used to evaluate federal building performance, has traditionally been defined as the amount of energy used per square foot. GSA's Green Building Advisory Committee has recently proposed two additional methodologies for measuring EUI: energy use per occupant and area-based EUI measuring energy used in commuter transportation to and from the building.[220] The Advisory Committee says a building's energy use patterns may appear to vary based on

Symptoms in Green Mark-Certified Compared with Non-Certified Office Buildings," *Indoor Air*, vol. 29, no. 1 (January 2019), pp. 112-29, doi: 10.1111/ina.12515.

[216] Ibid.

[217] Ibid.

[218] Piers MacNaughton et al., "Environmental Perceptions and Health Before and After Relocation to a Green Building," *Building and Environment*, vol. 104 (August 2016), pp. 138-44, https://doi.org/10.1016/j.buildenv.2016.05.011.

[219] Grace Ding, "Sustainable Construction—The Role of Environmental Assessment Tools," *Journal of Environmental Management* 86 (February 2008): 451–64, https://www.researchgate.net/publication/6516125_Sustainable_Construction_-_the_Role_of_Environmental_Assessment_Tools; Andrew J. Nelson and Ari Frankel, "Building Labels vs. Environmental Performance Metrics: Measuring What's Important about Building Sustainability" (RREEF Real Estate, October 2012), http://realestate.deutscheam.com/content/_media/Research_Sustainability_Metrics_in_the_Real_Estate_Sector-Oct_2012.pdf.

[220] EUI Task Force, "Expanding the Concept of Energy Use Intensity (EUI): A Proposal to GSA's Green Building Advisory Committee" (General Services Administration, January 17, 2017), https://www.gsa.gov/portal/getMediaData?mediaId=154598.

which metric is used. Another study by Pacific Northwest National Laboratory cautioned that a lack of accurate building occupancy data could complicate efforts to calculate occupancy-adjusted EUI.[221] Furthermore, there is some research that estimated energy performance measures like those included in LEED have little correlation with actual, measured performance, like that of an ENERGY STAR score.[222]

Given the life expectancy of buildings—in most cases far longer than occupancy by any given resident—measurement of performance is important not only initially but over the building's entire lifespan. In the absence of such regular measurement and adjustment, environmental performance is likely to deteriorate over time for many elements. Eventually, some form of standard life-cycle assessment may be feasible for whole buildings.[223]

EISA requires that federal agencies measure the performance of their buildings against specified targets, especially with respect to energy use. Targets are more stringent for new construction than existing stock. Energy performance is to be measured against a baseline of consumption levels in 2003. Determination of an accurate baseline may be difficult in the absence of adequate measurement of energy use.

Despite the recognized importance of measurement and the availability of options and resources for its application, uncertainties and gaps exist that can make effective application challenging. Consensus may not exist on specific measurement goals or metrics. Reliable and consistent data are often difficult to obtain.[224] Measurement science relating to green building is an active area of research. In 2008, the National Science and Technology Council listed the development of appropriate measurement science as the top research need for progress in green building.[225] Developing metrics and tools for measuring building sustainability is a priority of the National Institute of Standards and Technology.[226] In 2013, NIST began operating the Net-Zero Energy Residential Test Facility (NZERTF) to research building energy efficiency. Current projects related to measurement in the test facility include measurement approaches and data collection for assessing thermal comfort, measurement of hot water distribution effectiveness, measured impact of heat pump water heater on the space conditioning requirements, an assessment of the spatial variation in outdoor temperature measurement and its impact on modeling of thermal loads introduced by ventilation systems.[227]

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[221] A. Selvacanabady and K. Judd, "The Influence of Occupancy on Building Energy Use Intensity and the Utility of an Occupancy-Adjusted Performance Metric," PNNL-26019 (Pacific Northwest National Laboratory, January 2017), http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26019.pdf.

[222] New Buildings Institute, "High Performance Buildings Measured Performance and Key Performance Indicators."

[223] A life cycle assessment is a method for analyzing the environmental impacts of something throughout its lifespan, from initial creation through destruction or disposal—a "cradle-to-grave" evaluation. For one approach involving buildings, see National Institute of Standards and Technology, "Metrics and Tools for Sustainable Buildings Project," *NIST*, July 13, 2017, https://www.nist.gov/programs-projects/metrics-and-tools-sustainable-buildings-project.

[224] For more on the challenges surrounding building performance measurements, see Joel Ann Todd, "Measuring Performance of Sustainable Buildings," *Whole Building Design Guide*, December 8, 2016, http://wbdg.org/resources/measuring-performance-sustainable-buildings.

[225] National Science and Technology Council, Committee on Technology, "Report of the Subcommittee on Buildings Technology Research and Development: Federal R&D Agenda for Net-Zero Energy, High-Performance Green Buildings," October 2008, http://www.bfrl.nist.gov/buildingtechnology/documents/FederalRDAgendaforNetZeroEnergyHighPerformanceGreenBuildings.pdf.

[226] National Institute of Standards and Technology, "Metrics and Tools for Sustainable Buildings Project."

[227] For more information on NIST's NZERTF, see https://www.nist.gov/el/net-zero-energy-residential-test-facility.

Progress Toward Federal Goals

Agency progress toward meeting federally mandated green building goals varies widely. OMB releases annual sustainability and energy scorecards for each agency with sustainability reporting requirements. These scorecards report on agency progress toward federal sustainability goals in the following areas: GHG Emission Reductions,[228] Reduction in Energy Intensity, Use of Renewable Energy, Reduction in Potable Water Intensity, Reduction in Fleet Petroleum Use, Green Buildings, and Sustainable Contracts. Scorecards include both numeric reports of agency progress, in the form of percentage reductions in target areas, and a color score of green, yellow, or red. The precise meaning of a score color differs slightly for each target area. Generally, however, a green score indicates that an agency had met or was on track to meet the target; yellow indicated that some progress has been made toward a target; and red indicated that the agency was neither on track to achieving a given target nor demonstrating significant progress.

Federal progress toward three buildings-related goals is discussed below. See **Figure 1** for information on the reported progress of selected agencies toward those goals.

- **Green Building Goal:** E.O. 13834 directed federal agencies to ensure that at least 15% of agency buildings with more than 10,000 square feet of floorspace comply with the Guiding Principles.[229] Some agencies have already surpassed this target while others are making progress. The Department of Defense is the only major federal agency that has achieved compliance in fewer than 2% of buildings; several others have received a red score in the green buildings category from OMB for FY2019.
- **Energy Intensity Goal:** EISA set a goal for federal facilities to reduce energy intensity by 30% from 2003 levels by 2015. Many agencies did not meet this goal. Government-wide energy intensity declined 20.7% during this period. As of FY2019, the goal set for FY2015 had still not been achieved, though government-wide reduction in energy intensity had decreased by 25.6% from the 2003 level.
- **Potable Water Intensity Goal:** In 2015, E.O. 13693 established a 36% reduction goal in potable water intensity from 2007 levels by 2025. E.O. 13834 decreased that goal to a 20% reduction in potable water intensity relative to FY2007. Many agencies have already achieved the earlier goal set out in E.O. 13693, therefore most agencies have achieved the E.O. 13834 20% target. Government-wide potable water intensity achieved a 20% reduction in FY2014; the federal government has continued to reduce its water use. As of FY2019, government wide potable water intensity was down 27.5% compared to the 2007 baseline.

[228] EISA requires agencies report greenhouse gas emissions; it does not specify what types of emissions. Federal GHG emissions can be categorized as either direct emissions from sources owned or controlled by a federal agency (Scope 1), indirect emissions resulting from the generation of electricity, heat, or steam that a federal agency has purchased (Scope 2), or indirect emissions from sources not owned or directly controlled by a federal agency but related to its activities (Scope 3). The Obama Administration required agencies to report specified Scope 3 GHG emissions along with Scope 1 and 2. The implementing instructions for E.O. 13834 stated that GSA would propose methodologies to standardize and streamline Scope 3 reporting and that CEQ may update the Accounting Guidance documents for reporting Scope 3 GHG emissions. For more information, see CEQ, "Implementing Instructions for Executive Order 13834: Efficient Federal Operations," April 2019, p. 34.

[229] E.O. 13834 was revoked by E.O. 13990 on January 20, 2021, with the exception of sections 6 (Duties of the Federal Chief Sustainability Office), 7 (Duties of Heads of Agencies), and 11 (General Provisions).

Figure 1. Selected Agency Progress Toward Selected Green Building Goals for FY2019

Agencies Ordered by the size of their property holdings	Building Sq. Ft. Meeting Guiding Principles (GP) %, FY2019 (Goal 15%)	OMB Score [a]	Reduction in Energy Intensity from 2003 %, FY2019 (Goal 30%)	OMB Score [b]	Reduction in Water Intensity from 2007 %, FY2019 (Goal 20%)	OMB Score [c]
Department of Defense	1.9	YELLOW	20.9	YELLOW	28.0	GREEN
General Services Administration	37.5	GREEN	29.3	YELLOW	34.3	GREEN
Dept. of Energy	10.4	RED	41.2	GREEN	32.8	GREEN
Department of the Interior	5.0	YELLOW	46.3	GREEN	24.4	GREEN
Department of Justice	6.1	RED	47.5	GREEN	17.3	YELLOW
Department of Agriculture	46.7	GREEN	39.7	GREEN	25.9	GREEN
Department of Homeland Security	12.4	RED	28.6	YELLOW	31.2	GREEN
National Aeronautics and Space Admin.	23.8	GREEN	41.3	GREEN	34.3	YELLOW
Department of Health and Human Services	8.5	YELLOW	23.1	RED	21.1	YELLOW
Department of Transportation	5.6	YELLOW	33.9	GREEN	26.3	YELLOW
Department of Labor	9.5	RED	33.9	GREEN	34.6	YELLOW
Department of Veterans Affairs	43.8	YELLOW	28.5	RED	34.5	GREEN
Environmental Protection Agency	27.8	GREEN	37.5	GREEN	43.3	GREEN

OMB Score: Score is determined by OMB and factors in the percent, and also improvement (or lack of) from prior year. See notes for more detail.

GREEN Agency met goal and improved from prior year

YELLOW Agency met goal or improved from prior year

RED Agency did not meet goal and did not improve from prior year

Source: CRS developed reporting data provided in FY2019 OMB Scorecards on Efficient Federal Operations/Management, available at https://www.sustainability.gov/performance.html. Agencies included in this chart were selected from the reporting agencies on the basis of amount of floorspace owned and leased (see **Table 2**), with the exception of EPA, which is included due its substantial green building activities, despite its small spatial footprint. Agencies are ordered by the size of their property holdings. Scores were developed by OMB; see notes for more detail.

Notes:

a. For high-performance sustainable buildings, agencies are assessed on the number and gross square footage (GSF) of federal buildings that meet the Guiding Principles (GP): Green (at least 15% of buildings or GSF meet GP *and* the agency increased percentage meeting GP compared to prior year), Yellow (at least 15% of buildings or GSF meet GP *or* the agency increased percentage meeting GP compared to prior year), and Red (fewer than 15% of buildings or GSF meet GP *and* the agency decreased percentage meeting GP compared to prior year).

b. For facility energy efficiency, agencies are assessed on meeting a 30% reduction in energy intensity from a 2003 baseline: Green (achieved 30% reduction compared to 2003 *and* reduced energy intensity from the prior year), Yellow (achieved 30% reduction compared to 2003 *or* reduced energy intensity from the prior year), and Red (did not achieve 30% reduced compared to 2003 *and* did not reduce energy intensity from the prior year).

c. For water efficiency, agencies are assessed on meeting a 20% reduction in potable water use intensity compared to a 2007 baseline: Green (achieved 20% reduction in potable water use intensity *and* reduced potable water use intensity compared to prior year), Yellow (achieved 20% reduction in potable water use intensity *or* reduced potable water use intensity compared to prior year), and Red (did not meet a 20% reduction compared to 2007 *and* did not reduce potable water use intensity from the prior year).

Issues for Congress

Among the questions Congress may expect to face with respect to green building are:

- How well are current federal green building programs working? How effective are current methods for coordinating the green building activities of different agencies?
- To what extent, if any, and by what means should Congress extend federal efforts to facilitate and support adoption and implementation of green building measures throughout the United States?
- What priorities should Congress give to the different elements of green building, especially those such as siting that have received less attention in the past?
- What actions, if any, should Congress take to facilitate the growth of scientific and technical knowledge relating to green building?

If Congress seeks to take additional action on such questions, it could do so through appropriations, new statutory requirements, and tax law. Other options could include reviewing current and proposed agency programs, regulations, and policies.

Federal Green Buildings: Oversight and Legislation

GAO has released several reports over the last decade addressing various federal efforts relating to green building. One of those reports identified 94 initiatives across 11 agencies relating to green building in the nonfederal sector.[230] Few of those initiatives focused on green building in the integrative sense it is discussed in this report, but rather focused on specific elements such as energy, IEQ, or water. GAO recommended that agencies coordinate to assess the relative performance of the initiatives.

Congress may examine how well federal agencies are implementing green building programs, and what impacts those efforts are having on the adoption of green building practices both within the federal government and nationwide. In addition to oversight of the activities of individual agencies, it may also be useful to examine how well agency efforts are being coordinated.

Congress could consider identifying ways in which current green building efforts in federal agencies could be further enhanced. Some in Congress have recommended that federal policy should require all new construction or major renovations of federal buildings achieve net-zero GHG emissions by 2030.[231] In addition to accelerating green building for new and existing stock, Congress might consider whether programs and activities are sufficiently integrated within agencies such as EPA and DOE, and whether activities across agencies are sufficiently harmonized, such as through participation in the WBDG.[232]

[230] Government Accountability Office, "Green Building: Federal Initiatives for the Nonfederal Sector Could Benefit from More Interagency Collaboration," GAO-12-79, (November 9, 2011), http://www.gao.gov/new.items/d1279.pdf. Agencies whose programs were examined by GAO but are not discussed in the section in this report on "Programs and Activities of Selected Federal Agencies" were the Departments of Agriculture, Education, Health and Human Services, Transportation, and the Treasury, as well as the Small Business Administration.

[231] U.S. Congress, House Select Committee on the Climate Crisis, *Solving the Climate Crisis*, 116th Cong., 1st sess., H.Rept. 116-63 (Washington, DC: GPO, 2020), p. 176.

[232] For more information, see the text box "Whole Building Design Guide."

Congress may consider whether to extend the energy reduction goals for existing federal buildings. As discussed previously in the "Legislative and Policy Framework" section, EISA set a goal of 30% reduction from a 2003 baseline by 2015. However, government-wide energy reduction, as of 2019, is 25.6% lower than 2003 levels.[233]

Adoption and Implementation of Green Building

Some of the challenges in achieving federal sustainability goals in buildings depend on how well these policies are adopted and implemented within the agencies and beyond the federal government in the private building sector.

Financial Incentives

In addition to programs and activities such as those described above, some federal agencies such as the Federal Housing Administration and the Department of Veterans Affairs (VA) also support the availability of mortgages that promote energy efficiency. Lenders who provide such mortgages may also become ENERGY STAR partners.[234]

Congress could broaden the scope of mortgage and tax incentives to include elements of green building. These could include extending tax incentives,[235] funding the State Energy-Efficient Appliance Rebate Program (SEEARP) authorized by EPACT 2005, and directing HUD to issue underwriting for energy efficiency or other elements of green building.[236]

Congress could consider identifying ways in which current green building efforts in federal agencies could be further enhanced. In addition to accelerating green building for new and existing stock, Congress might consider whether programs and activities are sufficiently integrated within agencies such as EPA and DOE, and whether activities across agencies are sufficiently harmonized, such as through participation in the WBDG.

Codes and Standards

Congress may consider changes to federal agency involvement in building codes and standards, although such efforts might be complicated by federalism issues[237] and differences in regional requirements relating to climate and other variables. One projection suggests that the cumulative primary energy savings achieved by building energy codes from 2010 to 2040 would be 12.82

[233] In the 116th Congress, several bills would have set a new goal for federal agencies to reduce their energy use incrementally by 2.5% each year relative to a 2018 baseline from FY2020 to FY2030, including H.R. 2, H.R. 5650, and S. 1857.

[234] For more information on these HUD and VA programs, see CRS Report R40913, *Renewable Energy and Energy Efficiency Incentives: A Summary of Federal Programs*, by Lynn J. Cunningham CRS Report.

[235] For information on energy tax provisions as it relates to building energy efficiency, see CRS Report R46451, *Energy Tax Provisions Expiring in 2020, 2021, 2022, and 2023 ("Tax Extenders")*, by Molly F. Sherlock, Margot L. Crandall-Hollick, and Donald J. Marples.

[236] For more information on energy efficiency underwriting, see CRS Report R44911, *The Energy Savings and Industrial Competitiveness Act: S. 385 and H.R. 1443*, by Corrie E. Clark.

[237] Alexandra B. Klass, "State Standards for Nationwide Products Revisited: Federalism, Green Building Codes, and Appliance Efficiency Standards," *Harvard Environmental Law Review*, vol. 34 (2010), p. 335.

quadrillion BTU.[238] Those energy savings could reduce utility bills for consumers, with cumulative savings of $126 billion dollars from 2010 to 2040.[239]

Priorities Among Elements of Green Building

Among the elements of green building discussed in this report, energy has generally received more attention than any other.[240] Congress may examine whether federal efforts in green building are effectively balanced among the component elements.

For example, with the all-encompassing effects of the COVID-19 pandemic, Congress may consider whether to address directly the element of health and buildings. Under the Guiding Principles for Sustainable Buildings, all new construction or existing federal buildings must adhere to ASHRAE Standard 55, for thermal comfort, and either Standard 62.1 or Standard 62.2, both for adequate ventilation and indoor air quality, to qualify as sustainable federal buildings. Proper air filtration with the use of high-efficiency particulate air (HEPA) filters is an important element of reducing the risk of indoor infection.[241] Congress may consider whether additional requirements for air filtration would be appropriate or whether energy conservation measures should include additional considerations for indoor air quality.

In addition, Congress may explore whether the incremental approach embodied in most green building activities is sufficient to address national needs, or if some modification or acceleration of efforts would be preferable.

Knowledge Base and Workforce Development

Development of the scientific and technological knowledge base for green building is supported by R&D funded by both federal and private-sector sources.[242]

Congress may consider whether federal funding levels and priorities should be modified, and whether to create incentives for increasing private-sector R&D funding. In addition, Congress may consider whether the availability of training and education relating to relevant areas of expertise is sufficient to ensure a knowledgeable workforce for construction, certification, and operation of both federal green buildings and others, such as schools and hospitals.

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[238] R.A. Athalyte, B. Liu, and D. Sivraman, et al., *Impacts of Model Building Energy Codes*, Pacific Northwest National Laboratory, PNNL-25611 Rev. 1, October 2016, p. v, https://www.energycodes.gov/sites/default/files/documents/Impacts_Of_Model_Energy_Codes.pdf. The United States consumes roughly 100 quadrillion BTU annually.

[239] Ibid. p. v.

[240] This priority is not surprising, given concerns about fossil fuel imports, strategic vulnerability, negative effects of climate change, and the high and inefficient levels of use of energy by most of the current building stock in the United States.

[241] Bolashikov, Z D, and A K Melikov. "Methods for Air Cleaning and Protection of Building Occupants from Airborne Pathogens," *Building and Environment* vol. 44, 7 (2009): 1378-1385. doi:10.1016/j.buildenv.2008.09.001.

[242] According to a 2007 study, green building received less than 0.5% of total funding for federal nondefense R&D; see Mara Baum, "Green Building Research Funding: An Assessment of Current Activity in the United States," U.S. Green Building Council, 2007, https://www.usgbc.org/resources/green-building-research-funding-assessment-current-activity-united-states. According to a 2003 study, construction sector R&D intensity was much lower than the industry average; see Robert Cassidy, ed., "White Paper on Sustainability," Building Design and Construction Supplement, November 2003, p. 48, https://www.bdcnetwork.com/sites/default/files/BD%2BC%202003%20White%20Paper%20on%20Sustainability.pdf.

Special-Use Buildings

Certain building types—so-called special-use buildings—perform essential, but extremely resource-intensive tasks. Some agencies have reported challenges in complying with federal green building requirements due to the number of special-use buildings in their inventories.[243] Special-use buildings including DOE's large number of data centers, laboratories, and accelerators; EPA's scientific laboratories; and the VA's hospitals have all proven challenging to bring into compliance with the Guiding Principles.[244]

Hospitals, for example, are complex to design and must meet substantial regulatory requirements, even before sustainability is taken into account.[245] They are among the most resource-intensive buildings, consuming almost three times as much energy per square foot as a typical office building[246] and posing unique challenges to other elements of green building such as air quality. Hospitals thus offer substantial opportunities for environmental performance improvements, but these must be achieved without compromising their primary mission of improving healthcare outcomes for patients. Some green techniques, such as daylighting and the use of nontoxic building materials, have obvious benefits for health and wellbeing that translate readily to a healthcare environment. Conversely, some energy and water conservation techniques may not be appropriate in a hospital setting, where water heating and flow rates must be tightly controlled for health and safety reasons. Similarly, scientific laboratories and data centers face trade-offs and challenges in implementing energy-saving features without compromising mission-driven building functions that rely on higher-than-average building energy consumption.

Congress may consider whether to make special consideration for special-use buildings, recognizing that they consume a disproportionate amount of energy and resources while performing essential tasks for the federal government. For example, the Energy Act of 2020 (Division Z of P.L. 116-260) requires the Secretary of Energy to develop a utilization metric for data center energy efficiency and the Director of OMB, in coordination with the Secretary, to establish performance goals related to the energy use of information technology used by federal agencies.

[243] GAO, "Federal Green Building: Federal Efforts and Third-Party Certification Help Agencies Implement Key Requirements, but Challenges Remain," GAO-15-667 (July 2015), http://www.gao.gov/assets/680/671618.pdf.

[244] Ibid., pp. 26-27.

[245] Robert F. Carr and WBDG Health Care Subcommittee, "Health Care Facilities," Whole Building Design Guide, April 6, 2017, http://wbdg.org/building-types/health-care-facilities.

[246] EIA, "2012 Commercial Buildings Energy Consumption Survey: Energy Usage Summary," March 18, 2016, https://www.eia.gov/consumption/commercial/reports/2012/energyusage/.

Appendix. Federal Green Building Programs

Several agencies have programs and activities that have a broader focus than reducing the environmental impacts of the facilities of that agency. Several such agencies are discussed below.

General Services Administration

The General Services Administration manages about 425 million square feet of space in over 8,500 buildings, providing workspace for over 1.2 million federal workers.[247] In 2010, the agency announced that it would require all GSA-owned new construction and major renovation projects to be LEED-certified at the Gold level or above.[248] Properties that GSA leases on behalf of another agency may be either LEED or Green Globes certified at the Silver or Two Globes levels, respectively.[249] GSA's Green Proving Ground program conducts evaluations of next-generation building technologies and recommends those that meet agency standards for deployment throughout GSA's property holdings.[250]

Several offices contribute to GSA green building efforts, including the Energy Program, Environment Program, Leasing Program, Office of Design and Construction, and the Office of Federal High-Performance Green Buildings.[251] EISA required GSA to establish the Office of Federal High-Performance Green Buildings to coordinate activities relating to such buildings across federal agencies (42 U.S.C. 17092). The office delivers actionable information to improve building performance and conducts assessments on existing green buildings. It created and maintains the Sustainable Facilities Tool (SF Tool), an interactive website supplying green construction, purchasing, and operations resources and information to federal agencies and other interested parties.[252] Much of the research and recommendations generated by the office's other programs are made available on the SF Tool website. The Facility Management Institute is another GSA initiative intended to assist agencies in improving the operations and management of federal buildings.[253]

GSA has several green-building programs and projects that are the result of collaborations with other agencies and offices. EISA (Sections 433 and 436) directed the Director of the Office of Federal High-Performance Green Buildings to provide recommendations to the Secretary of Energy on rating and certification systems that can be used by agencies for meeting federal green building requirements, based on the results of a study to be conducted by the office every five

[247] GSA, "FY2015 FRPP Open Data Set," May 2016, https://www.gsa.gov/portal/getMediaData?mediaId=132270; GSA, "Strategic Plan: Fiscal Year 2014-2018," July 2014, https://www.gsa.gov/portal/mediaId/187599/fileName/GSA_FY14-18_GSA_Strategic_Plan.action.

[248] GGSA, "GSA Moves to LEED Gold for All New Federal Buildings and Major Renovations" (Press Release, October 28, 2010), https://www.gsa.gov/portal/content/197325.

[249] James C. Wisner, Assistant Commissioner, GSA, "Leasing Alert (LA-FY17-03)—Green Building Rating Certification for New Construction and Tenant Interiors: LEED® and Green Globes," Memorandum to Regional Commissioners, Directors, and Officers (December 13, 2016), https://www.gsa.gov/portal/getMediaData?mediaId=153842.

[250] GSA, "GPG Program," November 2019, https://www.gsa.gov/governmentwide-initiatives/sustainability/emerging-building-technologies/about-gsas-proving-ground-gpg.

[251] For more on GSA's sustainability programs related to buildings, see GSA, "Sustainable GSA: Buildings," 2017, https://gsa.gov/sustainability/#/buildings.

[252] GSA, "Sustainable Facilities Tool," 2017, https://sftool.gov/.

[253] GSA, "Facility Management Institute," May 31, 2017, https://www.gsa.gov/portal/content/160715.

years (42 U.S.C. §6834(a)(3); 42 U.S.C. §17092).[254] The office must also coordinate with DOE on commercial high-performance green building activities under EISA.

GSA and DOE co-chair the Interagency Sustainable Working Group (ISWG), which serves as a forum for information exchange and promotes agency implementation of goals for federal sustainable buildings.[255] GSA participates in climate adaptation planning for buildings as part of the Agency Adaptation Planning Working Group, which is a subgroup in the Interagency Climate Change Task Force. GSA was also a leader in the interagency effort to develop sustainable design principles for the federal government, culminating in the development of the Whole Building Design Guide.[256]

GSA has also collaborated with the Department of Health and Human Services and New York City agencies to develop FITWEL, a voluntary certification program to promote occupant health and wellness through the design of workplaces.[257]

Department of Energy

Most of the external green building activities of the Department of Energy relate to the energy element (see "Elements of Green Building"), through the Building Technologies Office (BTO), the Federal Energy Management Program (FEMP), and the Weatherization and Intergovernmental Programs Office of the Office of Energy Efficiency and Renewable Energy (EERE).[258]

BTO sponsors and performs R&D to improve both commercial and residential energy efficiency. It is also involved in the development of energy codes and enforcement of appliance and equipment standards,[259] transfer of relevant technologies to the marketplace, and integrated design of energy-efficient buildings.

BTO has several notable programs, including:

- Building America[260] is a DOE-building industry R&D partnership focused on a whole-building, integrated approach to improving energy savings in residential buildings.

[254] The act requires the Director to identify a green building certification system that the Director "deems to be most likely to encourage a comprehensive and environmentally sound approach to certification of green buildings." For new construction or major renovation projects, GSA recommends that agencies choose between USGBC's LEED certification system (version 4.0), and GBI's Green Globes certification system (version 2013). For existing buildings, GSA recommends that agencies choose from among five certification systems: Building Owners and Managers Association (BOMA) BEST Sustainable Buildings (version 3.0), BREEAM In-Use USA (version 2016), Green Globes (version 2013), USGBC's LEED (version 4.0), and Living Building Challenge (version 3.1). Letter from Emily W. Murphy, Administrator of GSA, to Rick Perry, Secretary of DOE, September 16, 2019, https://www.gsa.gov/cdnstatic/DOE%20Letter%20(Final%20-%20signed%202019).pdf.

[255] CEQ, Office of Federal Sustainability, *Implementing Instructions for Executive Order 13834 Efficient Federal Operations*, April 2019, p. 40, https://www.sustainability.gov/pdfs/eo13834_instructions.pdf.

[256] GSA, "Sustainability Matters," 2008, https://www.gsa.gov/graphics/pbs/Sustainability_Matters_508.pdf.

[257] GSA, *2016 Strategic Sustainability Performance Plan*, June 30, 2016, https://www.gsa.gov/cdnstatic/GSA_FY_2016_SSPP_Final_Cleared_508.pdf.

[258] DOE, "Building Technologies Office," 2017, https://energy.gov/eere/buildings/building-technologies-office. Also, see other DOE programs, such as Solar Energy Technologies.

[259] For information on DOE enforcement of equipment standards established by EPACT 2005 and other legislation, see DOE, "Appliance and Equipment Standards Program," 2017, https://energy.gov/eere/buildings/appliance-and-equipment-standards-program.

[260] DOE, "Building America: Bringing Building Innovations to Market," 2017, https://energy.gov/eere/buildings/

- The Commercial Buildings Integration program implements initiatives related to energy savings in commercial buildings, including improving building design, accelerating market adoption of high-efficiency technologies, and increasing access to building performance data.[261]
- The Better Buildings Alliance is a public-private partnership that promotes energy efficiency in commercial buildings through collaboration with members of the U.S. commercial building community.[262]
- Energy Star is a joint program between DOE and EPA that uses voluntary labeling to promote energy-efficient products. Zero Energy Ready Home is a recognition program that builds on the requirements of Energy Star and EPA's Indoor airPLUS program to recognize builders that achieve a minimum energy efficiency improvement of 40% over the average new home.[263]
- The Building Performance Database provides public access to data on the energy performance of commercial buildings.[264]

The Federal Energy Management Program assists federal agencies in implementing energy and water management, including the designation required by EPACT 2005 of energy-efficient and water-efficient products for purchase by agencies.[265] FEMP provides assistance with procurement, construction, operations, and maintenance. FEMP and GSA co-chair the ISWG, which serves as a forum for information exchange and promotes agency implementation of goals for federal sustainable buildings.[266] FEMP also collects data and issues reports annually on energy consumption by agencies and on related topics.[267] FEMP was formally authorized by the Energy Act of 2020 (Division Z of P.L. 116-260).

Among other DOE entities, the Energy Information Administration collects and reports on data relating to energy, including that used by buildings, most notably the residential and commercial energy consumption surveys.[268] Some of DOE's national laboratories also perform R&D relating to green buildings. The Advanced Research Projects Agency-Energy (ARPA-E) funds R&D for early-stage energy-related technologies, including several projects focused on developing innovative, energy-efficient heating and cooling systems for buildings.[269]

building-america-bringing-building-innovations-market.

[261] DOE, Building Technologies Office, "Commercial Building Activities," https://www.energy.gov/eere/buildings/commercial-building-activities.

[262] DOE, Better Buildings Initiative, "About the Better Buildings Alliance," *Department of Energy*, 2017, https://betterbuildingssolutioncenter.energy.gov/alliance/about.

[263] DOE, "Guidelines for Participating in the DOE Zero Energy Ready Home," 2017, https://www.energy.gov/eere/buildings/guidelines-participating-doe-zero-energy-ready-home.

[264] DOE, "Building Performance Database," 2017, https://energy.gov/eere/buildings/building-performance-database.

[265] DOE, "Federal Energy Management Program," 2017, https://energy.gov/eere/femp/federal-energy-management-program.

[266] CEQ, Office of Federal Sustainability, *Implementing Instructions for Executive Order 13834 Efficient Federal Operations*, April 2019, p. 40, https://www.sustainability.gov/pdfs/eo13834_instructions.pdf.

[267] DOE, "Federal Facility Reporting Requirements and Performance Data," 2017, https://energy.gov/eere/femp/federal-facility-reporting-requirements-and-performance-data.

[268] See EIA, "Commercial Buildings Energy Consumption Survey (CBECS)," *Department of Energy*, 2017;EIA, "Residential Energy Consumption Survey (RECS)," *Department of Energy*, 2017.

[269] DOE, "ARPA-E Programs," 2017, https://arpa-e.energy.gov/?q=program-listing.

Environmental Protection Agency

The Environmental Protection Agency has a broad range of programs and activities relating to one or more of the main elements of green building. Programs and activities include:

- **Energy.** EPA originated the ENERGY STAR program. The ENERGY STAR Portfolio Manager can be used to measure, track, and benchmark building energy use. The agency's Green Power Partnership supports the procurement of power from renewable resources by government and private-sector organizations.
- **Water.** EPA administers WaterSense, a voluntary labeling program established in 2006 to promote water efficiency. Manufacturers may earn WaterSense labels for their products, and landscape-irrigation professionals can be certified under the program. WaterSense-labelled products and services are independently certified to be at least 20% more water efficient than average.[270] The Green Infrastructure Collaborative and related activities promote community adoption of green infrastructure, a stormwater management approach that uses vegetation, soils, permeable pavements, and other practices to reduce stormwater runoff and maintain or restore natural water filtration and storage in built environments.[271]
- **Materials and Waste.** The Sustainable Materials Management (SMM)[272] program encourages a life-cycle materials management approach that seeks to reduce environmental and human health impacts associated with materials use, from extraction to disposal. SMM provides resources for governments and businesses on assessing and reducing material use, purchasing recycled materials, and increasing recycling and reuse of construction and demolition materials. SMM programs include WasteWise, a public/private partnership in which participants set goals and report progress on preventing waste, expanding recycling, and increasing purchasing of recycled materials; and the Federal Green Challenge, which encourages government agencies to reduce their waste footprint and water usage, among other goals.

  The Environmentally Preferable Purchasing (EPP) Program[273] assists federal agencies in meeting green purchasing requirements. The Comprehensive Procurement Guideline program identifies recycled products that comply with RCRA requirements.[274]
- **Health.** EPA supports activities such as R&D and awards programs to develop safer and more environmentally friendly chemicals, including "green chemistry" technologies. The Indoor Air Quality Program provides information and tools to ensure the protection of indoor environmental quality in schools, residences, and commercial buildings. Indoor airPLUS is a voluntary partnership and labeling program that specifies minimum air quality design features for homes.

[270] EPA, "About WaterSense," https://www.epa.gov/watersense/about-watersense.

[271] EPA, "Green Infrastructure Collaborative," January 13, 2017,https://www.epa.gov/green-infrastructure/green-infrastructure-collaborative.

[272] EPA, "Sustainable Materials Management," July 25, 2017, https://www.epa.gov/smm.

[273] EPA, "About the Environmentally Preferable Purchasing Program," March 23, 2017, https://www.epa.gov/greenerproducts/about-environmentally-preferable-purchasing-program.

[274] EPA, "Comprehensive Procurement Guideline (CPG) Program," 2017,https://www.epa.gov/smm/comprehensive-procurement-guideline-cpg-program.

- **Siting.** The Smart Location Database[275] is a nationwide geographic data resource that measures neighborhood characteristics such as housing density, neighborhood design, and transit accessibility to produce a measurement of a location's siting efficiency.[276] The agency also has a variety of programs and activities relating to smart growth and sustainability.

EPA has also published resources on implementing green building policies for local governments and tribal communities.[277]

Department of Defense

The Department of Defense has the largest building footprint in the federal government, with a portfolio that contains more than 279,000 buildings covering approximately 2.3 billion square feet and located across thousands of sites worldwide.[278]

DOD issues its own requirements for department-owned buildings and facilities under the Unified Facilities Criteria (UFC) program.[279] UFC documents contain technical criteria and standards relating to the planning, design, construction, operations, and maintenance of DOD facilities.[280] Two recently issued UFC documents contain requirements relating to green building:

- **UFC 1-200-02** ***High Performance and Sustainable Building Requirements*** (2020) provides guidance toward complying with the minimum building requirements for federal buildings established by EISA, EPACT 2005, the Guiding Principles, and E.O. 13693. All new construction and major renovations must comply with these criteria.
- **UFC 3-210-10** ***Low Impact Development*** (2020) provides guidance for complying with EISA provisions governing stormwater management by using low-impact development (LID) techniques aimed at infiltrating and storing stormwater in order to restore site hydrology and mitigate adverse effects of runoff.[281]

Some of the DOD service branches have created their own branch-wide green building goals and initiatives. The Army issued a directive in 2014, expanding a Net Zero Installations pilot project into an Army-wide initiative.[282] The Air Force uses Sustainability Development Indicators to

[275] The Smart Location Calculator was developed with assistance from GSA (GSA, *2016 Strategic Sustainability Performance Plan*, June 30, 2016, https://www.gsa.gov/cdnstatic/GSA_FY_2016_SSPP_Final_Cleared_508.pdf).

[276] EPA, "Smart Location Mapping," April 20, 2017, https://www.epa.gov/smartgrowth/smart-location-mapping.

[277] EPA, "Location and Green Building," March 29, 2017, https://www.epa.gov/smartgrowth/location-and-green-building.

[278] DOD, "Base Structure Report Fiscal Year 2018 Baseline," https://www.acq.osd.mil/eie/Downloads/BSI/Base%20Structure%20Report%20FY18.pdf.

[279] John Conger, Acting Deputy Under Secretary of Defense for Installations and Environment, "Department of Defense Sustainable Buildings Policy," Memorandum to Assistant Secretaries and Directors (November 10, 2013), memorandum, http://www.usace.army.mil/Portals/2/docs/Sustainability/Hydrology_LID/DoD_Sustainable_Buildings_Policy_(10%20Nov%202013).pdf.

[280] Whole Building Design Guide, "Department of Defense: Unified Facilities Criteria Program," 2017, https://www.wbdg.org/ffc/dod/.

[281] DOD, "United Facilities Criteria (UFC): Low Impact Development," UFC 3 210-10 (March 1, 2020), https://www.wbdg.org/FFC/DOD/UFC/ufc_3_210_10_2015_c3.pdf.

[282] John M. McHugh, Secretary of the Army, "Army Directive 2014-02 (Net Zero Installations Policy)," Memorandum for SEE Distribution (January 28, 2014), http://www.asaie.army.mil/Public/ES/doc/Army%20Directive%202014-

ensure that installation development plans consider a wide range of environmental impact areas and performance elements.[283]

In December 2016, DOD and EPA signed a Memorandum of Understanding listing goals to work together to implement sustainable and resilient military installations, promote a sustainable and resilient natural and built infrastructure, and to engage DOD installations as test beds for innovative technologies.[284]

Office of Federal Sustainability

The position of Federal Chief Sustainability Officer was originally established under the title of the Federal Environmental Executive in 1993 by Executive Order 12873.[285] Executive Orders 13423, 13693, and 13834 broadened that position to include an Office of the Federal Environmental Executive in the CEQ, later renamed the Office of the Chief Sustainability Officer, and extended the duties to include assisting and monitoring the implementation by agencies of the order, including its green building requirements, and advising the Council on Environmental Quality.[286]

National Institute of Standards and Technology

The green building efforts of the National Institute of Standards and Technology are housed in NIST's Engineering Laboratory.[287] The Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure Program focuses on improvements in measurement science and data relating especially to intelligent building systems, sustainably engineered materials, and achieving net-zero energy buildings with high indoor air quality.

A component of this program is the Net-Zero Energy High-Performance Buildings Program, which is focused on developing building metrics for overall building sustainability and reducing building energy usage through improvements in specific component areas.[288] The Net-Zero Energy Residential Test Facility (NZERTF), developed under this program, is a laboratory and demonstration facility dedicated to the development of measurement science needed to achieve net-zero energy homes.[289] NIST has also developed Building for Environmental and Economic

02%20(NZ%20Policy).pdf.

[283] DOD, "Strategic Sustainability Performance Plan FY2016."

[284] DOD and EPA, "Memorandum of Understanding Between the Office of the Assistant Secretary of Defense for Energy, Installations and Environment and the U.S. Environmental Protection Agency Office of Research and Development, Office of Policy," February 2017, http://www.denix.osd.mil/sustainability/home/success/epa-and-dod-sign-mou/.

[285] Executive Order 12873, Federal Acquisition, Recycling, and Waste Prevention, October 20, 1993, https://www.archives.gov/files/federal-register/executive-orders/pdf/12873.pdf.

[286] Per Executive Order 13834, EPA is directed to provide funding to the Council of Environmental Quality through the Office of Environmental Quality Management Fund. Executive Order E.O. 13834, "Efficient Federal Operations," 83 *Federal Register* 23771, May 17, 2018, https://www.federalregister.gov/documents/2018/05/22/2018-11101/efficient-federal-operations.

[287] NIST, "About EL," *NIST*, September 26, 2016, https://www.nist.gov/el/about-el.

[288] NIST, "Net-Zero Energy, High-Performance Buildings Program," July 17, 2017, https://www.nist.gov/programs-projects/net-zero-energy-high-performance-buildings-program.

[289] NIST, "Net-Zero Energy Residential Test Facility," July 23, 2013, https://www.nist.gov/sites/default/files/documents/2017/04/28/netzerofinal.pdf; National Institute of Standards and Technology, "Net-Zero Energy Residential Test Facility (NZERTF)," June 1, 2016, https://www.nist.gov/el/net-zero-energy-residential-test-facility.

Sustainability (BEES),[290] a software tool that uses life-cycle assessment methods to facilitate the selection of environmentally preferable building products.

NIST has also helped to add resources on climate resiliency for buildings to the U.S. Climate Resilience Toolkit,[291] through participation in the Community Resilience Panel for Buildings and Infrastructure Systems, which it cosponsors.[292]

Department of Housing and Urban Development

The Department of Housing and Urban Development administers several mortgage insurance and home-financing programs that contain provisions intended to encourage the adoption of green building elements in public housing.[293] As an incentive for multifamily properties owned by participants of DOE's Better Buildings Challenge, the Office of Multifamily Housing Programs established a Management Add-On Fee incentive to address potential market and policy barriers to owners to "green" their properties.[294] HUD has identified four categories of applicable add-on fees: operations and maintenance, tenant engagement, data collection, and benchmarking. The add-on fee incentive is intended to help owners of HUD-insured and HUD-assisted properties who are participants of the Better Buildings Challenge to pay for the additional cost of energy and water efficiency improvements.[295] The Federal Housing Administration (FHA) administers the Energy Efficient Mortgage Program, a program intended to enable homeowners and buyers to finance the cost of energy-efficiency improvements through their FHA-insured mortgage.[296] The Public Housing Capital Fund and the Public Housing Operating Fund provide funding to Public Housing Agencies that may be used to make energy and water efficiency improvements.[297] In addition, energy performance contracting—which uses the cost savings from reduced energy consumption to repay the cost of implementing energy and water conservation measures—is available for public housing.[298]

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[290] NIST, "BEES," December 23, 2016, https://www.nist.gov/services-resources/software/bees.

[291] United States Global Change Research Program, "U.S. Climate Resilience Toolkit," May 17, 2015, https://toolkit.climate.gov/content/about.

[292] Other cosponsors include EPA, HUD's Office of Economic Resilience, Federal Emergency Management Agency, and the Department of Homeland Security's Office of Infrastructure Protection.

[293] In addition to these, several HUD initiatives have been short-term and have concluded. These initiatives include a budget neutral demonstration program for energy and water conservation improvements at multifamily residential units, which was active through FY2019 (Sec. 81001 of Fixing America's Surface Transportation (FAST) Act, P.L. 114-94); the Multifamily Energy Innovation Fund, which was available through FY2013 (Consolidated Appropriations Act, 2010, P.L. 111-117); and the Green Retrofit Program for HUD multifamily housing, which was funded through the American Recovery and Reinvestment Act of 2009, P.L. 111-5.

[294] HUD and DOE expanded the Better Buildings Challenge (BBC) in December 2013 to include multifamily buildings; HUD, "Moving to the Next Level: Progress Report and Energy Update Report," *Report to Congress Section 154, Energy Policy Act of 2005*, August 2016, p. 24, https://www.hud.gov/sites/documents/ReporttoCong8-9-16.pdf.

[295] HUD, "Multifamily Better Buildings Challenge Incentive: Allowable Management Add-On Fees Revised," memorandum, September 19, 2014, https://www.hud.gov/sites/documents/BBC_REVISION.PDF.

[296] For more on the Energy Efficient Mortgage Program, see HUD, "Energy Efficient Mortgage Program," 2017, https://portal.hud.gov/hudportal/HUD?src=/program_offices/housing/sfh/eem/energy-r. In addition, FHA includes guidance regarding accounting for energy efficiency improvements in appraisals and FHA-insured loan qualifications, see FHA, *Single Family Housing Policy Handbook*, v. 4000.1, August 2019, pp. 332 and 600, https://www.hud.gov/sites/dfiles/OCHCO/documents/4000.1hsgh.pdf.

[297] See HUD, "Public Housing Programs," 2017, https://portal.hud.gov/hudportal/HUD?src=/program_offices/public_indian_housing/programs/ph/programs.

[298] See HUD, "Energy Performance Contracting," https://www.hud.gov/program_offices/public_indian_housing/programs/ph/phecc/eperformance. For more information on energy savings performance contracts in the federal

government generally, see CRS Report R45411, Energy Savings Performance Contracts (ESPCs) and Utility Energy Service Contracts (UESCs), by Corrie E. Clark.

HUD also administers the Lead Hazard Control and Healthy Homes Program, which conducts research and provides grants to reduce home health hazards relating to lead-based paint, exposure to mold, moisture, poor indoor air quality, pesticides, dust, and other substances that contribute to poor health outcomes.[299] The FY2020 appropriations law set aside $5 million from the Healthy Homes Initiative to provide grants in up to five communities "to demonstrate whether the coordination of Healthy Homes remediation activities with weatherization activities achieves cost savings and better outcomes in improving the safety and quality of homes."[300] HUD released a notice of funding availability (NOFA) for the Healthy Homes and Weatherization Cooperation Demonstration in September 2020.[301]

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Disclaimer

[299] HUD, "Office of Lead Hazard Control and Healthy Homes (OLHCHH)," 2017, https://portal.hud.gov/hudportal/HUD?src=/program_offices/healthy_homes.

[300] P.L. 116-94; 113 Stat. 2998.

[301] HUD, *FY2020 Healthy Homes and Weatherization Cooperation Demonstration Program NOFA*, available at https://www.hud.gov/sites/dfiles/SPM/documents/Foa_Content_of_FR-6400-N-62.pdf.