Issues in Green Building and the Federal Response: An Introduction

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Summary

The construction, characteristics, operation, and demolition of buildings are increasingly recognized as a major source of environmental impact. Without significant transformation of building construction and operations, such impacts are 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. However, the term is used differently by different proponents and practitioners, denoting a continuum of practices, from those differing minimally from standard practices, to those aimed at providing buildings with a minimum of environmental impact.

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. 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.

Green building has received substantial attention from government, industry, and public interest groups. Several federal laws, executive orders, and other policy instruments have provisions relating to green building. Among these are the energy policy acts (EPACT) 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), and Executive Orders 13423 and 13514. EISA and other policy instruments require all federal agencies to implement green building practices. However, several agencies have programs and activities that have a broader focus than the facilities of that agency. Among them are the General Services Administration, Department of Energy, Environmental Protection Agency, the Office of the Federal Environmental Executive, the National Institute of Standards and Technology, and the Department of Housing and Urban Development.

Green building raises issues relating to performance, cost, market penetration, and the approach itself. Among the questions Congress and the Obama Administration 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 impact of human activity has been a source of controversy and concern for decades. 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 several years, however, concerns have increased greatly about greenhouse gases, resource depletion, and degradation of ecological services such as water supply.

The construction, characteristics, operation, and demolition of buildings are increasingly recognized as a major source of environmental impact, including direct effects on humans:

- Buildings account for about a third of energy consumption world-wide, and 40% in the United States, with residential buildings contributing slightly more than half of that percentage.[1] From 1980 to 2006, total building energy consumption in the United States increased more than 46%. Whether such growth rates will continue in the future is uncertain.[2]
- Use of water by buildings in the United States grew by more than 26% between 1985 and 2005.[3] Such increases in water use are occurring in the context of stresses to the water supply caused by recent droughts and growing concerns about drying trends in the climates of western states.[4]
- Building demolition and construction accounted for 60% of nonindustrial waste tonnage in the United States in 1996, with about one-fourth recovered through processing or recycling.[5]
- Buildings produce almost 40% of carbon dioxide emissions in the United States, with a projected increase in such emissions of more than 1% per year through 2030.[6]
- Some characteristics of buildings are known to affect several aspects of human health and productivity, such as the incidence of allergies and respiratory illness. Most people spend far more time inside buildings than outside, and the air in buildings often has substantially higher concentrations of pollutants than the air outside.[7] "Sick building syndrome" has been estimated to affect as much as a

[1] National Science and Technology Council, "Federal R&D Agenda for Net-Zero Energy, High-Performance Green Buildings," October 2008, http://www.whitehouse.gov/files/documents/ostp/NSTC%20Reports/Federal%20RD%20Agenda%20for%20Net%20Zero%20Energy%20High%20Performance%20Green%20Buildings%20Oct2008.pdf.

[2] Department of Energy, *2009 Buildings Energy Data Book*, November 2009, http://buildingsdatabook.eren.doe.gov/docs%5CDataBooks%5C2009_BEDB_Updated.pdf. The projected growth rate depends on the success of actions to reduce building energy use Department of Energy, *Annual Energy Outlook 2010*, DOE/EIA-0380(2010), April 2010, http://www.eia.doe.gov/oiaf/aeo/pdf/0383%282010%29.pdf.

[3] Department of Energy, *2009 Buildings Energy Data Book.*

[4] CRS Report RL34580, *Drought in the United States: Causes and Issues for Congress*, by Peter Folger, Betsy A. Cody, and Nicole T. Carter.

[5] Environmental Protection Agency, *Buildings and the Environment: A Statistical Summary*, December 20, 2004, http://www.epa.gov/greenbuilding/pubs/gbstats.pdf.

[6] Department of Energy, *2009 Buildings Energy Data Book.*

[7] Environmental Protection Agency, *Healthy Buildings, Healthy People: A Vision for the 21st Century*, October 2001, http://www.epa.gov/iaq/hbhp/hbhp_report.pdf. Mara Baum, *Green Building Research Funding: An Assessment of* (continued...)

quarter of office workers. Temperature and lighting have been found to have significant effects on worker performance.[8]

- Buildings and the built environment[9] with which they are associated create impermeable surfaces that have substantial impacts on storm-water management, resulting in greatly increased run-off, decreased natural water storage, and increased pollution.[10]
- The location of a building can have significant transportation and ecological impacts. For example, if an organization constructs a new green building for its offices, but chooses a location with no access to public transportation, the additional energy required for transportation by private vehicle may exceed energy savings from the operation of the building itself.[11]

Without significant transformation of building construction and operations, such impacts are expected to increase with population growth and changes in other demographic and economic factors. One significant tool in efforts to achieve the desired transformation is *green building.* While it is widely considered desirable, the concept is used in a variety of different ways, and its application also raises concerns about actual performance, cost, and the sufficiency of the approach to solve the problems it is intended to address.

This report discusses what the concept of green building means, major federal policies and programs relating to green building, and associated issues, including some that may confront the 111th Congress.

What Is Green Building?

Environmentally sensitive building is not a particularly recent phenomenon,[12] 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),[13] followed within a few years by the founding of the U.S. Green Building Council (USGBC)[14] and other organizations. The most prominent federal green building project

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Current Activity in the United States (U.S. Green Building Council, 2007), http://www.usgbc.org/ShowFile.aspx?DocumentID=2465.

[8] William J. Fisk, "How IEQ affects health, productivity," *ASHRAE Journal* 44, no. 5 (May 2002): 56.

[9] The buildings, infrastructure, and related artefacts created by humans are known collectively as the built environment.

[10] See, for example, National Research Council, *Urban Stormwater Management in the United States* (Washington, DC: National Academy Press, 2008), http://www.nap.edu/catalog.php?record_id=12465.

[11] Alex Wilson and Rachel Navaro, "Driving to Green Buildings.," *Environmental Building News* 16, no. 9 (2007): 1-18.

[12] For a brief history, see, for example, Robert Cassidy and others, "White Paper on Sustainability," *Building Design & Construction* Supplement (November 2003): 48 p., http://www.usgbc.org/Docs/Resources/BDCWhitePaperR2.pdf.

[13] American Institute of Architects, "AIA/COTE: A History Within a Movement," 2008, http://www.aia.org/practicing/groups/kc/AIAS077347.

[14] 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 (http://www.sbicouncil.org), a trade association, also became involved in green building in the 1990s. The international World Green Building Council (http://www.worldgbc.org) was founded several years later, in 1999. That organization (continued...)

in that decade was the "Greening of the White House."[15] The subsequent growth and diversity of the green building movement in the United States and other countries has led to some uncertainty in characterizing what green building actually is.[16] Different proponents and practitioners use the term to denote various practices along a 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."

Other practitioners aim to provide buildings with drastically reduced environmental impact. The extreme approach at this end of the scale is the so-called "zero-impact" building, which is intended to have no net environmental impact, including but not limited to zero net energy use;[17] or even a "minus-impact" building, which would provide a net environmental benefit.

In general, ***green building*** **might best be characterized succinctly as integrated building practices that significantly reduce 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.[18]

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. Second, it is not limited to only one factor, such as energy consumption, but involves integration across several, as is discussed below.[19]

While green building is often used interchangeably with *sustainable building* and related terms, the latter may be better thought of as a form of green building, but with a more stringent goal of buildings that will indefinitely maintain environmental footprints that are small enough that they will not impede future human activity and the functioning of ecosystems.[20]

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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.

[15] See The White House, "Greening of the White House," n.d., http://clinton4.nara.gov/Initiatives/Climate/WHgreening.html.

[16] The U.S. Green Building Council, arguably the leading proponent of green building in the United States, does not formally define the concept of green building, relying instead on descriptions of its building rating program.

[17] A zero-net-energy building (also called a net-zero-energy building) produces as much energy from renewable sources such as solar power as it consumes.

[18] See, for example, Commission for Environmental Cooperation, "Green Building in North America," 2008, http://www.cec.org/greenbuilding. 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*, http://ec.europa.eu/environment/natres/studies.htm), and *carbon footprint*, which can be characterized as the net amount of greenhouse gases being produced as a result of an activity.

[19] For a more in-depth discussion of these points, see CRS Report R41197, *Green Procurement: Overview and Issues for Congress*, by Eric A. Fischer.

[20] These characterizations draw most heavily on descriptions in some documents from the Building Science Corporation (http://www.buildingscience.com/index_html; see text box on page 6). Some observers may argue for other characterizations of "sustainable building," such as "zero-impact." See discussion on "Approach".

Another term often used interchangeably with green building is *high-performance building.* However, high-performance building usually involves factors such as cost 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,[21]

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.[22]

Additional objectives may also be considered in the design of high-performance buildings, including aesthetics and historical preservation.[23]

The Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) further refined the concept by establishing a detailed definition for *high-performance green buildings*. (See text box on p. 6).

Descriptions of green building generally focus on a number of common elements, especially energy, water, materials, waste, and health.[24] Siting is also a common element, particularly with respect to transportation, ecology, and smart growth.[25] The siting element is increasing in prominence as more attention is focused on the built environment beyond the building itself. Most descriptions do not explicitly discuss serviceability or the related elements of productivity and functionality, but that may be because those are assumed to be integral elements of any building design. However, they are included explicitly among the objectives for high-performance buildings. Other elements, such as disaster resistance, may also be considered. This objective has also risen in prominence in the wake of the terrorist attacks of 2001, Hurricane Katrina, and other disasters.

[21] § 914(a), P.L. 109-58.

[22] § 401(12), P.L. 110-140.

[23] Whole Building Design Guide, "Whole Building Design," 2010, http://www.wbdg.org/wbdg_approach.php.

[24] 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," August 25, 2008, http://www.epa.gov/greenbuilding/pubs/components.htm). The Cascadia Region Green Building Council has developed a "living building challenge" with six "performance areas": site, energy, materials, water, indoor quality, and beauty plus inspiration (Cascadia Region Green Building Council, *The Living Building Challenge*, August 2008, http://www.cascadiagbc.org/lbc).

[25] Smart growth is defined differently by different organizations, but the various definitions have in 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*, January 2001, http://www.epa.gov/dced/pdf/built.pdf.

Energy

A reduced energy footprint is probably the most widely cited element of green building.[26] Goals include

- energy efficiency and curtailment, through such means as energy-efficient appliances and lighting, and weatherization; and
- use of alternative, renewable sources of energy, such as solar or geothermal power or combustion of biomass.

Energy is widely considered a crucial element because of the economic costs and environmental impacts associated with energy use. Costs are of growing concern because of uncertainties about fossil-fuel supplies and other factors. Pollution-related concerns include not only health effects but potential contributions to global warming. According to one study, the greatest opportunity to reduce energy demand globally is by improving energy use in residential buildings, through currently available technology.[27]

Federal law sets numeric requirements for reductions in energy use by federal buildings.[28] The total energy consumption by such buildings declined by more than 10% between 1998 and 2005. Nevertheless, 2005 consumption slightly exceeded the federal goal.[29]

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.[30]

[26] See, for example, Building Science Corporation, *Towards Sustainability—Green Building, Sustainability Objectives, and Building America Whole House Systems*, Research Report, February 2008, http://www.buildingscience.com/documents/reports/rr-0801-towards-sustainability2014green-building-sustainability-objectives-and-building-america-whole-house-systems-research. 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.

[27] Florian Bressard et al., *Curbing Global Energy Demand Growth: The Energy Productivity Opportunity* (McKinsey Global Institute, May 2007), http://www.mckinsey.com/mgi/reports/pdfs/Curbing_Global_Energy/MGI_Curbing_Global_Energy_full_report.pdf. The study refers specifically to energy productivity, defined as the level of economic output achieved per unit of consumed energy. That is the inverse of energy intensity, which is energy input per dollar of economic output.

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

[29] The energy consumption in FY1998 was 0.72 quadrillion BTU, or quads (Department of Energy, *2000 BTS Core Databook*, August 7, 2000, http://buildingsdatabook.eren.doe.gov/docs%5CDataBooks%5C2000_BEDB.pdf). In FY2005 it was 0.65 quads (Department of Energy, *2009 Buildings Energy Data Book*), 600 BTU per square foot higher than the goal set by Executive Order 13123, "Greening the Government Through Efficient Energy Management," *Federal Register* 64, no. 109 (June 8, 1999): 30581-30860.

[30] See, for example, Wilson and Navaro, "Driving to Green Buildings," for an example of other impacts potentially outweighing savings from energy efficiency.

Definitions of Green Building

Green building, green architecture, sustainable building, high-performance building, and low-impact development are among the terms used to denote practices that reduce the environmental impact of components of the built environment. In the absence of a common consensus usage, a comparison of different terms and interpretations may be useful:

Energy Independence and Security Act of 2007 (P.L. 110-140):

The term "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;
(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.

> **Note:** This is the only definition in federal law and therefore should be broadly applicable to federal efforts. However, its applicability may be somewhat limited in that it refers specifically to high-performance green buildings rather than green buildings in general.

Environmental Protection Agency:

Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high performance building.

Office of the Federal Environmental Executive:

Green building [is] the practice of (1) increasing the efficiency with which buildings and their sites use energy, water, and materials, and (2) reducing building impacts on human health and the environment, through better siting, design, construction, operation, maintenance, and removal—the complete building life cycle.

Sustainable Buildings Industry Council:

A sustainable building is one in which the site, design, construction, occupancy, maintenance, and deconstruction of the building are accounted for in ways that promote energy, water, and material efficiencies, while providing healthy, productive, and comfortable indoor environments and long-term benefits to owners, occupants, and society as a whole.

Building Science Corporation:

'Green building' is a label for the process of design and construction which aims to produce buildings that are less damaging to the environment—and the people that use them—than most buildings currently built today. [It] focuses on incremental steps to solve known and measurable problems with ... current practice.

'Sustainable building' ... refers more precisely to the goal of designing and constructing buildings that have no net impact on the environment, such that a total built environment composed of similar buildings could co-exist with the world's ecological balance indefinitely. [It] seeks models for an unidentified future state of society.

King County, Washington:

Green building, or sustainable building, is defined by King County as design, construction and operation practices that significantly reduce resource consumption and environmental impacts through sustainable site planning, energy efficiency, water

conservation, waste minimization, pollution prevention, using resource-efficient materials, [and]providing enhanced indoor environmental quality for occupants.

Low Impact Development (LID) is an approach to land development that focuses on how water enters a site, is stored on-site, and leaves a site. Land development that incorporates LID practices minimizes impervious surface, protects and enhances native vegetation and soils, and manages stormwater at its source.

Sources: Environmental Protection Agency, "Green Building: Basic Information," April 18, 2008, http://www.epa.gov/greenbuilding/pubs/about.htm.

Office of the Federal Environmental Executive," The Federal Commitment to Green Building: Experiences and Expectations," 2003, http://www.epa.gov/greenbuilding/pdf/2010_fed_gb_report.pdf.

P.L. 110-140, §401(13).

Sustainable Buildings Industry Council, "What is Sustainability? What is Beyond Green? What is a High-Performance Building?" 2008, http://www.sbicouncil.org/displaycommon.cfm?an=1&subarticlenbr=124.

Building Science Corporation, Towards Sustainability: Green Building, Sustainability Objectives, and Building America Whole House Systems, Research Report (Building Science Corporation, February 2008), p.4, http://www.buildingscience.com/documents/reports/rr-0801-towards-sustainability2014green-building-sustainability-objectives-and-building-america-whole-house-systems-research/view?searchterm=rr-0801.

King County Department of Development and Environmental Services, "Green Building & Low Impact Development: Frequently Asked Questions," Bulletin 55, May 15, 2008, http://www.kingcounty.gov/property/permits/publications/~/media/property/permits/documents/bulletins/55.ashx.

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.[31] Reductions can be achieved through such measures as reduced-flow plumbing fixtures,[32] recycling of wastewater,[33] and landscaping designed to reduce irrigation requirements.

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 storm water where it is generated."[34] Among the methods used are reduction in impervious surfaces through landscaping, use of porous materials, green roofs (see text box on page 9), and so forth; and use of holding ponds, swales, rain gardens, and similar measures.

[31] See CRS Report RL34580, *Drought in the United States: Causes and Issues for Congress*.

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

[33] 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.

[34] Whole Building Design Guide, "Low Impact Development Technologies," May 16, 2008, http://www.wbdg.org/resources/lidtech.php. Low-impact building is sometimes used as a synonym for low-impact development and sometimes as a synonym for green or sustainable building.

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,[35] and health. "Environmentally preferable" or "green" 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.[36] They may also be designed to reduce health risks such as those from volatile organic compounds (VOCs) such as formaldehyde.

Waste

The environmental impact of waste from standard demolition and construction processes can be reduced through more efficient use of materials and recycling of waste products.[37] Landscaping can be planned to reduce or eliminate chemical pollutants from grounds maintenance and to recycle waste such as lawn clippings through mulching and composting. High-efficiency boilers and furnaces can reduce the production of many atmospheric pollutants. Operational solid waste such as paper and foodstuffs can be recycled or otherwise processed to reduce their environmental impact.

Health

Several factors can influence the health impacts of buildings. For some, the health effects are obvious, such as use of materials without heavy metals, VOCs, asbestos,[38] or other potentially toxic substances. However, other factors, such as lighting, climate control, and ergonomic design, can also have significant impacts on the health of building occupants.[39]

Siting

Where a building is situated can have significant effects on its environmental footprint.[40] For example, siting of buildings near transportation hubs can facilitate the use of public transportation

[35] *Embodied energy* can be defined as "the energy used during the entire life cycle of a product including the energy used for manufacturing, transporting, and disposing of the product" (Department of Energy, *2008 Buildings Energy Data Book*).

[36] EPA has developed guidance for obtaining such products, including a database of specifications and products that meet them (see Environmental Protection Agency, "Environmentally Preferable Purchasing (EPP)," November 7, 2007, http://www.epa.gov/epp).

[37] Environmental Protection Agency, "Construction and Demolition Materials," January 7, 2009, http://www.epa.gov/epawaste/conserve/rrr/imr/cdm/index.htm.

[38] Asbestos is present in many older buildings and is still used in some construction materials (Environmental Protection Agency, "Asbestos in Products and Buildings," December 10, 2008, http://www.epa.gov/asbestos//pubs/pubs.html).

[39] Environmental Protection Agency, "Green Indoor Environments," October 14, 2008, http://www.epa.gov/iaq/greenbuilding/.

[40] Whole Building Design Guide, "Optimize Site Potential," October 13, 2008, http://www.wbdg.org/design/site_potential.php.

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[41] and native species of plants and animals. The orientation of building axes and surfaces, and the building's proximity to trees and other plantings, affect its heating and cooling requirements (see text box on page 12).

Green and Cool Roofs

The use of extensive plantings on rooftops, called "green roofs," is one way to reach some of the goals of green building. The practice appears to be more common in Europe than in the United States. Proponents cite several benefits:

Increased roof longevity. Plantings can help insulate an impervious roof membrane from the deleterious effects of the elements, such as sun, wind, and ice, thereby increasing the useful life of the membrane.

Energy savings. The plantings serve as an insulating barrier, thereby reducing energy required for heating and cooling.

Other benefits. Plantings may provide benefits in stormwater management, recycling of wastewater, and provision of social amenities, if the roof is accessible to building occupants.

Potential disadvantages of green roofs include the following:

Cost. The installation cost of a green roof may be twice that of a conventional roof but will vary with several factors, including the kinds of plantings and other features chosen.

Maintenance. Green roofs will require maintenance similar to other plantings. For example, they may require watering, if local rainfall is insufficient.

Damage from plants. Improper design or implementation might lead to problems such as leakage of water into the building or root penetration into the roof structure.

Feasibility. The roof structure must be sufficiently strong and intact to support the weight of the plantings, and must meet other structural requirements. Also, green roofs do not appear to be generally feasible on steeply sloped roofs and are usually found on flat or gently sloped rooftops.

Cool or reflective roofs are those made with materials that reflect light rather than absorbing it. Usually those materials are lighter in color than typical roofing materials, and their use reduces the amount of heat created from solar radiation striking the roof. Cool roofs can be less expensive and easier to install and maintain than green roofs, but their potential benefits are more limited than green roofs.

Since green and cool roofs are used on building structures, specific guidelines and standards are available for them. The LEED rating system developed by the U.S. Green Building Council (see p. 11) includes optional credits for such roofs.

Source: Green Roofs for Healthy Cities, "About Green Roofs," December 8, 2009, http://www.greenroofs.org/index.php/about-green-roofs; Environmental Protection Agency, "Cool Roofs," September 16, 2009, http://www.epa.gov/heatisld/mitigation/coolroofs.htm; Bryan Urban and Kurt Roth, *Guidelines for Selecting Cool Roofs* (Department of Energy, July 2010).

Serviceability

A building that is not useful to its occupants is unlikely to be worth its cost, no matter how much less an environmental footprint it has than other buildings. Therefore, productivity and other measures of utility comprise an important element of green building. Some evidence exists that

[41] Potential sites may provide services before development 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.

green buildings can lead to improved productivity among occupants.[42] While this element is not generally considered as a separate element in green-building design (see, for example, **Table 1**), it is explicitly identified as an objective for high-performance buildings.

Disaster Resistance

Resistance to hazards such as earthquakes, hurricanes, flooding, subsidence, and forest fires can increase the useful life of a building and permit it to function when services such as transportation and utilities are not available. Efforts may include approaches such as resistant construction and on-site power generation, such as through photovoltaic and wind-turbine technology, and water recycling capabilities.

Integration

One of the most salient features of green building is integration. Although the elements described above could be and often are addressed separately for each stage in a building's life cycle, the green building approach focuses on how the set of elements affects the environmental footprint of a building throughout its life cycle, from site selection, initial design, and construction, to operations during the building's useful life, through eventual demolition and its aftermath.[43]

This approach, with its focus 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.

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.[44] 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.

[42] Greg Kats, *The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force* (Sustainable Building Task Force, October 2003), http://www.usgbc.org/Docs/News/News477.pdf.

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

[44] See, for example, Building Science Corporation, "Building Science Digests," n.d., http://www.buildingscience.com/doctypes/digest. 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.

Balance Across Stages

A focus on only 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. Thus, 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.[45] A green building approach can reduce such problems by facilitating an assessment of the impact from actions at one stage on all the others.

Interdependence

Many factors are also clearly interdependent. For example, use of environmentally preferable products can affect occupant health, which in turn can affect productivity. A zero-net-energy building may be well-prepared to function during periods when power is unavailable from utilities, such as after a natural disaster. On-site stormwater management can facilitate the provision of ecological services.

Leadership in Energy and Environmental Design (LEED)

The relationships among the various elements of green building, and the lack of a single, readily apparent metric for determining how well a building conforms, among other factors, have led to the development of rating and certification systems used to assess how well a building meets green criteria. The best known system within the United States is Leadership in Energy and Environmental Design (LEED), developed by the U.S. Green Building Council (USGBC), with support from the federal government and other sources.

LEED is a consensus-based certification system focusing on seven green building elements: site, water, energy, materials, indoor environment, innovation, and regional environmental priorities.[46] There are separate LEED rating systems for several different building categories: new commercial construction, existing buildings, homes, schools, and others.

LEED provides third-party certification to one of four levels (certified, silver, gold, and platinum). It therefore permits a building to be labeled as environmentally superior to others and in that way is analogous to environmental labeling programs such as the federal Energy Star program (see text box on p. 28).

To be certified, a building must meet a set of mandatory basic requirements for most elements[47] and must also receive a designated number of the total points that can be earned within each element from optional items (see **Table 1** for an example). While this "checklist" approach has

[45] Department of Energy, *2008 Buildings Energy Data Book*, Tables 1.6.2 and 1.6.3. The embodied energy also tends to be higher for concrete.

[46] U.S. Green Building Council, "LEED Rating Systems," 2008, http://www.usgbc.org/DisplayPage.aspx?CMSPageID=222. BREEAM uses nine categories: land use, ecology, transport, water consumption, energy, materials, health and well-being, pollution, and management (Cassidy and others, "White Paper on Sustainability").

[47] In most building categories, the innovation and regional categories do not have any required items.

been criticized (see below), it permits comparatively simple assessment of compliance and facilitates the kind of integrated consideration of factors that is a hallmark of green building.

Urban Plantings

It is generally recognized among experts in forestry and horticulture that urban plantings of various types can provide a range of environmental and other benefits. Among the benefits commonly reported are the following:

Temperature. In warm weather, plants can provide shade and also help to cool an area through the evaporation of water from their leaves (evaporative cooling). Also, large plants such as trees can save on heating costs in cold weather by reducing the effects of wind.

Air quality. Plants can trap airborne pollutants (especially trees with large surface areas) and sequester carbon in their leaves and other parts.

Water quality. Plants can reduce storm-water run-off and soil erosion.

Noise. Plants can absorb sound from vehicles and other sources of urban noise, thereby reducing noise pollution.

Social and economic benefits. Trees and other plants can provide recreational opportunities, aesthetic benefits, habitat for urban wildlife, increased property values and occupancy rates, increased customer visits to businesses, and even reduction in crime.

Most of the above benefits have been demonstrated in specific instances through various research projects in urban areas, although the degree to which they may apply in any given case will vary. Attempts to measure the benefits have yielded results such as the following:

- Reductions in energy costs for air conditioning of approximately 15-25% in summer, and 7% heating-energy reduction in winter from reductions in wind speed;
- Removal of pollutants including nitrogen, sulfur, and carbon oxides (including carbon dioxide), heavy metals, ozone, and an approximately 10% or higher reduction in particulate pollutants;
- Up to 20% reduction in run-off of water during storms, and up to 95% reduction in sediment run-off; and
- 10–20% increase in property values.

Caution is required in interpreting such examples, since the actual effects will depend on a wide range of factors, from the kinds of plantings and species used to the local climate and other conditions. Also, the benefits may be disputed by some observers. For example, it might be argued that use of light-colored surfaces reflects sunlight and provides a reduction in ambient temperature equivalent to the ameliorating effects of plants. In addition, there are costs and potential disadvantages associated with plantings, including the following:

Costs of plantings. Species, size of plants, location, and other factors can influence how much urban plantings cost to establish.

Maintenance. These costs will vary with the kinds and locations of plantings, and includes such activities as pruning, irrigation, pest control, recycling or disposal of fallen leaves and other plant residue, and fire protection. Plantings that are improperly planned or maintained can create significant problems—for example, densely planted areas can provide cover for criminal activity.

Damage. Plants can cause damage to structures such as sidewalks, sewerage and other underground infrastructure, especially through root growth, and trees or large branches may cause damage to buildings, vehicles, power lines, and other property and utilities if they fall, such as during storms.

Air quality. Pollen produced by plants can cause allergic reactions, and volatile organic compounds that in some cases can contribute to, rather than reduce, certain kinds of pollution such as ozone.

As with the benefits of plantings, the actual costs and disadvantages will depend on a wide range of factors.

Sources: Southern Center for Urban Forest Research & Information, USDA Forest Service, Urban Forestry Manual, September 2006, available at http://www.urbanforestrysouth.org.

Chris Hastie, "The Benefits of Urban Trees," Warwick (England) District Council, July 2003, available at http://library.tree-care.info/docs/BenefitsOfTrees.zip.

David J. Nowak, "The Effects of Urban Trees on Air Quality," USDA Forest Service, Syracuse, New York, July 2003,

available at http://www.fs.fed.us/ne/syracuse/TREE%20Air%20Qual.pdf.

Table 1. LEED for New Construction

Rating Summary

Elements	Basic Requirements	Maximum Points
Sustainable sites	Construction activity Pollution prevention	26
Water efficiency	Water use reduction	10
Energy and atmosphere	Fundamental commissioning of the building energy systems Minimum energy performance Fundamental refrigerant management	35
Materials and resources	Storage and collection of recyclables	14
Indoor environmental quality	Minimum indoor air quality performance Environmental tobacco smoke control	15
Innovation and design process		6
Regional environmental priorities		4
Total		*110*
Rating Level		**Minimum Points**
Certified		40
Silver		50
Gold		60
Platinum		80

Source: U.S. Green Building Council, "LEED 2009 for New Construction and Major Renovations," April 2010, http://www.usgbc.org/ShowFile.aspx?DocumentID=7244.

Notes: Points are awarded for specified credits under each element, such as alternative transportation, water-efficient landscaping, green power, use of regional materials, and use of daylighting.

LEED's prospective approach can be beneficial. Good initial design is essential to ensure high performance. Retrofitting existing buildings to reduce their environmental footprints can be costly and imperfect. For that and other reasons, the most effective green building efforts are likely in most cases to involve new buildings. Even so, a substantially smaller environmental footprint is feasible for much of the existing building stock.

The rating system is regularly updated, with the most recent revision released in 2009. That release increased weightings for energy- and greenhouse-gas-related measures, and added a regional element to address local environmental requirements.[48]

The rate of LEED certification has increased annually since the first certification in the year 2000.[49] As of November 2008, more than 5,000 buildings and other projects in the United States were LEED-certified,[50] most of them commercial and government buildings,[51] and they include more than 241 federal projects, according to USGBC.[52]

Other Systems

Several other systems exist for guiding the construction of green buildings,[53] but they are not yet widely used in the United States. The National Association of Home Builders has developed a National Building Standard for residential construction. Unlike rating systems such as LEED, this consensus standard, released in 2009, was developed under the auspices of and approved by the American National Standards Institute (ANSI).[54] In 2010, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), together with USGBC and the

[48] Department of Energy, "U.S. Green Building Council Revises its LEED Rating System," November 26, 2008, http://www1.eere.energy.gov/femp/news/news_detail.html?news_id=12122.

[49] 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.

[50] U.S. Green Building Council, *Green Building by the Numbers*, December 2008, http://www.usgbc.org/ShowFile.aspx?DocumentID=3340.

[51] General Services Administration, *What is LEED?*, Fact Sheet, October 30, 2008, http://www.gsa.gov/graphics/staffoffices/What_is_LEED.doc.

[52] U.S. Green Building Council, "Certified Project Directory," July 2010, http://www.usgbc.org/LEED/Project/CertifiedProjectList.aspx?CMSPageID=247, and "Government Resources," May 31, 2010, http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1779. The General Services Administration (GSA) lists 45 projects under the agency's jurisdiction as having LEED certification (General Services Administration, "LEED Building Information," February 28, 2010, http://www.gsa.gov/Portal/gsa/ep/channelView.do?pageTypeId=17109&channelPage=%2Fep%2Fchannel%2FgsaOverview.jsp&channelId=-25925). GSA manages about 45% of federal government office space (K.M. Fowler and E.M. Rauch, *Sustainable Building Rating Systems* (Pacific Northwest National Laboratory, July 2006), http://www.gsa.gov/graphics/pbs/GSA_Assessing_Green_Full_Report.pdf).

[53] Among other rating systems are the Building Research Establishment Environmental Assessment Method (BREEAM), a British system developed in 1990 (http://www.breeam.org); the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), a Japanese system (http://www.ibec.or.jp/CASBEE/english/index.htm); the Sustainable Building Challenge Assessment Tool (SBTool, formerly called GBTool), from the International Initiative for Sustainable Built Environment (http://www.iisbe.org); and Green Globes, a system developed in Canada and based on BREEAM (http://www.thegbi.org). The National Association of Homebuilders has also developed a green building standard (http://www.nahbrc.org/technical/standards/greenbuilding.aspx). This list is by no means exhaustive (see, for example, Grace Ding, "Sustainable construction—The role of environmental assessment tools," *Journal of Environmental Management* 86 (2008): 451-464; Fowler and Rauch, *Sustainable Building Rating Systems*. Different systems emphasize different aspects of green building and therefore whether one or another is more appropriate may depend on local conditions and priorities. For example, one analysis found that LEED focuses somewhat more than BREEAM on the health and comfort of occupants, while BREEAM emphasizes environmental impacts more (Anonymous, "Assessing the assessor: BREEAM vs LEED," *Sustain* 9, no. 6: 30-33, http://www.breeam.org/filelibrary/BREEAM_v_LEED_Sustain_Magazine.pdf).

[54] Such standards are developed according to a specified process involving consensus from relevant stakeholders, public review, response to comments (American National Standards Institute, "Overview of the U.S. Standardization System," July 2007, http://publicaa.ansi.org/sites/apdl/Documents/News%20and%20Publications/Other%20Documents/US-Stdzn-System-FINAL.pdf).

Illuminating Engineering Society of North America (IES), released a high-performance green building standard for nonresidential buildings.[55]

Selected Issues in Green Building

Green building raises issues relating to performance, measurement, cost, market penetration, and approach. These are briefly described below.[56]

Performance

Much of the focus of green building efforts, including rating systems such as LEED, has been on design and construction specifications. Actual performance is expected to be better than conventional buildings, but few assessments have been done. Consequently, it is not certain if a nominally green building, even one that is certified, will perform in a manner that is significantly better or worse than a conventional building.

A study of energy use by more than 100 LEED-certified buildings found that most buildings performed well above the national average.[57] However, about one in seven performed worse than average. Since the average improvement was 24%, the study appears to support the efficacy of the LEED approach.

However, the study has been criticized as misleading because of purported sample bias, inappropriate baselines for comparison, and other concerns. Consequently, some observers have raised doubts about whether such buildings actually consume less energy than similar, uncertified buildings on average.[58] Because other rating systems are not widely used in the United States, little information is available on the performance of buildings constructed under those systems in the U.S. market.

A General Services Administration (GSA) study of 12 green federal buildings, most of which had received LEED certification, found that the buildings studied performed better than the national average in energy use.[59] This study also examined operating costs, occupant satisfaction, water use, and carbon emissions. It found that the buildings studied performed better than national averages in all those categories as well.

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[55] ASHRAE, "Guide to Standard 189.1," *ASHRAE Journal* (June 2010), http://www.ashrae.org/docLib/20100622_AJGuidetoStandard1891.pdf.

[56] For discussion of these and other factors associated with barriers to improving energy efficiency in buildings, see CRS Report R40670, *Energy Efficiency in Buildings: Critical Barriers and Congressional Policy*, by Paul W. Parfomak, Fred Sissine, and Eric A. Fischer.

[57] Turner and Frankel, *Energy Performance of LEED Buildings*.

[58] Henry Gifford, "A Better Way to Rate Green Buildings," September 1, 2008, http://869789182725854870-a-energysavingscience-com-s-sites.googlegroups.com/a/energysavingscience.com/www/articles/henrysarticles/BuildingRatingSystems.pdf?attredirects=0; Joseph W. Lstiburek, *Prioritizing Green—It's the Energy Stupid*, Insights (Building Science Corporation, November 2008), http://www.buildingscience.com/documents/insights/bsi-007-prioritizing-green2014it-s-the-energy-stupid/?full_view=1. 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* (National Institute of Standards and Technology, September 2002), http://www.bfrl.nist.gov/oae/publications/gcrs/02836.pdf).

[59] Office of Applied Science, GSA Public Buildings Service, *Assessing Green Building Performance.*

While the few available performance results for green buildings appear to be at least somewhat encouraging, many uncertainties remain. That is not surprising given the recent onset of integrated green building efforts, the relatively long lead times for construction, and the long life cycles of buildings. As experience with green buildings accumulates, their performance benefits and disadvantages should become clearer.

Measurement

Performance measurement is important for ensuring that green buildings meet the environmental targets claimed for them and to assess ways to improve those targets;[60] but efforts to measure 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.[61]

Building systems may also be commissioned—that is, independently assessed to ensure they are designed, installed, tested, and capable of being operated as planned.[62] Available data support the contention that commissioning improves environmental performance, especially for energy use.[63] The process can be used not only for new buildings, but also existing ones, either during retrofitting or continuing operations.

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 entire lifespan of the building. 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.[64]

In addition to certification and commissioning, an organization can develop an environmental management system (EMS), for which international standards are available.[65] 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

[60] Kats, *The Costs and Financial Benefits of Green Buildings*.

[61] Grace Ding, "Sustainable construction—The role of environmental assessment tools," *Journal of Environmental Management* 86 (2008): 451-464.

[62] Whole Building Design Guide, "Building Commissioning," October 2, 2008, http://www.wbdg.org/project/buildingcomm.php.

[63] Evan Mills et al., *The Cost-Effectiveness of Commercial-Buildings Commissioning* (Lawrence Berkeley National Laboratory, December 15, 2004), http://eetd.lbl.gov/emills/PUBS/Cx-Costs-Benefits.html.

[64] 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. A general international standard for such assessments has been developed (ISO 14040 and 14044; see International Standards Organization, "13.020.10: Environmental management," n.d., http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_ics_browse.htm?ICS1=13&ICS2=20&ICS3=10). See also Environmental Protection Agency, "LCA 101," October 17, 2008, http://www.epa.gov/ord/NRMRL/lcaccess/lca101.html.

[65] The standard is ISO 14001. See International Standards Organization, "ISO 14000 essentials," n.d , http://www.iso.org/iso/iso_14000_essentials, and related documents on the website. EPA has promoted testing and adoption of this standard by local governments and nonprofit organizations with respect to wastewater management (Environmental Protection Agency, "Frequently Asked Questions, Voluntary Environmental Management Systems/ISO 14001," December 17, 2007, http://www.epa.gov/OWM/iso14001/isofaq.htm).

environmental performance, and prevent pollution, among other things. Such commitments are arguably far easier to meet if the EMS includes performance measurement.

The Energy Independence and Security Act of 2007 (P.L. 110-140) and Executive Order 13423 (discussed below) require 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 2005. Determination of an accurate baseline may be difficult in the absence of adequate measurement of energy use. Executive Order 13514 (also discussed below) requires the use of performance scorecards to track agency compliance with the goals laid out in the order.

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 may be difficult to obtain. Measurement science relating to green building is an active area of research, but some observers believe that current efforts are inadequate. The National Science and Technology Council lists the development of appropriate measurement science as the top research need for progress in green building.[66]

Cost

It is widely believed that the initial costs of green buildings are higher than for conventional buildings. Such higher costs can result from several sources. Not only can many features, such as high-efficiency appliances and lighting, 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 cumbersome.

However, proponents of green building assert that operational cost savings will eventually recoup any initially higher investment. The use of integrated design may also result in some reductions in initial costs.[67] Some evidence exists to support that claim.[68] However, information on true costs is not always easy to obtain, and such informational barriers can distort perceptions about the economic benefits of green building.

Some observers also 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"[69] 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.

The structure of real estate markets can exacerbate cost problems. Building owners, especially homeowners, often move after a few years,[70] reducing the time they would require for a return on

[66] National Science and Technology Council, *Federal R&D Agenda for Green Buildings.*

[67] Cassidy and others, "White Paper on Sustainability."

[68] Kats, *The Costs and Financial Benefits of Green Buildings*; Office of Applied Science, GSA Public Buildings Service, *Assessing Green Building Performance.*

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

[70] Almost half of Americans moved between 1995 and 2000 (U.S. Census Bureau, "Census 2000 Migration Data and Reports," August 26, 2008, http://www.census.gov/population/www/cen2000/migration/index.html).

their initial investment through operational savings. Although green building investments may increase the resale value of the building, such projected increases are uncertain and may not be sufficiently attractive. The problem is exacerbated if the building is rented or leased, especially if the tenant pays for utilities. Owners would have little incentive to make green building investments, because they would receive little financial return, and the return received by tenants would depend on the length of their tenure—only long-term tenants would be likely to benefit from making such an investment.[71] This is sometimes called the principal/agent problem.[72]

Finally, many potential beneficiaries of green building are subject to severe capital constraints on such investments, even outside the residential sector. Such constraints are reported to be a problem with respect to such significant users of energy as educational institutions, hospitals, and municipalities.[73]

Cost barriers to the use of green building may decrease as the practice becomes more widespread if economies of scale lower any initial cost differential. Also, financial incentives may change in response to increasing demand.

Market Penetration

The prevalence of green building has increased substantially, 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. However, green buildings still comprise a relatively small portion of building construction. In 2005, according to one analysis, only 2% of new residential and commercial construction in the United States consisted of green building. That percentage has been projected to reach 5% or more by 2010, although that projection did not take into account the recent economic downturn, which may affect the trends in adoption of green building.[74] The significance of this relatively small amount of reported market share also does not take into account existing building stock, little of which was constructed according to green building criteria, and which will only slowly be retrofitted or replaced.[75]

The building industry is a substantial component of the U.S. economy. In 2006, the value of building construction and renovation exceeded $1 trillion and accounted for more than 9% of U.S. gross domestic product.[76] Therefore, greater market penetration of green building may have significant economic impacts. However, any such increase may require significant changes in attitudes about green building among both building professionals and clients.[77]

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[71] Such arguments about cost problems are often cited as a barrier to wider implementation of green building. See, for example, Department of Energy, *Building Technologies Program Planned Program Activities for 2008-2012*, 2008, http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/myp08complete.pdf.

[72] Bressard et al., *Curbing Global Energy Demand Growth*.

[73] Ibid.

[74] McGraw-Hill Construction, *Residential Green Building SmartMarket Report*, SmartMarket Report, 2006.

[75] According to one estimate, about 3% of the current 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://www.cec.org/files/PDF/GBPaper4b_en.pdf).

[76] Department of Energy, *2008 Buildings Energy Data Book*, Table 1.3.1.

[77] A survey of selected building professionals in 2003 found substantial levels of skepticism about prospects for green (continued...)

Approach

Although green building is widely considered a positive development, some observers have expressed concerns about the approach. Some of those criticisms have been directed at rating and certification systems, for the reasons described above among others. Current efforts in general have been criticized. Some argue that they 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.[78] 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.[79] Such approaches would arguably need to go beyond individual buildings and include other components of the built environment.[80]

There is also concern among some observers about misperceptions about green building, especially a failure to appreciate the integrative nature of the effort required. Instead, some may regard it as something that can simply be added on to a construction project, rather than being an integral part of the project from its inception onward.

The scientific and technological knowledge base for green building is also limited, which is not surprising given the recent origin of the discipline. These limitations make it difficult to identify the most appropriate approaches. Substantial research is considered by many as needed to improve the knowledge base relating to all elements of green building.[81]

Such issues can be compounded by differences in goals and perspectives among different proponents of green building.[82] 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.

Legislative and Policy Framework

Several federal laws, executive orders, and other policy instruments have provisions relating to green building. Selected relevant provisions are described below. However, the list presented in this report is not exhaustive. For example, the Resource Conservation and Recovery Act of 1976

(...continued)

building among respondents. More than half had clients who had rejected green building proposals, citing cost concerns and simple lack of interest, among other factors (Cassidy and others, "White Paper on Sustainability."). The degree to which such attitudes might have changed since is not clear.

[78] Anya Kamenetz, "The Green Standard?," *Fast Company*, December 19, 2007, http://www.fastcompany.com/magazine/119/the-green-standard.html.

[79] Victor Olgyay and Julee Herdt, "The application of ecosystems services criteria for green building assessment," *Solar Energy* 77 (February 26, 2004): 389-398.

[80] For example, the Cascadia Region Green Building Council has developed the Living Site and Infrastructure Challenge, "to define the highest measure of sustainability possible in the built environment for non-building infrastructure" (Cascadia Regional Green Building Council, *The Living Site and Infrastructure Challenge*, November 2007).

[81] See, for example, National Science and Technology Council, "Federal R&D Agenda for Green Buildings"; Department of Energy, *Building Technologies Program Planned Program Activities for 2008-2012*; Baum, *Green Building Research Funding*.

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

(RCRA), as amended (42 U.S.C. §6901 et seq.), requires agencies to procure products with recycled content. In addition, several bills have been introduced in the 111th Congress that would address various aspects of green building (see, for example, H.R. 2454, H.R. 5019, S. 1462, and S. 1733). Also, this report does not include discussion of state and local policies, which have substantial influence on green building efforts within those jurisdictions.

Energy Policy Act of 1992

The Energy Policy Act of 1992 (P.L. 102-486), known as EPACT 1992, contained incentives and requirements relating to efficient use of energy and water in federal, commercial, and residential buildings. It included, among other matters, provisions relating to state building energy codes,[83] energy efficiency in federal buildings and public housing, a pilot program for mortgages for energy efficient housing,[84] the development of energy efficient technologies, and energy and water efficiency requirements for appliances, plumbing fixtures, and building materials.

Energy Policy Act of 2005

Among other provisions, the Energy Policy Act of 2005 (P.L. 109-58), known as EPACT 2005, required the development of energy and water conservation programs for congressional buildings, and a reduction in energy consumption by federal buildings of 20% (relative to 2003) by 2015;[85] promoted the procurement of energy-efficient products by federal agencies; established a testbed program for advanced building efficiency; set an energy consumption target for new federal buildings of 30% below existing standards; and required the application of sustainable-design principles to new and replacement federal buildings. It also continued authorization of DOE's weatherization assistance program.

The act set an improvement goal of 25% by 2012 from a 1990 base for state energy conservation plans. 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.

It established the Energy Star labeling program as a joint program of DOE and EPA,[86] and established public information and education programs relating to energy conservation. It also set energy and water conservation standards for various specific products. The act requires agencies to purchase products that either have an Energy Star label or are designated as energy-efficient by the Department of Energy.[87]

[83] For a summary, see "National Legislation on Building Energy Codes," Table 7.3.5 in Department of Energy, *2008 Buildings Energy Data Book*. Most states now have energy codes, although specific requirements vary.

[84] The limits on these mortgages were modified by the Housing and Economic Recovery Act of 2008 (P.L. 110-289).

[85] This was later modified (see below).

[86] EPA began the program in 1992. See text box on page 28.

[87] The Department of Agriculture also administers a labeling and procurement program, for biobased products (http://www.biopreferred.gov/Default.aspx). The program was established in the Farm Security and Rural Investment Act of 2002 (P.L. 107-171) and revised in the Food, Conservation and Energy Act of 2008 (P.L. 110-234).

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. The act also provided various tax incentives to businesses and individuals for energy and water efficiency.

Energy Independence and Security Act of 2007

The Energy Independence and Security Act of 2007 (P.L. 110-140), known as EISA, provided both a general legislative framework for federal green building efforts, including a definition of high-performance green building[88] (see text box on page 6), and specific actions and requirements. Titles III, IV, and V relate most specifically to green building.[89]

Title III set efficiency standards for various appliances and electric lighting. It also required the use of energy-efficient lighting in facilities leased by the General Services Administration (GSA), and further directed that such facilities adhere to energy efficiency and renewable energy requirements to be set by GSA.

Title IV has provisions relating to residential, commercial, federal, and certain other kinds of buildings.

Residential. The act increased funding for DOE's program to provide assistance to low-income families for weatherization of residences, to improve energy efficiency. It required a feasibility study by DOE of the unfunded state rebate programs for energy efficiency and renewable energy that EPACT 2005 had authorized. It also established energy-efficiency standards for manufactured housing such as mobile homes.

Commercial. The act creates an Office of Commercial High-Performance Green Buildings within DOE to facilitate the development of green commercial buildings, including zero-net-energy buildings, in partnership with other federal and with nonfederal entities.

Federal. EISA increased the overall rate of required reduction in total energy consumption of federal buildings in each agency, from 20% (relative to 2003)[90] to 30% by 2015. It set more stringent energy goals for new construction and major renovations, requiring them to reach a 65% reduction by 2015, and zero-net energy use by 2030; and it required the identification and use of a green building certification system for such structures.[91] It also set general water-conservation guidelines and storm-water runoff requirements for property development.

[88] 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)). See also the definition in the Whole Building Design Guide (text box on page 26).

[89] For a summary of provisions in all the titles in this act, see CRS Report RL34294, *Energy Independence and Security Act of 2007: A Summary of Major Provisions*, by Fred Sissine.

[90] This goal was set by §102(a) of EPACT 2005.

[91] Prior to enactment of the law, the Bush Administration criticized it for, among other things, not including "additional building attributes beyond the energy efficiency and water consumption goals" for high-performance green buildings (The White House, "H.R. 6 – Energy Independence and Security Act of 2007," Statement of Administration Policy.) Only the energy goals in the law are numeric.

Federal buildings must undergo regular evaluations of energy and water use, with OMB issuing scorecards twice per year on agency performance in energy management. The life cycle over which energy costs are assessed was extended from 25 to 40 years.

Any new major equipment installed must be energy efficient, and the act accelerated the use of energy-efficient lighting and other cost-saving technologies in GSA facilities. Any buildings leased by a federal agency must have a recently earned Energy Star[92] label.

The act also established an Office of Federal High-Performance Green Buildings within GSA to coordinate and facilitate the development of such buildings in the federal sector. GAO is to perform audits of implementation of these requirements.

Other. The act contains provisions to facilitate the greening of schools, with emphasis on environmental health and energy efficiency. It also authorized energy-efficiency assistance for state and local public facilities and institutions of higher learning. It required the Department of Housing and Urban Development to use updated energy-efficiency standards for public and assisted housing. It also established green building research and demonstration projects through GSA, DOE, and EPA.

Title V contains energy-efficiency provisions relating to the U.S. Capitol complex,[93] and amended provisions in law relating to energy savings performance contracts.[94] It also specified certain actions to promote energy efficiency at executive branch agencies and in the supply of electricity and natural gas by utilities, and for state and local governments to develop and implement strategies for energy efficiency and conservation.

Other relevant provisions in the bill include authorization of research and development (R&D) relating to energy efficiency and renewable energy, and loans and other activities to help small businesses improve energy efficiency.

American Recovery and Reinvestment Act of 2009

The American Recovery and Reinvestment Act of 2009 (P.L. 111-5, ARRA) provided $4.5 billion to convert facilities of the General Services Administration (GSA) to high-performance green buildings. It also provided $250 million to the Department of Housing and Urban Development for green retrofits of housing. It permitted states to use a portion of provided education funds for green renovations of public schools. It also provided funds to various agencies for energy-efficiency improvements to buildings.

Executive Order 13423

In January 2007, prior to the enactment of EISA in December of that year, President Bush signed Executive Order 13423, *Strengthening Federal Environmental, Energy, and Transportation*

[92] Energy Star is a joint program of EPA and DOE (http://www.energystar.gov; see text box on page 28).

[93] For a discussion of legislative branch provisions in the act and other initiatives, see CRS Report RL34694, *Administering Green Programs in Congress: Issues and Options*, by Jacob R. Straus.

[94] For a discussion of such contracts, see CRS Report RL32543, *Energy Savings Performance Contracts: Reauthorization Issues*, by Anthony Andrews.

Management.[95] It replaced several executive orders promulgated in the Clinton Administration (13101, 13123, 13134, 13148, and 13149).

The order contains goals for energy efficiency in federal buildings similar to those in EISA and the executive orders it superseded, and it lays out more specific goals than does that act for reduction in water use by agencies (16% by 2015). It establishes, as a basis for new construction and major renovations, the guiding principles set forth in the interagency memorandum of understanding, "Federal Leadership in High Performance and Sustainable Buildings" (see below); and it requires that by 2015, 15% of federal buildings conform to those principles. It gives responsibility for implementing the policy in the executive order to the Federal Environmental Executive.[96]

Executive Order 13514

In October 2009, President Obama signed Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*.[97] The order sets goals for greenhouse gas production, water consumption, and green building. It requires reduction in greenhouse gas emissions by federal agencies through several means, including "reducing energy intensity in agency buildings." By FY2020, agencies are to reduce greenhouse gas emissions relative to FY 2008, and reduce potable water use by 26% relative to FY2007 and other water by 20% relative to FY2010. All new construction and major renovations are to comply with the "Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings,"[98] and by FY 2015 at least 15% of existing buildings are to comply, with annual progress toward 100% compliance.

Interagency Green Building Memorandum of Understanding

In 2006, representatives of 17 federal agencies and offices[99] signed a memorandum of understanding (MOU) titled "Federal Leadership in High Performance and Sustainable Buildings."[100] The MOU was developed concurrently with the enactment of EPACT 2005.[101] The heart of the agreement is a statement of five "guiding principles" for high performance and sustainable buildings:

[95] The executive order is available at http://edocket.access.gpo.gov/2007/pdf/07-374.pdf.

[96] This position was established in 1993 by an earlier executive order.

[97] The executive order is available at http://frwebgate5.access.gpo.gov/cgi-bin/PDFgate.cgi?WAISdocID=654025441795+3+2+0&WAISaction=retrieve. See also CRS Report R40974, *Executive Order 13514: Sustainability and Greenhouse Gas Emissions Reduction* , by Richard J. Campbell and Anthony Andrews.

[98] See "Interagency Green Building Memorandum of Understanding."

[99] Those agencies were the Departments of Agriculture, Defense, Energy, Interior, Health and Human Services, Homeland Security, Housing and Urban Development, Justice, 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.

[100] http://www.wbdg.org/pdfs/sustainable_mou.pdf.

[101] National Institute of Building Sciences, "Executive Order 13423 Technical Guidance—Frequently Asked Questions," *Whole Building Design Guide,* n.d.

Employ Integrated Design Principles. This principle includes use of an integrated project team; incorporation of relevant performance goals for "siting, energy, water, materials, and indoor environmental quality;" consideration of the entire life cycle of the building; and methods to verify that performance goals are met.

Optimize Energy Performance. This involves establishment of an energy performance goal for the entire building, including reduction in energy costs of 20%-30% below existing standards; and measures to track performance in comparison to Energy Star benchmarks.

Protect and Conserve Water. This involves reducing indoor use of potable water by 20% and outdoor use by 50% in comparison to baselines, and reducing runoff.

Enhance Indoor Environmental Quality. This principle requires meeting established standards for temperature, humidity, and ventilation; controlling moisture to prevent damage and mold; providing daylight in most spaces that is at least 2% above the amount available directly; using dimming and glare controls; using materials that emit low amounts of pollutants; and taking other steps to protect air quality in the building.

Reduce Environmental Impact of Materials. This involves using materials with recycled and biobased (renewable and sustainable) content that is at or above recommended levels, eliminating ozone-depleting compounds, and recycling at least half of construction waste where possible.

The guiding principles serve as a basis for the building policies in E.O. 13423 and related instructions for implementation and are included in E.O. 13514.

Programs and Activities of Selected Federal Agencies

The federal government owns or leases about half a million buildings, comprising about 3 billion square feet in floor space[102] (**Table 2**). EISA and other policy instruments require all federal agencies to implement green building practices for buildings they control. This report does not discuss green building within individual agencies, although such efforts may be substantial.[103] However, several agencies have programs and activities that have a broader focus than the facilities of that agency. This section of the report discusses selected examples.[104]

[102] Department of Energy, *2008 Buildings Energy Data Book*.

[103] See, for example, CRS Report R40111, *Department of Defense Facilities Energy Conservation Policies and Spending*, by Anthony Andrews; Donna McIntire, "Overseas Building Operations (OBO)" (presented at the EISA 2030 Forum, National Academy of Sciences, July 22, 2008).

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

General Services Administration

The General Services Administration (GSA) provides facilities for about 60 federal agencies,[105] managing about 6% of federal floorspace and a roughly equal amount of leased space.[106] The agency requires that all of its new construction and major renovation projects be LEED-certified.[107] GSA was a leader in the efforts to develop sustainable design principles for the federal government, culminating in the development of the Whole Building Design Guide (see text box on page 26).[108]

EISA (§436) required GSA to establish an Office of Federal High-Performance Green Buildings, to coordinate activities relating to such buildings across federal agencies. The office is housed in the Public Buildings Service. Although GSA's focus is on federal buildings, the office is also tasked with coordinating activities with the Department of Energy's Office of Commercial High-Performance Green Buildings established by §421 of EISA.

Table 2. Percentages of Total Federal Building Floorspace Under the Jurisdiction of Various Agencies, 2005

Agency	% of Total
Department of Defense	66
US Postal Service	12
General Services Administration	6
Department of Veterans Affairs	5
Department of Energy	2
Other	8

Source: DOE, *2009 Buildings Energy Data Book,* Table 4.2.1, http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=4.2.1.

Department of Energy

Most of the Department of Energy's green building activities relate to energy, through the Building Technologies Program (BT) and the Federal Energy Management Program (FEMP) of the Office of Energy Efficiency and Renewable Energy (EERE).[109]

BT 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 equipment standards,[110]

[105] General Services Administration, "Fast Facts," Fact Sheet, October 30, 2008, http://www.gsa.gov/graphics/staffoffices/Fast_Facts.doc.

[106] General Services Administration, "Public Buildings Service," June 24, 2010, http://www.gsa.gov/portal/content/104444.

[107] Several state and local governments also have requirements for LEED certification or similar efforts (see Cassidy and others, "White Paper on Sustainability.")

[108] Office of Applied Science, *Sustainability Matters* (General Services Administration, 2008), http://www.gsa.gov/graphics/pbs/oaspublications.pdf.

[109] http://www1.eere.energy.gov. See also other programs such as Solar Energy Technologies.

[110] For information on DOE enforcement of equipment standards established by EPACT 2005 and other legislation, see (continued...)

transfer of relevant technologies to the marketplace, and integrated design of energy efficient buildings. A major focus for the program in the next several years will be on enabling the development of cost-effective zero-net-energy buildings for the residential and commercial sectors.[111]

BT has several notable programs, including the following:

- Building America,[112] an R&D program in partnership with the building industry. It focuses on a whole-building, integrated approach to improving energy savings in residential buildings.
- The High-Performance Commercial Buildings program is a public-private partnership program that uses a whole-building approach to improve energy savings in commercial buildings.[113]
- Energy Star is a joint program with EPA that uses voluntary labeling to promote energy-efficient products (see text box on p. 28).
- The Buildings Energy Data Book[114] provides data on energy consumption and other building-related topics for the residential, commercial, and federal sectors. It is updated annually.

Whole Building Design Guide

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 11 federal agencies and many private-sector and nonprofit organizations. It is hosted by the National Institute of Building Sciences, with federal funding provided by the Department of Defense (the Navy began the WBDG in 1997), The General Services Administration, the Department of Veterans Affairs, the Department of Energy (four of the five largest managers of federal floorspace—see **Table 2**), and the National Aeronautics and Space Administration.

The site describes the goals of the approach 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." The most relevant goal for green building is the last. 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.

The whole-building approach promoted by the site 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.

Sources: Whole Building Design Guide, "WBDG - The Whole Building Design Guide," n.d., http://www.wbdg.org/index.php; OFEE, "The Federal Commitment to Green Building," 2003, http://www.epa.gov/greenbuilding/pdf/2010_fed_gb_report.pdf.

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Department of Energy, "Building Technologies Program: Appliances and Commercial Equipment Standards," August 13, 2008, http://www1.eere.energy.gov/buildings/appliance_standards/index.html.

[111] Department of Energy, *Building Technologies Program Planned Program Activities for 2008-2012.*

[112] http://www1.eere.energy.gov/buildings/building_america/index.html.

[113] http://www1.eere.energy.gov/buildings/commercial_initiative.

[114] http://buildingsdatabook.eren.doe.gov.

FEMP[115] assists federal agencies in implementing energy savings and management, including the designation required by EPACT 2005 of energy-efficient products for purchase by agencies. It provides assistance with procurement, construction, operations, and maintenance. It also chairs the Interagency Sustainability Working Group, which is responsible for assisting agencies in implementing sustainable building design, including technical guidance for implementation of the sustainable buildings requirements in E.O. 13423. FEMP collects data and issues reports annually on energy consumption by agencies and related topics.[116]

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.[117] Some of DOE's national laboratories also perform R&D relating to green buildings.

Environmental Protection Agency

Along with DOE, the Environmental Protection Agency has the broadest range of programs and activities relating to green building, addressing a wide range of elements. Notable programs and activities include the following:[118]

- **Energy.** EPA originated the Energy Star program (see text box on page 28). The agency's Green Power Partnership supports the procurement of power from renewable resources by government and private-sector organizations.
- **Water.** EPA administers Water Sense, a voluntary labeling program established in 2006 to promote water efficiency. Manufacturers may earn Water Sense labels for their products, and landscape-irrigation professionals can be certified under the program.
- **Materials**. The Construction Initiative, part of the agency's Resource Conservation Challenge,[119] is a collaborative public/private partnership program aimed at increasing recycling and reuse of materials in construction activities. The Lifecycle Building Challenge is a competition to promote building materials reuse.

  The Environmentally Preferable Purchasing (EPP) Program assists federal agencies in meeting green purchasing requirements and includes an online database of environmental information about products and services.[120] The Comprehensive Procurement Guideline program identifies recycled products that comply with RCRA requirements.

[115] http://www1.eere.energy.gov/femp/index.html.

[116] Department of Energy, "Information Resources," November 24, 2008, http://www1.eere.energy.gov/femp/information/publications.html#policy.

[117] See Department of Energy, "Residential Energy Consumption Survey," n.d., http://www.eia.doe.gov/emeu/recs/contents.html; and Department of Energy, "Commercial Buildings Energy Consumption Survey," n.d., http://www.eia.doe.gov/emeu/cbecs/contents.html.

[118] Environmental Protection Agency, "Components of Green Building."

[119] Environmental Protection Agency, "Resource Conservation Challenge (RCC)," January 13, 2009, http://www.epa.gov/epawaste/rcc/index.htm.

[120] Environmental Protection Agency, "Database of Environmental Information for Products and Services," January 13, 2009, http://yosemite1.epa.gov/oppt/eppstand2.nsf.

- **Waste.** The Industrial Materials Recycling Program provides information aimed at reducing construction and industrial waste and promoting its recycling and reuse. The Greenscapes program promotes and provides information on waste reduction in landscaping operations.
- **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 Environments Program provides information and tools to ensure the protection of indoor environmental quality in schools, residences, and commercial buildings.
- **Siting.** The Green Infrastructure Partnership and related activities promote landscaping and building techniques such as green roofs (see text box on p. 9) to reduce stormwater runoff and maintain or restore the natural hydrology of a building site. The agency also has a variety of programs and activities relating to smart growth and sustainability.

Recognizing the broad range of separate programs and activities relating to green building, EPA has announced a green building strategy to improve coordination among its programs and encourage broader adoption of green building practices. Objectives include improved standards and metrics, enhanced research, wider understanding about green building, and increased use of the approach.[121]

Energy Star

Energy Star is a voluntary labeling program established by EPA in 1992. It is now a joint EPA/DOE program. It is designed to overcome market barriers to the adoption of energy-efficient products and services.

Residential: The agencies work with manufacturers to identify appliances and other products that are cost-effective and energy efficient. Products meeting the criteria receive an Energy Star label. The agencies provide information directly to consumers about the thousands of labeled products. Among the product categories included are office equipment, home electronics, heating and cooling (HVAC), appliances, lighting, and windows. The program has also partnered with builders to create Energy Star-qualified homes and with lenders to encourage the use of "green mortgages" to promote energy efficient housing.

Commercial: EPA offers partnerships to businesses and other organizations that make top-level managerial commitments to adopt superior energy management. Partners continually assess energy use within their organizations and use an integrated approach in upgrading buildings. EPA provides standardized measurement tools and a recognition program to assist and promote these efforts.

Federal: EPACT 2005 requires federal agencies to purchase either Energy Star products or those designated as energy efficient by FEMP. EISA requires additionally that federal agencies lease only facilities with a recent Energy Star label.

Source: EPA, "ENERGY STAR – The Power to Protect the Environment through Energy Efficiency," July 2003, http://www.energystar.gov/ia/partners/downloads/energy_star_report_aug_2003.pdf.

Office of the Federal Environmental Executive

The position of Federal Environmental Executive was established in 1993 by Executive Order 12873. Executive Order 13423 broadened that position to include an Office of Federal

[121] Environmental Protection Agency, "Under Construction: A New Green Building Strategy for EPA," Press Release, April 21, 2008, http://yosemite.epa.gov/opa/admpress.nsf/a883dc3da7094f97852572a00065d7d8/8fe974c1df288b858525743200623fc3!OpenDocument.

Environmental Executive (OFEE),[122] and extended the duties to include monitoring of implementation by agencies of the order, including its green building requirements, and advising the Council on Environmental Quality.

National Institute of Standards and Technology

The green building efforts of the National Institute of Standards and Technology (NIST) are housed in the institute's Building and Fire Research Laboratory.[123] The Healthy and Sustainable Buildings program focuses on improvements in measurement science and data relating especially to energy efficiency and indoor air quality. The Cybernetic Building Systems program focuses on automation technology relating to green building. One notable result of NIST's work is the Building for Environmental and Economic Sustainability tool (BEES),[124] a software tool that uses life-cycle assessment methods to facilitate the selection of environmentally preferable building products.

Department of Housing and Urban Development

The Green Initiative in the Department of Housing and Urban Development (HUD) is a voluntary program to encourage green building in the rehabilitation of certain residential housing.[125] The department's Healthy Homes program focuses on improving indoor environmental quality in housing for low-income families.[126]

The cross-sector Partnership for Advancing Technology in Housing (PATH) is coordinated by HUD's Office of Policy Development and Research. Its goals are to promote green building[127] and other innovations in housing technology by reducing regulatory and other barriers to their use, disseminating information, and fostering research.

Issues for Congress

Four of the questions Congress and the Obama Administration are expected 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?

[122] http://www.ofee.gov.

[123] http://www.bfrl.nist.gov.

[124] See National Institute of Standards and Technology, "BEES 4.0," August 20, 2007, http://www.bfrl.nist.gov/oae/software/bees/bees.html.

[125] Department of Housing and Urban Development, "OAHP's M2M Green Initiative," n.d , http://www.hud.gov/offices/hsg/omhar/paes/greenini.cfm.

[126] Department of Housing and Urban Development, "HUD's Healthy Homes Initiative," September 16, 2008, http://www.hud.gov/offices/lead/hhi/index.cfm.

[127] Partnership for Advancing Technology in Housing, "Guide to Green," February 28, 2008, http://www.pathnet.org/sp.asp?id=24934.

- To what extent 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 should Congress take to facilitate the growth of scientific and technical knowledge relating to green building?

If Congress wishes to take additional action on such questions, it could do so through appropriations, new statutory requirements, and tax law. It could also review current and proposed agency programs, regulations, and policies.

Oversight of Federal Green Building Programs

There appears to have been little direct congressional oversight to date of federal green building programs.[128] That is not surprising given the recent establishment of such programs and the broad range of federal agencies involved in the efforts, among other factors.

Congress may wish to examine how well federal agencies are implementing green building programs, and what impacts those efforts are having on the adoption of green building practices 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.

Adoption and Implementation of Green Building

In addition to programs and activities such as those described above, the federal government also supports the availability of mortgages that promote energy efficiency, through the Federal Housing Administration, the Veterans Administration, Fannie Mae, and Freddie Mac. Lenders who provide such mortgages may also become Energy Star partners (see text box on p. 28).

If Congress finds that such measures are not adequate, it could consider such steps as providing stronger mortgage and tax incentives, broadening the scope of mortgage and tax incentives to include elements of green building in addition to energy, funding the rebate program authorized by EPACT 2005,[129] and specific appropriations to speed adoption of green building in areas

[128] The Government Accountability Office has examined some programs in the following reports: Government Accountability Office, *Green Affordable Housing: HUD Has Made Progress in Promoting Green Building, but Expanding Efforts Could Help Reduce Energy Costs and Benefit Tenants*, October 2008, http://www.gao.gov/new.items/d0946.pdf; and Government Accountability Office, "Status of GSA's Implementation of Selected Green Building Provisions of the Energy Independence and Security Act of 2007," http://www.gao.gov/new.items/d09111r.pdf; Government Accountability Office, *Agencies Are Taking Steps to Meet High-Performance Federal Building Requirements, but Face Challenges*, GAO-10-22, October 2009, http://www.gao.gov/new.items/d1022.pdf; Government Accountability Office, *Federal Energy Management: GSA's Recovery Act Program Is on Track, but Opportunities Exist to Improve Transparency, Performance Criteria, and Risk Management*, GAO-10-630, June 2010, http://www.gao.gov/new.items/d10630.pdf. Also, the House Committee on Transportation and Infrastructure held a hearing on May 26, 2010, to examine progress on ARRA infrastructure investments. The hearing included testimony from GSA and USGBC (available at http://transportation.house.gov/hearings/hearingDetail.aspx?NewsID=1201).

[129] Some observers argue that incentive programs can be several times more effective in stimulating energy efficiency (continued...)

where market penetration has been lagging, such as residential renovation. Congress could also consider regulatory actions, although such efforts might be complicated by federalism issues and differences in regional requirements relating to climate and other variables.

Congress could also consider identifying ways in which current green building efforts in federal agencies could be 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 by additional agencies in the WBDG..

Priorities Among Elements of Green Building

Among the elements of green building discussed in this report, energy has received far more attention than any other. This priority is not surprising, given increasing concerns about fossil fuel imports, strategic vulnerability, global warming, and the high and inefficient levels of use of energy by most of the current building stock in the United States. Nevertheless, Congress may wish to examine whether federal efforts in green building are effectively balanced among the component elements. If they are not, existing programs relating to particular elements could be strengthened or new ones established.

In addition, Congress may wish to explore whether the incremental approach embodied in most green building activities is sufficient to address national needs, or if some modification, such as a stronger emphasis on sustainable building (in the sense it is used in this report), would be preferable.

Knowledge Base

Development of the scientific and technological knowledge base for green building is supported by R&D funded by both federal and private-sector sources. Levels of funding from both sources may be suboptimal to address the needs currently identified.

According to one recent study, green building has received less than 0.5% of total funding for federal nondefense R&D.[130] Also, despite its economic importance, the construction sector invests in R&D at a much lower rate than the industry average.[131]

Funding for R&D relating to the different elements of green building is disparate. About 75% of total, federal and nonfederal, green building R&D funding from 2002 to 2005 was energy-related, with 20% for materials and resources, and the remaining 5% for other elements and in integrative and economic R&D. Given the range of green building elements and the need for improved knowledge about them, as well as the accepted importance of integration and economics to successful green building efforts, Congress may wish to consider whether federal funding levels

(...continued)

than increases in energy prices (see Bressard et al., *Curbing Global Energy Demand Growth*).

[130] Baum, *Green Building Research Funding*.

[131] Estimates vary from 10% to 40% of the industry average as a percentage of sales (Cassidy and others, "White Paper on Sustainability"; National Science Foundation, *Research and Development in Industry: 2003*, 2006, http://www.nsf.gov/statistics/nsf07314/content.cfm?pub_id=2488&id=2, Table 26).

and priorities should be modified, and whether to create incentives for increasing private-sector R&D funding.

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