CHARLES J. KIBERT

SUSTAINABLE CONSTRUCTION

GREEN BUILDING DESIGN AND DELIVERY

FIFTH EDITION

WILEY

Sustainable Construction

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Green Building Design and Delivery

Fifth Edition

Charles J. Kibert

This book is printed on acid-free paper ∞.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.

Published simultaneously in Canada.

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Library of Congress Cataloging-in-Publication Data

Names: Kibert, Charles J., author.

Title: Sustainable construction : green building design and delivery / Charles J. Kibert.

Description: Fifth edition. | Hoboken, NY : Wiley, [2022] | Includes index.

Identifiers: LCCN 2021031014 (print) | LCCN 2021031015 (ebook) | ISBN 9781119706458 (hardback) | ISBN 9781119706465 (adobe pdf) | ISBN 9781119706441 (epub)

Subjects: LCSH: Sustainable construction. | Sustainable buildings—United States—Design and construction. | Green technology—United States. | Sustainable architecture.

Classification: LCC TH880 .K53 2021 (print) | LCC TH880 (ebook) | DDC 690.028/6—dc23

LC record available at https://lccn.loc.gov/2021031014

LC ebook record available at https://lccn.loc.gov/2021031015

Cover Design: Wiley
Cover Image: Courtesy of the University of Nottingham

For Charles, Nicole, and Alina,
and in memory of two friends and sustainability stalwarts,
Ray Anderson and Gisela Bosch

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Preface

The significant additions and changes for the fifth edition of *Sustainable Construction: Green Building Design and Delivery* include significant revisions to all chapters that were necessitated due to the rapid evolution of sustainable construction. The COVID-19 pandemic was ongoing during the creation of the fifth edition, and relevant information about its relationship to green building and sustainability has been provided as was known at the time. Chapters 4 and 5 on *LEED* and *Green Globes* respectively were heavily revised because these major assessment systems have changed significantly over the past few years. LEED version 4.1 is now the main building assessment product of the US Green Building Council for projects, and this recent version is covered in detail. A detailed review of the new standard, *ANSI/GBI 01–2019 Green Globes Assessment Protocol for Green Buildings*, that underpins the Green Globes assessment system is included in Chapter 5. Updated information on other major assessment systems, such as *Green Star*, the *Comprehensive Assessment System for Building Environmental Efficiency* (CASBEE), the *Building Research Establishment Environmental Assessment Method* (BREEAM), and the *Deutsche Gesellschaft für Nachhaltiges Bauen* (DGNB), has been provided.

Chapter 12 on carbon accounting was also significantly revised to include more insights into the importance of carbon neutral buildings. Case studies are provided that describe how project teams are developing strategies to offset a project's embodied and operational carbon. The emerging role of mass timber as both a structural material and for use as an offset for embodied carbon are covered both in Chapter 11 on materials and in Chapter 12.

A new Chapter 16 on resilience addresses the issue of climate change–induced disasters, which are growing in frequency and scale. Climate change resilience is an important emerging issue that is now being incorporated into the latest versions of building assessment systems even though there is some debate about the importance of its inclusion. As pointed out in Chapter 16, resilience could be said to represent the failure of sustainability, that sustainability by itself was not compelling enough to force a radical rethinking of anthropomorphic energy systems. The undesirable outcomes of this situation are continually increasing climate-change gases and ever more dangerous threats to global and local ecosystems.

The section in Chapter 17 on green skyscrapers was updated to reflect the continuing rapid growth in the numbers and quality of green skyscrapers around the world. Ken Yeang, the renowned Malaysian architect, first elaborated this concept in his 1996 book, *The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings*, and in his two other volumes on the subject: *Eco-Skyscrapers* (2007) and *Eco-Skyscrapers, Volume 2* (2011).

Although extremely busy with their day jobs designing significant green building projects around the world, several architecture firms gave generously of their time and resources to assist me. Katy Harris, senior partner at Foster + Partners, provided me access to materials such as reports, press releases, and graphics about the Bloomberg European Headquarters in London, the major case study in Chapter 1. For the major Chapter 12 case study, Rick Sharp of Fairhursts Design Group was kind enough to provide me with extremely helpful materials about the design of the GSK Carbon Neutral Laboratories, located at the University of Nottingham in the

UK. He arranged for a review of this case study by the client and project team to ensure its accuracy and for several Zoom calls with some of the key engineers who helped design this significant and noteworthy project. I am grateful for their openness, assistance, and generosity.

One of the significant case studies in this edition is in Chapter 11 on materials, and it covers the topic of closed loop or cradle-to-cradle materials strategies. The case study was developed with the assistance of Shaw Industries, who were very generous during a yearlong process that began with a meeting with their representatives at the 2019 USGBC annual Green Build conference and exhibition. The case study describes the approach that Shaw Industry used to develop the EcoWorx® carpet tile product line and how it squarely addresses the problem of keeping materials in productive use as long as possible. I am grateful to Kellie Ballew, vice president for Global Sustainability for Shaw Industries, and Kate Arora, communications manager for ShawContract®, and Dana Hartline.

This fifth edition has significantly more graphics than the fourth edition of *Sustainable Construction*, and a large number of organizations and companies were kind enough to permit the publication of their content in this edition. Thanks to all the contributors of these invaluable materials.

Thanks to Amy Odum at John Wiley & Sons for guiding me through the initial stages of the publication process. This edition would not have been possible without the enormous contributions of my PhD students, among them Maryam Kouhirostami, Mahya Sam, Samira Roostaie, Jiaxuan Li, and Ashish Asutosh. They were extremely dedicated to helping produce a comprehensive, quality outcome. During the time of producing the fifth edition, Samira was writing her dissertation on the topic of resilience and her work proved very helpful and was used in the section discussing the relationship between green building assessment and a climate-resilient built environment. I owe an enormous debt to all of them for their extremely hard work and dedication.

Charles J. Kibert
Gainesville, Florida

Chapter 1

Introduction and Overview

The application of the *sustainability* paradigm to the built environment is still a relatively recent phenomenon but, in a relatively short time, the resulting *sustainable construction* movement has gained significant strength and momentum. The effort to implement this thinking continues to expand, supported by certification schemes that officially designate a project as meeting ambitious sustainability criteria. In some countries such as the US, about half of all commercial and institutional projects are being evaluated for certification by third-party building assessment organizations such as the US Green Building Council (USGBC) and the Green Building Initiative. Recent surveys of green building activity in 20 countries on five continents indicate significant future increases in business investments in these high-performance buildings. One significant emerging trend is a growing gap between those implementing sustainable construction without green building assessment and those seeking green certification, a possible indication that sustainability and greening are becoming the norm (Dodge Data & Analytics 2018).

The strongest force shaping contemporary sustainable construction is the expected, near- and far-term effects of climate change. The *Special Report on Global Warming of 1.5ºC*, issued by the Intergovernmental Panel on Climate Change (IPCC) in October 2018, is having unprecedented impacts on the direction of green buildings and sustainable construction. The Special Report sounded what may be the final alarm for the world to act before climate change causes irreversible and catastrophic events that will take a heavy toll on the planet's climate and ecosystems. The Special Report also stated that the time frame for massive action is extremely short and daunting, or major effects such as significant sea level rise and more violent weather events will become permanent features of the planet's climate regime. The recent emergence of *resilience* as a consideration for green building projects is an important shift that is largely a response to climate change to ensure buildings can survive hurricanes, storm surges, flooding, and other climate-related effects. Chapter 17 addresses resilience and how it is being implemented by communities and project teams.

A second, more recent force, the COVID-19 pandemic of 2020, caused major disruptions of all types to include affecting how project teams should consider preventative measures such as improved ventilation systems, social distancing, screening of individuals, and other responses. For example, colleges and universities may need to design new buildings and retrofit existing facilities to provide more separation between students. Ultraviolet disinfection technologies integrated into building HVAC systems may be demanded. Clients will demand much more of their project teams in helping them design and build facilities that provide them with a competitive advantage in the context of enormous threats to human health, well-being, and profitability. Meetings, classes, conventions, and other gatherings will shift, at least in the short-term, to virtual platforms, thus affecting some of the basic assumptions about commercial and industrial buildings (BD&C 2020). Although the ravages of COVID-19 are likely to be halted due to the relatively rapid emergence of several effective vaccines and therapeutics, it is equally likely that other devastating viruses and diseases will emerge. As a result, measures that can help mitigate their spread are already being considered for inclusion in high-performance buildings to support the protection of human health.

The major strategy currently being used to guide the design and construction of high-performance buildings is *green building assessment*. Green building assessment generally means that a third-party organization reviews the project management, architectural and engineering design, building materials and products, and the construction process to determine the degree to which they have met specific criteria. Worldwide there are at least 40 building assessment systems, most prominently the United Kingdom's *Building Research Energy and Environmental Assessment Method* (BREEAM) and the US Green Building Council's *Leadership in Energy and Environmental Design* (LEED) green building assessment program. Over 570,000 buildings have been awarded a BREEAM certification and over 35,500 building projects have been assessed and certified according to the requirements of LEED. Harvard University boasts over 140 buildings certified in accordance with the LEED building assessment system, including several projects with the highest, or Platinum, rating and including labs, dormitories, libraries, classrooms, and offices. The sustainable construction movement is now international in scope, with almost 70 national green building councils establishing ambitious performance goals for the built environment in their countries. In addition to promoting green building, these councils develop and supervise building assessment systems that provide ratings for buildings based on a holistic evaluation of their performance against a wide array of environmental, economic, and social requirements. The outcome of applying sustainable construction approaches to creating a responsible built environment is most commonly referred to as *high-performance green buildings*, or simply, *green buildings*.

The Shifting Landscape of Green Buildings

There are many signs that the green building movement is permanently embedded as standard practice for owners, designers, and other stakeholders. A 2018 Dodge Data & Analytics Report surveyed the construction industry in 20 countries to determine changes in the green building market since 2012. The report analyzed several different indicators: the level of green activity, the benefits of building green, the triggers most likely to spur further green market growth, and the challenges that may hinder it. One of the key outcomes of this survey was that they determined that the percentage of respondents who expect to use green strategies in the design and construction activities is steadily increasing. The study found that the global average was expected to increase from 27 percent to 47 percent in the following three years. Additionally, about 50 percent of the respondents stated that they expect that most of their products will be green in the same time frame. It is clear from the study that the green building market continues to grow at a very steady pace and that the global uptake is likely to continue in the foreseeable future. One of the compelling arguments for green buildings is a financial one. This report found that owners are now seeing a 10 percent or greater increase in asset value for new green buildings compared to conventional buildings (Dodge 2018).

One of the factors helping to propel the continuing shift to green strategies is the business benefits of new green buildings and green retrofit projects. Figure 1.1 shows changes in

Business Benefits Expected From Green Building Investments

(Medians Reported in 2012, 2015, and 2018)

	New Green Building		
	2012	**2015**	**2018**
Decreased 12-Month Operating Costs	**8%**	**9%**	**8%**
Decreased 5-Year Operating Costs	**15%**	**14%**	**14%**
Increased Asset Value (According to Owners)	**5%**	**7%**	**7%**
Payback Time for Green Investments	**8 Years**	**8 Years**	**7 Years**
	Green Retrofit		
	2012	**2015**	**2018**
Decreased 12-Month Operating Costs	**9%**	**9%**	**9%**
Decreased 5-Year Operating Costs	**13%**	**13%**	**13%**
Increased Asset Value (According to Owners)	**4%**	**7%**	**5%**
Payback Time for Green Investments	**7 Years**	**6 Years**	**6 Years**

Figure 1.1 Benefits expected by businesses as a consequence of their investment in green buildings. (*Source:* Dodge Data and Analytics 2018)

perceptions over a six-year period by businesses regarding their investments in green building. The Dodge study shows that businesses expect they will experience significant operating cost savings, short payback periods, and passive value increases resulting from investments in green building projects.

The top triggers driving green building activity include client demands, environmental regulations, and healthier buildings (see Figure 1.2). Coupled with these triggers are a number of social reasons for implementing green buildings: improved occupant health and well-being, encouragement of sustainable business practices, increased worker productivity, development of a sense of community, and increase domestic economic activity (see Figure 1.3). As can be seen from this information, the creation of healthy buildings is the most prominent reason for adopting green building practices.

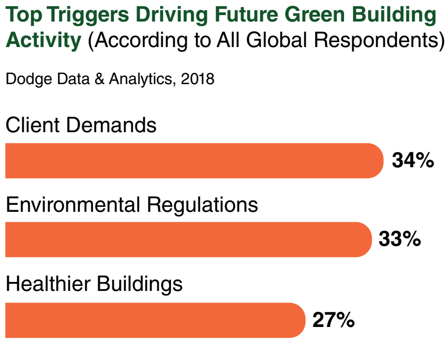

Figure 1.2 The top drivers or triggers that are pulling and pushing the increasing adoption green building strategies, by businesses. (*Source:* Dodge Data and Analytics 2018)

One trend that illustrates the shifting landscape for high-performance green building is the fact the major tech giants Apple and Google and a range of other tech companies have announced major projects that indicate their industry is embracing high-performance green building. Apple opened its new corporate campus in 2017 and its main building, the so-called "Spaceship," houses 12,000 employees. In first announcing the new project in 2006, the late Steve Jobs referred to it as "the best office building in the world." The architects for this cutting-edge facility are Foster + Partners, the renowned British architecture firm whose founder and chairman, Sir Norman Foster, was inspired by a London square surrounded by houses to guide the design concept. As the building evolved, it morphed into a circle surrounded by green space, the inverse of the London square. Located on about 175 acres (just under 71 hectares) in Cupertino, California, the 2.8 million ft^2 (260,000 m^2) building is sited in the midst of 7,000 plum, apple, cherry, and apricot trees, a signature feature of the area's commercial orchards. Only 20 percent of the site was disturbed by construction, resulting in abundant green space. Apple's Transportation Demand Management program emphasizes the use of bicycles, shuttles, and buses to move its employees to and from two San Francisco Bay regional public transit networks. The transportation program alternatives for Apple Park include buffered bike lanes and streets near the campus that are segregated from automobile traffic and wide enough to permit bicycles to pass each other. Hybrid and electric automobile charging stations serve 300 electric vehicles, and the system can be expanded as needed. The energy strategy for Apple's new office building was shaped around the *net zero energy* (NZE) concept, with extensive focus on passive design to maximize daylighting and natural cooling and ventilation. The result is a building that generates more energy from renewable sources than it consumes. Energy efficiency is important for the net zero strategy, and the lighting and all other energy-consuming systems were selected for minimal energy consumption. The central plant contains fuel cells, chillers, generators, and hot and condenser water storage. A low-carbon solar central plant with 17 megawatts (MW) of solar panels is installed on the roof, ensuring the campus runs entirely on renewable energy. This array supplies 70 percent of peak daytime energy with the remaining 30 percent supplied from other renewable energy sources.

Another tech giant with ambitious high-performance green building plans is Google. Early in 2015, as part of a planned massive expansion, Google announced a radical plan for expansion of its Mountain View, California, headquarters into the so-called Googleplex. The radical design included large tentlike structures with canopies of translucent glass floating above modular buildings that would be reconfigured as the company's projects and priorities change. The area beneath the glass canopy included walking and bicycle paths along meadows and streams that connect to nearby San Francisco Bay.

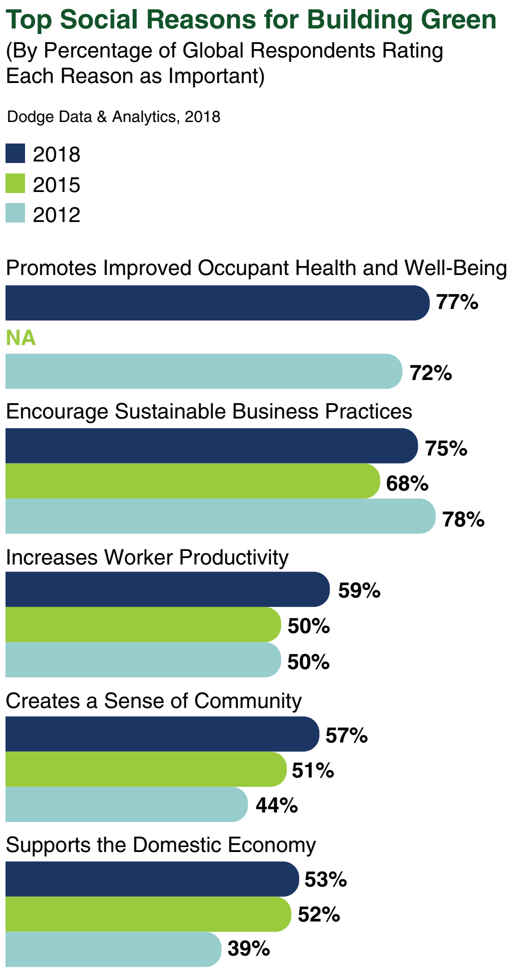

Figure 1.3 Of the social reasons for building green, the health and well-being of building occupants is the top choice. (*Source:* Dodge Data and Analytics 2018)

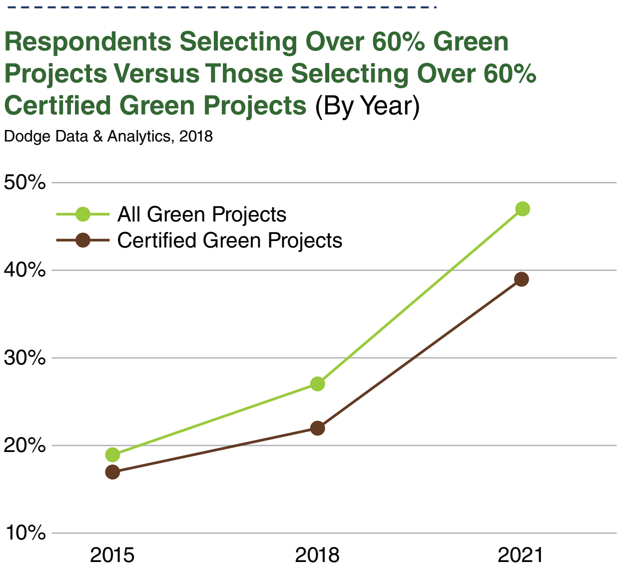

Figure 1.4 There is a shift taking place among major green building adopters indicating a slight reduction in the fraction of projects that are using third-party green building certification schemes. (*Source:* Dodge Data and Analytics 2018)

The emerging direction of design by the superstar collaboration between the Danish architect Bjarke Ingels and the London design firm Heatherwick Studio was an eco-friendly project that would feature radical passive design and integration with nature and local transportation networks. However, in mid-2015, the Mountain View City Council voted to allow Google just one-fourth of its planned expansion, with the remaining site being made available to another tech firm, LinkedIn. Despite this setback, Google, like many other technology-oriented companies, is committed to greening its buildings and infrastructure. One of its commitments is to invest in renewable energy, and the firm committed $145 million to finance a SunEdison plant north of Los Angeles. This was one of many renewable projects in which Google has invested over $1.5 billion.

Other tech firms are also leading the way with investments in architecturally significant, high-performance green buildings. Facebook hired the renowned architect Frank Gehry to design MPK 21, an expansion of its Menlo Park, California, campus (see Figures 1.5 and 1.6). It is clear that the behavior of these tech firms is part of an emerging pattern among start-up firms, which often begin their lives in college dorm rooms, storage units, garages, and living rooms They move out of such locations as they mature, renting offices in industrial parks. Then, when they have become super successful and flush with cash, they tend to build iconic monuments. However, in spite of the desire to make a splash by investing in signature headquarters buildings designed by well-known architects, the tech industries have managed to remain eco-conscious and serve as change agents by pushing society toward more sustainable behavior, particularly with respect to the built environment.

These trends, which mark the current state of high-performance green building around the world, indicate a maturing of the movement. The first of these buildings emerged around 1990, and the movement is now being mainstreamed, as evidenced by the incorporation of high-performance building rating systems, such as LEED, into standards and codes. Since the inception of its pilot version in 1998, LEED has dealt with building energy performance by specifying improvements beyond the requirements of these standards to earn points toward certification. The main energy standard in the United States is the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1, *Energy Standard*

Figure 1.5 Facebook's newest office building, MPK 21, in Menlo Park, California, is a Frank Gehry–designed building with a rooftop indoor/outdoor dining area. (*Source:* Bloomberg.com)

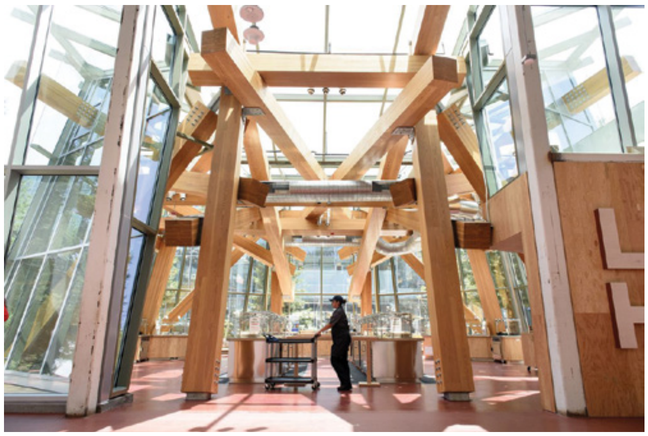

Figure 1.6 Interior of Facebook's MPK 21 building showing the spectacular daylighting system. (*Source:* Bloomberg.com)

for Buildings Except Low-Rise Residential Buildings. In the years since 1998, the energy consumption standards for new US buildings have been sliced by more than 50 percent, and each issue of ASHRAE 90.1 makes additional cuts. The outcome is that it is becoming more difficult to use green building rating systems to influence additional energy reductions because following ASHRAE 90.1 already results in highly efficient building. Nevertheless, many issues still need attention, such as the restoration of natural systems, urban planning, infrastructure, renewable energy systems, comprehensive indoor environmental quality, and stormwater management. To its credit, the green building movement has succeeded in creating a dramatic shift in thinking in a short time. Its continued presence is now needed to both push the cutting edge of building performance and to ensure that the success of its efforts is maintained for the long term.

The Roots of Sustainable Construction

The contemporary high-performance green building movement was sparked by finding answers to two important questions: What is a high-performance green building? How do we determine if a building meets the requirements of this definition? The first question is clearly important because having a common understanding of what comprises a green building is essential for coalescing effort around this idea. The answer to the second question is to implement a *building assessment* or *building rating* system that provides detailed criteria and a grading system for these advanced buildings. The breakthrough in thinking and approach first occurred in 1989 in the United Kingdom with the advent of a building assessment system known as *BREEAM* (Building Research Establishment Environmental Assessment Method). BREEAM was an immediate success because it proposed both a standard definition for green building and a means of evaluating its performance against the requirements of the building assessment system. BREEAM represented the first successful effort at evaluating buildings on a wide range of factors that included not only energy performance but also water consumption, indoor environmental quality, location, materials use, environmental impacts, and contribution to ecological system health, to name but a few of the general categories that can be included in an assessment. To say that BREEAM is a success is a huge understatement because over 2 million buildings have been registered for certification and about 250,000 have successfully navigated the certification process. Canada and Hong Kong subsequently adopted BREEAM as the platform for their national building assessment systems, thus providing their building industries with an accepted approach to green construction. In the United States, the USGBC developed an American building rating system with the acronym LEED. When launched as a fully tested rating system in 2000, LEED rapidly dominated the market for third-party green building certification. Similar systems were developed in other major countries: for example, *CASBEE* (Comprehensive Assessment System for Building Environmental Efficiency) in Japan (2004) and *Green Star* in Australia (2006). In Germany, which has always had a strong tradition of high-performance buildings, the German Green Building Council and the German government collaborated in 2009 to develop a building assessment system known as *DGNB* (Deutsche Gesellschaft für Nachhaltiges Bauen), which is in many respects the most advanced evolution of building assessment systems. BREEAM, LEED, CASBEE, Green Star, and DGNB represent the cutting edge of today's high-performance green building assessment systems, both defining the concept of high performance and providing a scoring system to indicate the success of the project in meeting its sustainability objectives.

In the United States, the green building movement is often considered to be the most successful of all the American environmental movements. It serves as a template for engaging and mobilizing a wide variety of stakeholders to accomplish an important sustainability goal, in this case dramatically improving the efficiency, health, and performance of the built environment. The green building movement provides a model for other sectors of economic endeavor about how to create a consensus-based, market-driven approach that has rapid uptake, not to mention broad impact. This movement has become a force of its own and, as a result, is compelling professionals engaged in all phases of building design, construction, operation, financing, insurance, and public policy to fundamentally rethink the nature of the built environment.

In the second decade of the twenty-first century, circumstances have changed significantly since the onset of the sustainable construction movement. In 1990, the global population was 5.2 billion, climate change was just entering the public consciousness, the United States had just become the world's sole superpower, and Americans were paying just $1.12 for a gallon of gasoline. Fast-forwarding more than a quarter century, the world's population is approaching 7.9 billion, the effects of climate change are becoming evident at a pace far more rapid than was predicted, and COVID-19 has created enormous disruptions for humans and the economy. Prices for gasoline have fluctuated widely due to a recent abundance of oil produced by fracking but are about 2.5 times higher than in 1990. The convergence of financial crises, climate change, increasing numbers of conflicts, and new diseases has produced an air of uncertainty that grips governments and institutions around the world. What is still not commonly recognized is that all these problems are linked, and that population and consumption remain the twin horns of the dilemma that confronts humanity. Population pressures, increased consumption by wealthier countries, the understandable desire for a good quality of life among the 5 billion impoverished people on the planet, and the depletion of finite, nonrenewable resources are all factors creating the wide range of environmental, social, and financial crises that are characteristic of contemporary life in the early twenty-first century (see Figure 1.7).

These changing conditions are affecting the built environment in significant ways. First, there is an increased demand for buildings that are resource-efficient, that use minimal energy and water, and whose material content will have value for future populations. In 2000, the typical office building in the United States consumed over 300 kilowatt-hours per m^2 per year (kWh/m^2/yr) or 100,000 BTU/ft^2/year (BTU/ft^2/yr). Today's high-performance buildings are approaching 100 kWh/m^2/yr (33,000 BTU/ft^2/yr).[1] In Germany, the energy profiles of high-performance buildings are even more remarkable, in the range of 50 kWh/m^2/yr (17,000 BTU/ft^2/yr). It is important to recognize that reduced energy consumption generally causes a proportional reduction in climate change impacts. Reductions in water consumption in high-performance buildings are also noteworthy. A high-performance building in the United States can reduce potable water consumption by 50 percent simply by opting for the most water-efficient fixtures available, including

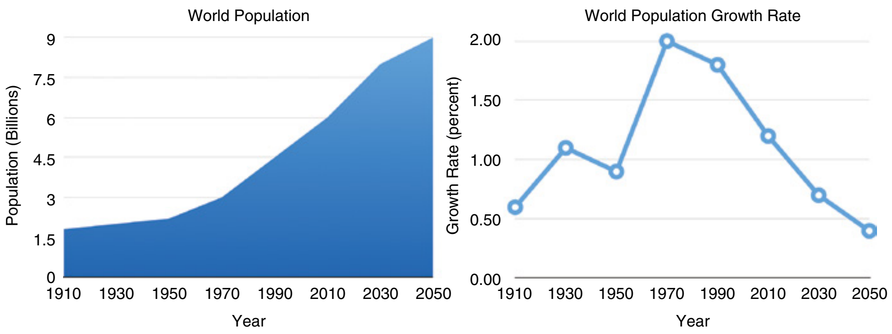

Figure 1.7 World population continues to increase, but the growth rate is declining, from about 1.2 percent in 2012 to a forecasted 0.5 percent in 2050. (*Source:* US Census Bureau)

high-efficiency toilets and high-efficiency urinals. By using alternative sources of water, such as rainwater and graywater, potable water consumption can be reduced by another 50 percent, to one-fourth that of a conventionally designed building water system. This is also referred to as a Factor 4 reduction in potable water use. Similar impressive impact reductions are emerging in materials consumption and waste generation.

Second, it has become clear over time that building location is a key factor in reducing energy consumption because transportation energy can amount to two times the operational energy of the building (Wilson and Navaro 2007; Fenner et al. 2020). Not only does this significant level of energy for commuting have environmental impacts, but it also represents a significant cost for the employees who make the daily commute. It is clear that the lower a building's energy consumption, the greater the proportion of total energy used in commuting. For example, a building that consumes 300 kWh/m^2/yr of operational energy and 200 kWh/m^2/yr of commuting energy by its occupants has 40 percent of its total energy devoted to transportation. A high-performance building in the same location with an energy profile of 100 kWh/m^2/yr and the same commuting energy of 200 kWh/m^2/yr would have 67 percent of its total energy consumed by transportation. Clearly, it makes sense to reduce transportation energy along with building energy consumption to have a significant impact on total energy consumption (see Figure 1.8).

Third, the threat of climate change is enormous and must be addressed across the entire life cycle of a building, including the energy invested in producing its materials and products and in constructing the building, commonly referred to as *embodied energy*. The energy invested in building materials and construction is significant, amounting to as much as 20 percent of the total life cycle energy of the facility. Furthermore, significant additional energy is invested by maintenance and renovation activities during the building's life cycle, sometimes exceeding the embodied energy of the construction materials. Perhaps the most noteworthy effort to address the built environment contribution to climate change is the *Architecture 2030 Challenge*, whose goal is to achieve a dramatic reduction in the greenhouse gas (GHG) emissions of the built environment by changing the way buildings and

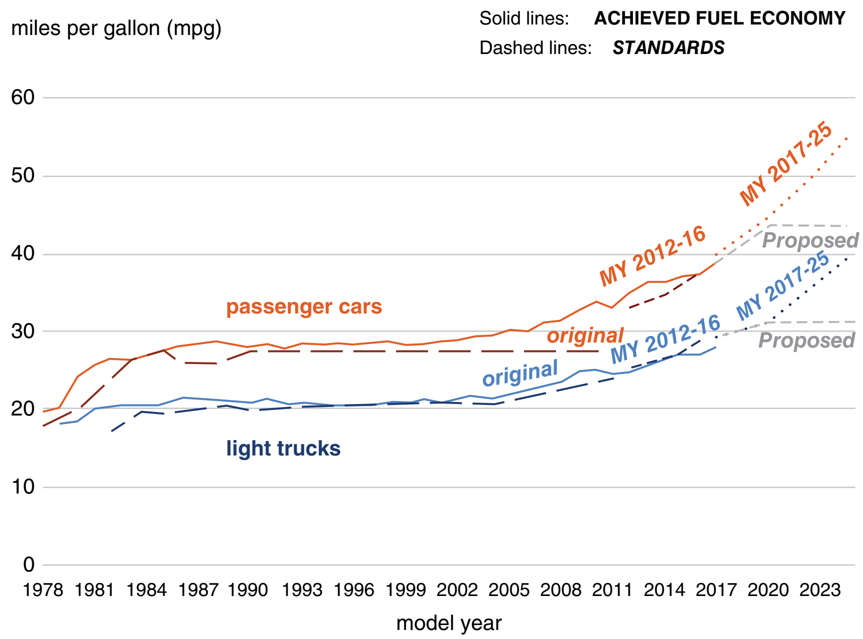

Figure 1.8 The fuel efficiency of US vehicles languished for decades before federal standards, due to the energy crises of the 1970s, demanded significant improvements in fuel performance. More recent requirements have increased dramatically the miles per gallon performance of both automobiles and trucks. (*Source:* EveryCRSReport.com, 2019)

developments are planned, designed, and constructed.[2] The 2030 Challenge asks the global architecture and building community to adopt the following targets:

- All new buildings, developments and major renovations shall be designed to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 70 percent below the regional (or country) average/median for that building type.
- At a minimum, an equal amount of existing building area shall be renovated annually to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 70 percent of the regional (or country) average/ median for that building type.
- The fossil fuel reduction standard for all new buildings and major renovations shall be increased to 80 percent in 2020, 90 percent in 2025, and be carbon neutral in 2030 (using no fossil fuel energy to operate).[3]

The *2030 Challenge for Product* addresses the GHG emissions of building materials and products and sets a goal of reducing the maximum carbon-equivalent footprint to 35 percent below the product category average by 2015 and eventually to 50 percent below the product category average by 2030.

The emerging concept of NZE, which, in its simplest form, suggests that buildings generate as much energy from renewables as they consume on an annual basis, also supports the goals of the 2030 Challenge. Every unit of energy generated by renewables that displaces energy generated from fossil fuels results in less climate change impact. An NZE building would, in effect, have no climate change impacts due to its operational energy. It is clear that influencing energy consumption and climate change requires a comprehensive approach that addresses all forms of energy consumption, including operational energy, embodied energy, and commuting energy.

In summary, high-performance building projects are now addressing three emerging challenges: (1) the demand for high-efficiency or *hyperefficient* buildings, (2) consideration of building location to minimize transportation energy, and (3) the challenges of climate change. These challenges are in addition to issues such as indoor environmental quality, protection of ecosystems and biodiversity, and risks associated with building materials. Building assessment systems such as LEED are being affected by these changes as is the very definition of green buildings. As time advances and more is learned about the future and its challenges, the design, construction, and operation of the built environment will adapt to meet this changing future landscape.

SUSTAINABLE DEVELOPMENT AND SUSTAINABLE CONSTRUCTION

The main impetus behind the high-performance green building movement is the sustainable development paradigm, which is changing not only physical structures but also the workings of the companies and organizations that populate the built environment, as well as the hearts and minds of the individuals who inhabit it.[4] Fueled by examples of personal and corporate irresponsibility and negative publicity resulting from events such as the collapse of the international finance system that triggered the Great Recession of 2008–2010, increased public concern about the behavior of private and public institutions has developed. As a result, accountability and transparency are becoming the watchwords of today's corporate world. Heightened corporate consciousness has embraced comprehensive sustainability reporting as the new standard for corporate transparency. The term *corporate transparency* refers to complete openness of companies about all financial transactions and all decisions that affect their employees and the communities in which they operate. Major companies, such as DuPont, the Ford Motor Company, and Hewlett-Packard, now employ triple bottom line reporting,[5] which involves a corporate refocus from mere financial results to a more comprehensive standard that includes environmental and social impacts. By adopting the cornerstone principles of sustainability in their annual reporting, corporations acknowledge their environmental and social impacts and ensure improvement in all arenas.

Still, other major forces, such as climate change and the rapid depletion of the world's oil reserves, threaten national economies and the quality of life in developed countries. Both are connected to our dependence on fossil fuels, especially oil. Climate change, caused at least in part by increasing concentrations of human-generated carbon dioxide (CO_2), methane, and other gases in Earth's atmosphere, is believed by many authoritative scientific institutions and Nobel laureates to profoundly affect our future temperature regimes and weather patterns.[6] Much of today's built environment will still exist during the coming era of rising temperatures and sea levels; however, little consideration has been given to how human activity and building construction should adapt to potentially significant climate alterations. Global temperature increases now must be considered when forming assumptions about passive design, the building envelope, materials selection, and the types of equipment required to cope with higher atmospheric energy levels.

The state of the global economy and consumption continue to significantly affect the state of Earth's environment. The Chinese economy grew at an official rate of 7 percent in 2015, with some estimates that it will continue to grow at or above this pace over the next few years. China produced about 2 million automobiles in 2000 and 22 million in 2020. China's burgeoning industries are in heavy competition with the United States and other major economies for oil and other key resources, such as steel and cement. The Chinese economy saw a sharp decline to 3.2 percent in the first three months of 2020 during the coronavirus lockdowns. However it is expected to rapidly recover to its normal fast growth rate in the early 2020s (see Figure 1.9) The rapid economic growth in China and India and concerns over the contribution of fossil fuel consumption to climate change will inevitably force the price of gasoline and other fossil fuel–derived energy sources to increase rapidly in the coming decades. At present, there are no foreseeable technological substitutes for large-scale replacement of fossil fuels. Alternatives such as hydrogen or fuels derived from coal and tar sands threaten to be prohibitively expensive. The

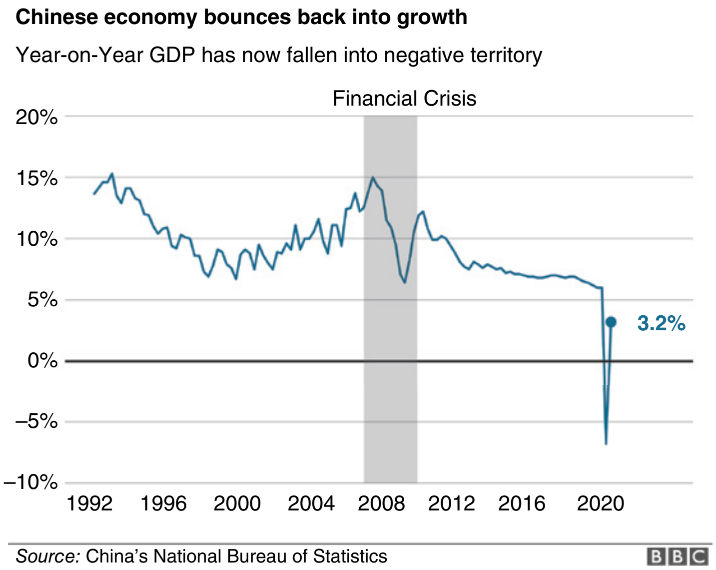

Figure 1.9 Chinese economy bounces back into growth (*Source:* BBC News)

expense of operating buildings that are heated and cooled using fuel oil and natural gas will likely increase, as will industrial, commercial, and personal transportation that is fossil fuel dependent. A shift toward hyperefficient buildings and transportation cannot begin soon enough.

The Vocabulary of Sustainable Development and Construction

A unique vocabulary is emerging to describe concepts related to sustainability and global environmental changes. Terms such as *Factor 4* and *Factor 10*, *ecological footprint*, *ecological rucksack*, *biomimicry*, the *Natural Step*, *eco-efficiency*, *ecological economics*, *biophilia*, and the *precautionary principle* describe the overarching philosophical and scientific concepts that apply to a paradigm shift toward sustainability. Complementary terms, such as *green building*, *building assessment*, *ecological design*, *life-cycle assessment (LCA)*, *life-cycle costing (LCC)*, *high-performance building*, and *charrette*, articulate specific techniques in the assessment and application of principles of sustainability to the built environment.

The sustainable development movement has been evolving worldwide for almost 25 years, causing significant changes in building delivery systems in a relatively short period. Sustainable construction, a subset of sustainable development, addresses the role of the built environment in contributing to the overarching vision of sustainability. The key vocabulary of this relatively new movement is discussed in the following sections and in Chapter 2. Additionally, a glossary of key terms and an index of abbreviations is included at the end of this book.

SUSTAINABLE CONSTRUCTION

The terms *high performance*, *green*, and *sustainable construction* often are used interchangeably; however, the term *sustainable construction* most comprehensively addresses the ecological, social, and economic issues of a building in the context of its community. In 1994, Task Group 16 of the Conseil International du Bâtiment (CIB), an international construction research networking organization, defined sustainable construction as "creating and operating a healthy built environment based on resource efficiency and ecological design."[7] Task Group 16 articulated seven Principles of Sustainable Construction that ideally would inform decision-making during each phase of the design and construction process, continuing throughout the building's entire life cycle (see Table 1.1; see also Kibert 1994). These factors also apply when evaluating the components and other resources needed for construction (see Figure 1.10). The Principles of Sustainable Construction apply across the entire life cycle of construction, from planning to disposal (here referred to as *deconstruction* rather than *demolition*). Furthermore, the principles apply to the resources needed to create and operate the built environment during its entire life cycle: land, materials, water, energy, and ecosystems.

TABLE 1.1

Principles of Sustainable Construction
1. Reduce resource consumption (reduce).
2. Reuse resources (reuse).
3. Use recyclable resources (recycle).
4. Protect nature (nature).
5. Eliminate toxics (toxics).
6. Apply life-cycle costing (economics).
7. Focus on quality (quality).

Source: Kibert 1994.

GREEN BUILDING

The term *green building* refers to the quality and characteristics of the actual structure created using the principles and methodologies of sustainable construction. Green buildings can be defined as "healthy facilities designed and built in a resource-efficient manner, using ecologically based principles" (Kibert 1994). Similarly, *ecological design*, *ecologically sustainable design*, and *green design* are terms that describe the application of sustainability principles to building design. Despite the prevalent

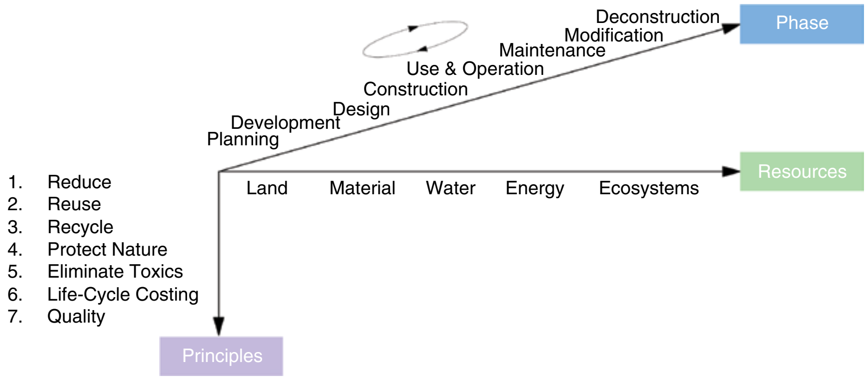

Figure 1.10 Framework for sustainable construction developed in 1994 by the CIB Task Group 16 (Sustainable Construction) for the purpose of articulating the potential contribution of the built environment to the attainment of sustainable development. (*Source:* Courtesy of Bilge Çelik)

use of these terms, truly sustainable green commercial buildings with renewable energy systems, closed materials loops, and full integration into the landscape are rare to nonexistent. Most existing green buildings feature incremental improvement over, rather than radical departure from, traditional construction methods. Nonetheless, this process of trial and error, along with the gradual incorporation of sustainability principles, continues to advance the industry's evolution toward the ultimate goal of achieving complete sustainability throughout all phases of the built environment's life cycle.

HIGH-PERFORMANCE BUILDINGS, SYSTEMS THINKING, AND WHOLE-BUILDING DESIGN

The term *high-performance building* recently has become popular as a synonym for green building in the United States. According to the Office of Energy Efficiency and Renewable Energy of the US Department of Energy, a high-performance commercial building "uses whole-building design to achieve energy, economic, and environmental performance that is substantially better than standard practice." This approach requires that the design team fully collaborate from the project's inception in a process often referred to as *integrated design*.

Whole-building design,[8] or integrated design, considers site, energy, materials, indoor air quality, acoustics, and natural resources as well as their interrelation with one another. In this process, a collaborative team of architects, engineers, building occupants, owners, and specialists in indoor air quality, materials, and energy and water efficiency uses systems thinking to consider the building structure and systems holistically, examining how they best work together to save energy and reduce the environmental impact. A common example of systems thinking is advanced daylighting strategy, which reduces the use of lighting fixtures during daylight, thereby decreasing daytime peak cooling loads and justifying a reduction in the size of the mechanical cooling system. This, in turn, results in reduced capital outlay and lower energy costs over the building's life cycle.

According to the Rocky Mountain Institute (RMI), a well-respected nonprofit organization specializing in energy and building issues, whole-systems thinking is a process through which the interconnections between systems are actively considered and solutions are sought that address multiple problems. Whole-systems thinking often is promoted as a cost-saving technique that allows additional capital to be invested in new building technology or systems. RMI cites developer Michael Corbett, who applied just such a concept in his 240-unit Village Homes subdivision in Davis, California, completed in 1981. Village Homes was one of the first modern-era developments to create an environmentally sensitive, human-scale residential community. The result of designing narrower streets was reduced stormwater runoff. Simple infiltration swales and on-site detention basins handled stormwater without the need for conventional stormwater infrastructure. The resulting $200,000 in savings was used to construct public parks, walkways, gardens, and other amenities that improved the quality of the community. Another example of systems thinking is Solaire, a 27-story luxury residential tower in New York City's Battery Park (see Figure 1.11) that, when completed in 2003, was the first green high-rise residential building in the United States. The façade of Solaire contains PV cells that convert sunlight directly into electricity, and the building itself uses 35 percent less energy than a comparable residential building. Solaire provides its residents with abundant natural light and excellent indoor air quality. The building collects rainwater in a basement tank for watering roof gardens. Wastewater is processed for reuse in the air-conditioning system's cooling towers or for flushing toilets. The roof gardens not only provide a beautiful urban landscape but also assist in insulating the building to reduce heating and cooling loads. This interconnection of many of the green building measures in Solaire indicates that the project team carefully selected approaches that would have multiple layers of benefit, the core of systems thinking.[9]

SUSTAINABLE DESIGN, ECOLOGICAL DESIGN, AND GREEN DESIGN

The issue of resource-conscious design is central to sustainable construction, which ultimately aims to minimize natural resource consumption and the resulting impact on ecological systems. Sustainable construction considers the role and potential interface with ecosystems to provide services in a synergistic fashion. With respect to materials selection, closing materials loops and eliminating solid, liquid, and gaseous emissions

Figure 1.11 Solaire, a 27-story residential tower on the Hudson River in New York City built in 2003, was the first high-rise residential building in the United States specifically designed to be environmentally responsible. (*Source:* Courtesy of the Albanese Development Corporation)

are key sustainability objectives. *Closed loop* describes a process of keeping materials in productive use by reuse and recycling rather than disposing of them as waste at the end of the product or building life cycle. Products in closed loops are easily disassembled, and the constituent materials can be recycled and are worthy of recycling. Because recycling is not entirely thermodynamically efficient, dissipation of residue into the biosphere is inevitable. Thus, the recycled materials must be inherently nontoxic to biological systems. Most common construction materials are not completely recyclable but rather are *downcyclable* for lower-value reuse, such as for fill or road subbase. Fortunately, aggregates, concrete, fill dirt, block, brick, mortar, tiles, terrazzo, and similar low technology materials are composed of inert substances with low ecological toxicity. In the United States, the 160 million tons (145 million metric tons [mt]) of construction and demolition waste produced annually make up about one-third of the total solid waste stream, consuming scarce landfill space, threatening water supplies, and driving up the costs of construction. As part of the green building delivery system, manufactured products are evaluated for their life-cycle impacts, to include energy consumption and emissions during resource extraction, transportation, product manufacturing, and installation during construction; operational impacts; and the effects of disposal.

LAND RESOURCES

Sustainable land use is based on the principle that land, particularly undeveloped, natural, or agricultural land (greenfields), is a precious finite resource and its development should be minimized. Effective planning is essential for creating efficient urban forms and minimizing urban sprawl, which leads to overdependence on automobiles for transportation, excessive fossil fuel consumption, and higher pollution levels. Like other resources, land is recyclable and should be restored to productive use whenever possible. Recycling disturbed land such as former industrial zones (brownfields) and blighted urban areas (grayfields) back to productive use facilitates land conservation and promotes economic and social revitalization in distressed areas.

ENERGY AND CARBON

Energy conservation is best addressed through effective building design, which integrates three general approaches: (1) fully implementing passive design; (2) designing a building envelope that is highly resistant to conductive, convective, and radiative heat transfer; and (3) employing renewable energy resources. Passive design employs the building's geometry, orientation, and mass to condition the structure using natural and climatologic features, such as the site's solar *insolation* (or incoming solar radiation), thermal chimney effects, prevailing winds, local topography, microclimate, and landscaping. Since buildings in the United States consume 40 percent of domestic primary energy,[10] increased energy efficiency and a shift to renewable energy sources can appreciably reduce CO_2 emissions and mitigate climate change.

WATER ISSUES

The availability of potable water is the limiting factor for development and construction in many areas of the world. In the high-growth Sun Belt and western regions of the United States, the demand for water threatens to rapidly outstrip the natural supply, even in normal, drought-free conditions.[11] California is experiencing an epic drought that threatens not only the most agriculturally productive region of the world but also the economy of the state and perhaps the United States. Climate alterations and erratic weather patterns precipitated by global warming threaten to further limit the availability of this most precious resource. Since only a small portion of Earth's hydrologic cycle yields potable water, protection of existing groundwater and surface water

Figure 1.12 The Lewis Center for Environmental Studies at Oberlin College in Oberlin, Ohio, was designed by a team led by William McDonough, a leading green building architect, and including John Todd, developer of the Living Machine. In addition to the superb design of the building's hydrologic strategy, the extensive PV system makes it an NZE building. (*Source:* Courtesy of Oberlin College)

supplies is increasingly critical. Once water is contaminated, it is extremely difficult, if not impossible, to reverse the damage. Water conservation techniques include the use of low-flow plumbing fixtures, water recycling, rainwater harvesting, and xeriscaping, a landscaping method that uses drought-resistant plants and resource-conserving techniques.[12] Innovative approaches to wastewater processing and stormwater management are also necessary to address the full scope of the building hydrologic cycle.

ECOSYSTEMS: THE FORGOTTEN RESOURCE

Sustainable construction considers the role and potential interface of ecosystems in providing services in a synergistic fashion. Integration of ecosystems with the built environment can play an important role in resource-conscious design. Such integration can supplant conventional manufactured systems and complex technologies in controlling external building loads, processing waste, absorbing stormwater, growing food, and providing natural beauty, sometimes referred to as *environmental amenity*. For example, the Lewis Center for Environmental Studies at Oberlin College in Oberlin, Ohio, uses a built-in natural system, referred to as a "Living Machine," to break down waste from the building's occupants; the effluent then flows into a reconstructed wetland (see Figure 1.12). The wetland also functions as a stormwater retention system, allowing pulses of stormwater to be stored and thereby reducing the burden on stormwater infrastructure. The restored wetland also provides environmental amenity in the form of native Ohio plants and wildlife.[13]

Rationale for High-Performance Buildings

High-performance green buildings marry the best features of conventional construction methods with emerging high-performance approaches. Green buildings are achieving rapid penetration in the US construction market for three primary reasons:

1. *Sustainable construction provides an ethical and practical response to issues of environmental impact and resource consumption*. Sustainability assumptions encompass the entire life cycle of the building and its constituent components, from resource extraction through disposal at the end of the useful life of the materials. Conditions and processes in factories are considered, along with the actual performance of their manufactured products in the completed building. High-performance green building design relies on renewable resources for energy systems; recycling and reuse of water and materials; integration of native and adapted species for landscaping; passive heating, cooling, and ventilation; and other approaches that minimize environmental impact and resource consumption.
2. *Green buildings virtually always make economic sense on life-cycle costing (LCC) basis, although they may be more expensive on a capital, or first-cost, basis*. Sophisticated energy-conserving lighting and air-conditioning systems with an exceptional response to interior and exterior climates will cost more than their conventional, code-compliant counterparts. Rainwater harvesting systems that collect and store rainwater for nonpotable uses will require additional piping, pumps, controls, storage tanks, and filtration components. However, most key green building systems will recoup their

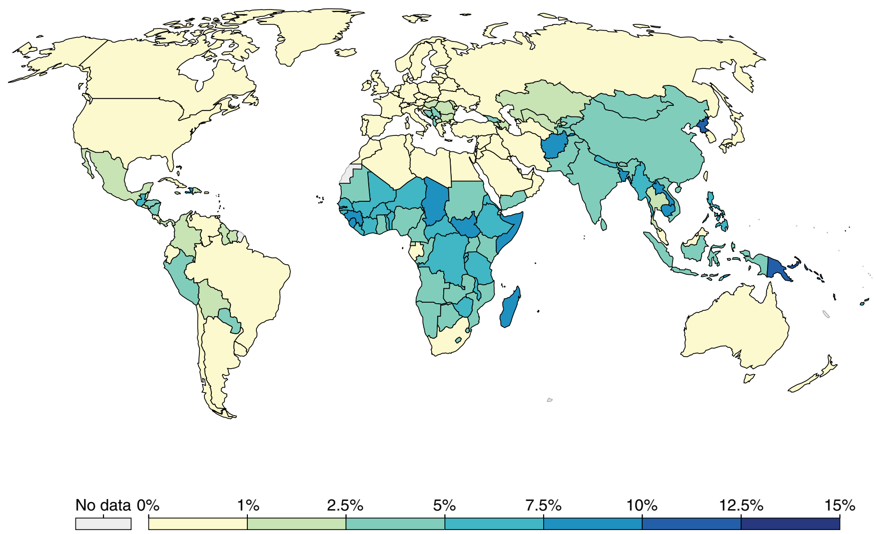

Figure 1.13 Share of deaths from indoor air pollution: 2017. (*Source:* IHME, Global Burden of Disease)

original investment within a relatively short time. As energy and water prices rise due to increasing demand and diminishing supply, the payback period will decrease.

3. *Sustainable design acknowledges the potential effect of the building, including its operation, on the health of its human occupants*. A 2012 report from the Global Indoor Health Network suggested that, globally, about 50 percent of all illnesses are caused by indoor air pollution (see Figure 1.13).[14] Estimates peg the direct and indirect costs of building-related illnesses (BRIs), including lost worker productivity, as exceeding $150 billion per year (Zabarsky 2002). In 2017, about 3 percent of global deaths were a result of indoor air pollution (Ritchie and Roser 2019). Conventional construction methods have traditionally paid little attention to sick building syndrome BRI and multiple chemical sensitivity until prompted by lawsuits. By contrast, green buildings are designed to promote occupant health; they include measures such as protecting ductwork during installation to avoid contamination during construction; specifying finishes with low to zero volatile organic compounds to prevent potentially hazardous chemical off-gassing; more precise sizing of heating and cooling components to promote dehumidification, thereby reducing mold; and the use of ultraviolet radiation to kill mold and bacteria in ventilation systems.[15]

State and Local Green Building Initiatives

At the onset of the green building movement, several state and local governments took the initiative in articulating guidelines aimed at facilitating high-performance construction. In 1999, the Pennsylvania Governor's Green Government Council (GGGC) used mixed but very appropriate terminology in its "Guidelines for Creating High-Performance Green Buildings." The lengthy but instructive definition of high-performance green building (see Table 1.2) focused as much on the collaborative involvement of the stakeholders as it did on the physical specifications of the structure itself.

Similar guidance was provided by the New York City Department of Design and Construction in its 1999 "High Performance Building Guidelines," in which the end product, the building, is hardly mentioned, and the emphasis is on the strong collaboration of the participants (see Table 1.3).

TABLE 1.2

High-Performance Green Building as Defined by the Pennsylvania GGGC
A project created via cooperation among building owners, facility managers, users, designers, and construction professionals through a collaborative team approach.
A project that engages the local and regional communities in all stages of the process, including design, construction, and occupancy.
A project that conceptualizes a number of systems that, when integrated, can bring efficiencies to mechanical operation and human performance.
A project that considers the true costs of a building's impact on the local and regional environment.
A project that considers the life-cycle costs of a product or system. These are costs associated with its manufacture, operation, maintenance, and disposal.
A building that creates opportunities for interaction with the natural environment and defers to contextual issues such as climate, orientation, and other influences.
A building that uses resources efficiently and maximizes use of local building materials.
A project that minimizes demolition and construction wastes and uses products that minimize waste in their production or disposal.
A building that is energy- and resource-efficient.
A building that can be easily reconfigured and reused.
A building with healthy indoor environments.
A project that uses appropriate technologies, including natural and low-tech products and systems, before applying complex or resource-intensive solutions.
A building that includes an environmentally sound operations and maintenance regimen.
A project that educates building occupants and users to the philosophies, strategies, and controls included in the design, construction, and maintenance of the project.

Source: Pennsylvania GGGC 1999.

TABLE 1.3

Goals for High-Performance Buildings According to the New York City Department of Design and Construction
Raise expectations for the facility's performance among the various participants.
Ensure that capital budgeting design and construction practices result in investments that make economic and environmental sense.
Mainstream these improved practices through (1) comprehensive pilot high-performance building efforts and (2) incremental use of individual high-performance strategies on projects of limited scope.
Create partnerships in the design and construction process around environmental and economic performance goals.
Save taxpayers money through reduced energy and material expenditures, waste disposal costs, and utility bills.
Improve the comfort, health, and well-being of building occupants and public visitors.
Design buildings with improved performance, which can be operated and maintained within the limits of existing resources.
Stimulate markets for sustainable technologies and products.

Source: Excerpted from "High Performance Building Guidelines" 1999.

The “High Performance Guidelines: Triangle Region Public Facilities,” published by the Triangle J Council of Governments in North Carolina in 2001, focused on three principles:

1. *Sustainability*, which is a long-term view that balances economics, equity, and environmental impacts
2. *An integrated approach*, which engages a multidisciplinary team at the outset of a project to work collaboratively throughout the process
3. *Feedback and data collection*, which quantifies both the finished facility and the process that created it and serves to generate improvements in future projects

Like the other state and local guidelines, North Carolina’s “High Performance Guidelines” emphasized the collaboration and process, rather than merely the physical characteristics of the completed building. Historically, building owners assumed that they were benefiting from this integrated approach as a matter of course. In practice, however, the lack of coordination among design professionals and their consultants often resulted in facilities that were problematic to build. Now the green building movement has begun to emphasize that strong coordination and collaboration is the true foundation of a high-quality building. This philosophy promises to influence the entire building industry and, ultimately, to enhance confidence in the design and construction professions.

Green Building Progress and Obstacles

Until recently considered a fringe movement, in the early twenty-first century, the green building concept has won industry acceptance, and it continues to influence building design, construction, operation, real estate development, and sales markets. Detailed knowledge of the options and procedures involved in “building green” is invaluable for any organization providing or procuring design or construction services. The number of commercial buildings certified with the USGBC for a LEED building assessment grew from just a few in 1999 to more than 26,500 in late 2009. By 2020, the number of certified buildings had grown to over 35,500. Federal and state governments, many cities, several universities, and a growing number of private-sector construction owners have declared sustainable or green materials and methods as their standard for procurement.

Despite the success of LEED and the US green building movement in general, challenges abound when implementing sustainability principles within the well-entrenched traditional construction industry. Although proponents of green buildings have argued that whole systems thinking must underlie the design phase of this new class of buildings, conventional building design and procurement processes are very difficult to change on a large scale. Additional impediments also may apply. For example, most jurisdictions do not yet permit the elimination of stormwater infrastructure in favor of using natural systems for stormwater control. Daylighting systems do not eliminate the need for a full lighting system since buildings generally must operate at night. Special low-emissivity (low-E) window glazing, skylights, light shelves, and other devices increase project cost. Controls that adjust lighting to compensate for varying amounts of available daylight, and occupancy sensors that turn lights on and off depending on occupancy, add additional expense and complexity. Rainwater harvesting systems require dedicated piping, a storage tank or cistern, controls, pumps, and valves, all of which add cost and complexity.

Green building materials often cost substantially more than the materials they replace. Compressed wheatboard, a green substitute for plywood, can cost as much

TABLE 1.4

Trends and Barriers to Green Building in the United States

Trends

1. Rapid penetration of the LEED green building rating system and growth of USGBC membership
2. Strong federal leadership
3. Public and private incentives
4. Expansion of state and local green building programs
5. Industry professionals taking action to educate members and integrate best practices
6. Corporate America capitalizing on green building benefits
7. Advances in green building technology

Barriers

1. Financial disincentives
   a. Lack of LCC analysis and use
   b. Real and perceived higher first costs
   c. Budget separation between capital and operating costs
   d. Security and sustainability perceived as trade-offs
   e. Inadequate funding for public school facilities
2. Insufficient research
   a. Inadequate research funding
   b. Insufficient research on indoor environments, productivity, and health
   c. Multiple research jurisdictions

Source: Adapted from US Green Building Council 2003.

as four times more than the plywood it replaces. The additional costs, and those associated with green building compliance and certification, often require owners to add a separate line item to the project budget. The danger is that, during the course constructing a building, when costs must be brought under control, the sustainability line item is one of the first to be "value-engineered" out of the project. To avoid this result, it is essential that the project team and the building owner clearly understand that sustainability goals and principles are paramount and that LCC should be the applicable standard when evaluating a system's true cost. Yet even LCC does not guarantee that certain measures will be cost-effective in the short or long term. Where water is artificially cheap, systems that use rainwater or graywater are difficult to justify financially, even under the most favorable assumptions. Finally, more expensive environmentally friendly materials may never pay for themselves in an LCC sense.

A summary of trends in, and barriers to, green building is presented in Table 1.4. They were generated by the Green Building Roundtable, a forum held by the USGBC for members of the US Senate Committee on Environment and Public Works in April 2002, and still apply today.

Trends in High-Performance Green Building

Even though the high-performance green building movement is relatively new, there have already been several shifts in direction as more is learned about the wider impacts of building and the accelerating effects of climate change. At the onset of this revolution in the early 1990s, the use of the *charrette* was a relatively new concept, as were integrated design, building commissioning, the design-build delivery system, and performance-based fees. All of these are now familiar green building themes and building industry professionals are familiar with their potential application.

Much has changed in a short span of time. Since 2008, energy prices have been erratic. Hydraulic fracturing (fracking) produced a rapid increase in oil and gas supplies in the United States. The result was equally rapid falling energy prices, which are causing havoc in the markets for renewable energy. Renewable energy had just become competitive with fossil fuel–based energy when the trend toward lower supplies of fossil fuel energy suddenly was reversed. However, the most significant environmental problem of our time, climate change, will only be exacerbated by short-term cheap energy. Within several decades, the world will be again faced with high energy prices plus the enormous and widespread impacts of climate change. This is a critical issue for green building, and thus the trend to NZE and net zero–carbon buildings that rely on extremely high energy and very high energy performance.

Another major shift is the demand for and increased attention to transparency for the products that constitute the built environment. A wide range of new tools have become available, such as environmental product declarations (EPDs), health product declarations (HPDs), risk-based assessments (RBAs), and multi-attribute standards. This is yet another indicator of the widening influence of the green building movement on the upstream activities of manufacturers and suppliers of built environment products.

New technologies, such as high-efficiency PV systems and building information modeling (BIM), are affecting approaches to project design and collaboration. Evidence is mounting that climate change is occurring significantly faster than even the most pessimistic models predicted. Some fundamental thinking about green building assessment has changed, and there is significant impetus toward integrating LCA far more deeply into project evaluation. The impacts of building location are being taken into account since it has become apparent that the energy and carbon associated with transportation is approaching the levels resulting from construction and operation of the built environment. The next sections address these emerging trends in more detail and provide some insights into how they are affecting high-performance green buildings.

TRANSPARENCY

The term *transparency*, when associated with the green building movement, is concerned with the open provision of information about: (1) building energy and water performance and (2) the impacts of the materials and products that compose the building. Building product transparency requires that manufacturers reveal product ingredients so that project teams will have information that allows them to decide if there are any potential toxicity problems with the chemicals that compose the product. Nonprofit organizations and industry associations are creating numerous tools designed to meet the demand of this relatively new movement. The trend toward product transparency and full disclosure is part of a larger trend in corporate sustainability in which large companies such as Walmart and Target are requiring their suppliers to disclose ingredients and to phase out certain chemicals of concern in their consumer products. Health Product Declarations, which have become mainstream tool, are one approach to addressing the demand for transparency. An HPD reports the materials or contents of a building product and the associated health effects. The content of this report and its format is governed by the HPD Open Standard ™. HPDs have a standard format to allow users to become familiar with the location of key elements of information. It is voluntary and can be used by manufacturers to disclose information about product ingredients that they judge would be useful to the market. The HPD is designed to be flexible and allows manufacturers to deal with issues of intellectual property or supply chain communication gaps by letting them characterize the level of disclosure they able to achieve. In short this means that the HPD does not force the manufacturer to disclose proprietary or competitive trade information.

A complementary tool connected to transparency is the EPD. Whereas HPDs are designed to disclose human health impacts, EPDs provide detailed information on the environmental impacts of products. EPDs are third-party LCAs using a methodology spelled out in the international standards, ISO 14025. Similar to HPDs, EPDs have a standard format that makes them fairly easy to use by project teams or other stakeholders. Some of the impacts reported via EPDs include global warming potential, ozone depletion potential, and eutrophication. Although these tools provide enormous amounts of information about products, their actual utility is still being debated. The nub of the debate is about whether these products can be used to judge which products are best from a health and environmental standpoint and whether project teams have the knowledge and resources to utilize these tools effectively. HPDs generally are categorized as *hazard-based* tools because they use a hazard list to scan product chemicals for potential issues. An alternative to hazard-based approaches is RBA; such assessments include in the analysis standard toxicological approaches involving dose and exposure scenarios.

The other type of transparency that is rapidly emerging is *building performance information*. In the United States, large cities are leading the drive to make energy and water consumption data for all buildings openly available. In general, these cities require not only disclosure of the performance data but also require efforts to reduce energy consumption. On Earth Day 2009, Mayor Michael Bloomberg announced New York City's *Greener, Greater Buildings Plan* (GGBP), which required the bench-marking and public disclosure of building energy performance and water consumption; periodic energy audits and building tune-ups known as *retro-commissioning*; lighting upgrades; submetering of large tenant spaces; and improvements to the city's building energy code. Roughly 80 percent of New York City's carbon footprint is connected to building operations, and the GGBP is designed to reduce the city's GHG emissions 30 percent by 2030. The *New York City Benchmarking Law* requires owners of large building to record their annual energy and water use in ENERGY STAR Portfolio Manager® and then submit the data to the City.

In April 2015, Atlanta, Georgia, became the first southern city to pass legislation requiring the collection and reporting of energy use data in the city's commercial buildings. In Atlanta, the goal is a 20 percent reduction in energy consumption by commercial buildings by 2030, creation of more than 1,000 jobs annually for the first few years, and cutting carbon emissions in half from 2013 levels by 2030. The *Atlanta Commercial Buildings Energy Efficiency Ordinance* also encourages periodic energy audits and improvements to existing building equipment and functions (i.e., retro-commissioning). Under the Commercial Buildings Energy Efficiency Ordinance, owners of commercial buildings, including multifamily buildings with an area greater than over 25,000 ft^2, are required to benchmark their energy and water usage, submit that data to the City on an annual basis, and have an ASHRAE Level 2 energy audit conducted every ten years (see Figure 1.14).

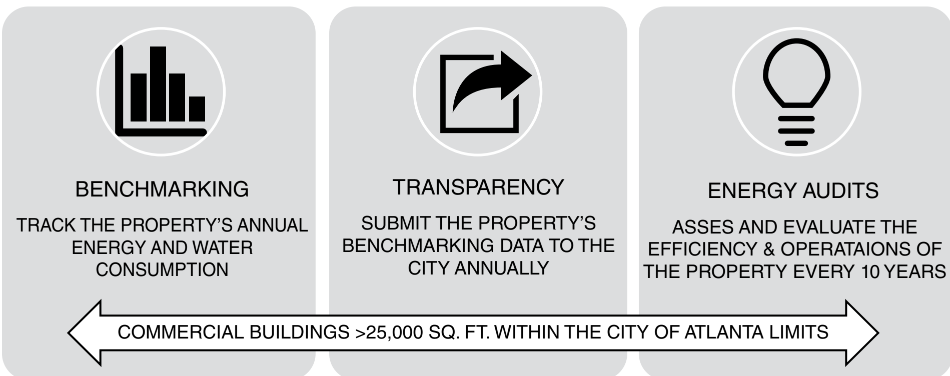

Figure 1.14 Overview of Atlanta benchmarking requirement. (*Source:* City of Atlanta Mayor's Office)

A more extensive discussion of building product transparency can be found in Chapter 11; additional insights into energy reporting are included in Chapter 9.

CARBON ACCOUNTING

By virtually all accounts, climate change seems to be accelerating and lining up with the worst-case scenarios hypothesized by scientists. One unexpected event that is rapidly increasing levels of atmospheric CO_2, the primary cause of climate change, is drought, which causes, among other things, the death of rainforest trees. Researchers calculate that millions of trees died in 2010 in the Amazon due to what has been referred to as a 100-year drought. The result is that the Amazon is soaking up much less CO_2 from the atmosphere, and the dead trees are releasing all the carbon they accumulated over 300 or more years. The widespread 2010 drought followed a similar drought in 2005 (another 100-year drought), which itself put an additional 5.5 billion tons (5 billion mt) of CO_2 into the atmosphere (see Lewis et al. 2011). In comparison, the United States, the world's second largest producer of CO_2 behind China, emitted 6.0 billion tons (5.3 billion mt) of CO_2 from fossil fuel use in 2019. The two droughts added an estimated 14.3 billion tons (13 billion mt) to atmospheric carbon and likely accelerated global warming.

And finally, the 2018 IPCC report stated that sea levels will most likely rise between 0.95 ft (0.29m) and 3.61 ft (1.1m) by the end of this century. The only conclusion that can be reached by observing the many positive feedback loops influencing climate change is that all indicators point to a much higher rate of change than had been predicted.

The result of these alarming changes is that releases of CO_2 into the atmosphere are becoming an increasingly serious issue. Governments around the world are making plans to reduce carbon emissions, which entails tracking or accounting for carbon to guide reducing its production. The built environment, with enormous quantities of *embodied energy*[18] and associated operational and transportation energy, is a ripe target for gaining control of global carbon emissions. It is likely that projects that can demonstrate significant reductions in total carbon emissions will be far better received than those with relatively high carbon footprints, which could conceivably be banned. New concepts, such as *low-carbon, carbon-neutral*, and *zero-carbon buildings*, are emerging in an effort to begin coping with the huge quantities of carbon emissions associated with the built environment. On the order of 40 percent of all carbon emissions are associated with building construction and operation, and it is likely that as much as another 20 percent could be attributable to transportation. Perhaps nowhere in the world has there been more interest and progress in low-carbon building than in the United Kingdom. The Carbon Trust was established by the government as a nonprofit company to take the lead in stimulating low-carbon actions, contributing to UK goals for lower carbon emissions, the development of low-carbon businesses, and increased energy security and associated jobs, with a vision of a low-carbon, competitive economy. We can expect to see control of carbon emissions and other measures to mitigate their impacts becoming an ever more prominent feature of high-performance green buildings. Chapter 12 provides details on how to account for the carbon footprint of the built environment.

NET ZERO BUILDINGS

In the early 1990s, William McDonough, the noted American green building architect and thinker, suggested that buildings should, among other things, "live off current solar income." Today, what seemed a rash prediction is becoming reality as the combination of high-performance buildings and high-efficiency, low-cost renewable energy technologies are providing the potential for buildings that, in fact, can live off current solar income. These are commonly referred to as NZE buildings. In general, these are grid-connected buildings that export excess energy produced during the day and import energy in the evenings, such that there is an energy balance over the course of the year. As a result, NZE buildings have a zero annual energy bill. The added bonus is that they are considered carbon neutral with respect to their operational energy.

An excellent example of an NZE building is the research support facility (RSF) designed and built for the National Renewable Energy Laboratory (NREL) in Golden, Colorado. The RSF is a 220,000 ft^2 (20,450-m^2), four-story building with a PV system on-site. It is interesting to note that a 2007 NREL study concluded that one-story buildings could achieve NZE if the building roof alone were used for the PV system but that it would be extremely difficult for two-story buildings to meet this goal (Griffith et al. 2007). Clearly, much has been learned in a short time because the RSF has four stories, twice the limit suggested by NREL's own research. The Energy Use Intensity (EUI) of the RSF is just 32,000 BTU/ft^2/yr (101 kWh/m^2/yr), making it a very low energy building with the potential for producing enough PV energy to meet all its annual energy needs (see Figures 1.15 through 1.18). The relatively narrow building floor plate, just 60 ft (19.4 m) wide, enables daylighting and natural ventilation for its 800 occupants, and 100 percent of the workstations are daylit. Building orientation and geometry minimize the need for east and west glazing. North and south glazing is optimally sized and shaded to provide daylighting while minimizing unwanted heat losses and gains. The building uses triple-glazed operable windows and window shading to address different orientations and positioning of its glazed openings. The operable windows can be used by the occupants to provide natural ventilation and cooling for the building. Electrochromic windows, which can be darkened using a small amount of electrical current, are used on the west side of the building to control glare and heat gain. The RSF has approximately 42 miles (67 km) of radiant piping embedded in all floors of the building to provide water for radiant cooling and heating the majority of the workspaces. This radiant system provides thermal conditioning for the building at a fraction of the energy costs of the forced-air systems used in most office buildings. A thermal storage labyrinth under the RSF stores heating and cooling in its concrete structure and is integrated into the building energy recovery system. Outdoor air is heated by a transpired solar collector

Figure 1.15 The NREL Research Support Facility in Golden, Colorado, is a four-story NZE building that combines low-energy design with high-efficiency photovoltaics to produce all the energy it requires over the course of a year. (*Source:* National Renewable Energy Laboratory)

system located on the façade of the structure. Approximately 1.6 MW of on-site PVs are being installed and dedicated to RSF use. Rooftop PV power will be added through a power purchase agreement, and PV power from adjacent parking areas will be purchased by the building through arrangement with a local utility. The RSF was awarded a LEED platinum rating in recognition of the success of its integrated design and the holistic approach of the project team.

The implementation of NZE is now national policy, and the US Department of Energy has programs in place with the objective that all new buildings will be NZE by 2050. In some local jurisdictions, such as Austin, Texas, new homes were required to be NZE by 2015. This important new trend appears to have significant momentum and will influence the direction of green building evolution.

Figure 1.16 Ground view of the air intake structure that conducts outside air into the thermal storage labyrinth in the crawl space of the NREL RSF. (*Source:* National Renewable Energy Laboratory)

BUILDING INFORMATION MODELING

The emergence of BIM as a design and visualization tool is an important trend for the building industry. Its three-dimensional modeling promises to provide owners with a far better representation of their projects, increase the quality of both design and construction, and increase the speed of construction. BIM makes the handling of complex projects with enormous information requirements far easier. One of the attributes of high-performance green building projects is their reliance on significant additional modeling, additional specification requirements, and the need to track numerous aspects of the construction process, such as construction waste management, indoor air quality protection during construction, and erosion and sedimentation control. Additionally, quantities of recycled materials, emissions from materials, and other data must be gathered for green building certification. BIM has the capability of accepting plug-ins that can perform energy modeling and daylighting simulation and provide a platform for the data required by green building certification bodies. BIM software makes it relatively easy to select the optimum site and building orientation to maximize renewable energy generation and daylighting and minimize energy consumption. BIM is an important and potentially powerful tool that can further increase the uptake of green buildings by lowering costs. Although not strictly relevant to green building certification, it makes the process far easier and less costly by providing "one-stop shopping" for information.

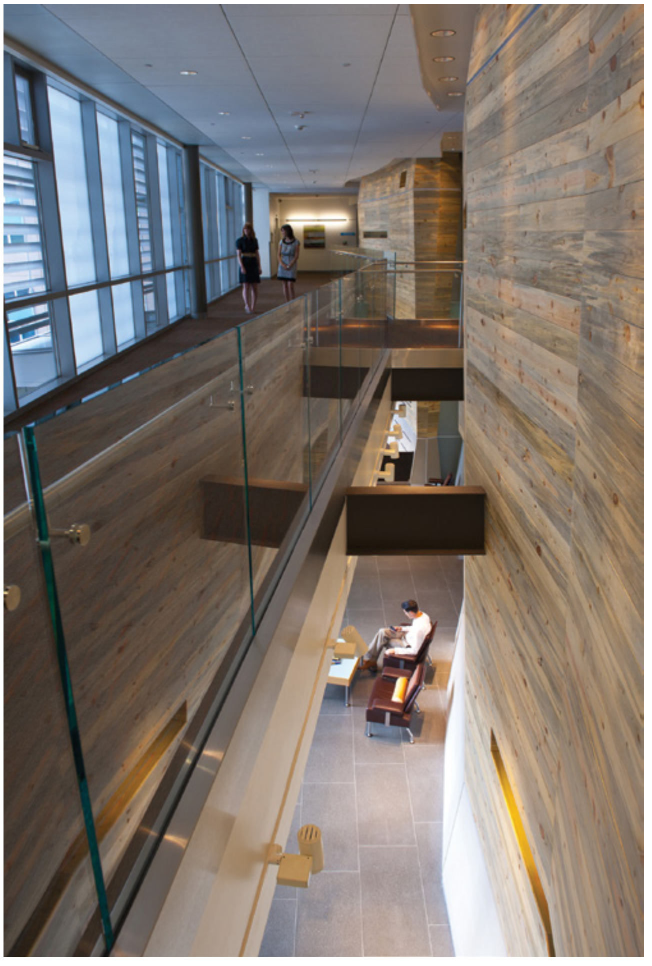

Figure 1.17 The daylighting system for the NREL RSF was designed using extensive simulation. Shading devices were carefully placed on the exterior and interior to manage both direct and indirect sunlight, distributing it evenly to create a bright, pleasant working environment. (*Source:* National Renewable Energy Laboratory)

LIFE-CYCLE ASSESSMENT

Although a mature concept, LCA is growing in importance because it allows the quantification of the environmental impacts of design decisions that span the entire life of the project. In the past, LCA was used to compare products and building assemblies, which provided some indication of how to improve decision-making but did not provide information about the long-term effects resulting from building operation. With the emergence of the German DGNB building assessment system, the environmental performance of the whole building—its materials, construction,

Figure 1.18 The fenestration for the NREL RSF was designed to provide excellent daylighting while controlling glare and unwanted solar thermal gain through the use of shading devices, recessed windows, and electrochromic glass. Operable windows allow the occupants to control their thermal comfort and obtain fresh air. (*Source:* National Renewable Energy Laboratory)

operation, disposal, and transportation impacts—can be quantified and compared to baselines that have been compiled to allow comparisons. Designers can quickly consider a wide variety of alternative building systems, materials, and sites and compare them to the norms for the type of building being considered. For example, the global warming and ozone depletion potentials for various alternatives per unit of building area can be compared to find the least damaging outcome. The Australian Green Star building assessment system considers energy not in energy units but in CO_2 equivalents to focus on the impact of climate change. LCA affords the design team the capability of quickly evaluating their energy strategies to find one that improves on the baselines established for carbon or other parameters. In North America, LCA is rewarded to some extent in the Green Globes rating system. It is part of ANSI/GBI 01–2019, Green Building Assessment Protocol for Commercial Buildings, a standard based on the Green Globes rating system and promulgated by ANSI and the GBI. LCA was also included as a pilot credit in the LEED system, and it appears in the latest version. The State of California also includes LCA as a voluntary measure in its 2019 Green Building Standards Code. In the future, as governments struggle to cope with reducing GHG emissions because the effects of climate change are causing economic problems and social dislocations, it is likely that LCA will become a mandatory area of evaluation for building design.

Book Organization

This book describes the high-performance green building delivery system, a rapidly emerging building delivery system that satisfies the owner while addressing sustainability considerations of economic, environmental, and social impact, from design through the end of the building's life cycle. A building delivery system is the process used by building owners to ensure that a facility meeting their specific needs is designed, built, and handed over for operation in a cost-effective manner. This book examines the design and construction of state-of-the-art green buildings in the United States, considering the nation's unique design and building traditions, products, services, building codes, and other characteristics. Best practices, technologies, and approaches of other countries are used to illustrate alternative techniques. Although intended primarily for a US audience, the general approaches described could apply broadly to green building efforts worldwide.

Much more so than in conventional construction delivery systems, the high-performance green building delivery system requires close collaboration among building owners, developers, architects, engineers, constructors, facility managers, building code officials, bankers, and real estate professionals. New certification systems with unique requirements must be considered. This book focuses largely on practical solutions to the regulatory and logistical challenges posed in implementing sustainable construction principles, delving into background and theory as needed. The USGBC's green building certification program is covered in detail. Other complementary or alternative standards, such as the GBI's Green Globes building assessment system, the federal government's Energy Star program, and the United Kingdom's BREEAM building certification program, are discussed. Economic analysis and the application of LCC, which provides a more comprehensive assessment of the economic benefits of green construction, also are considered.

Following this introduction, the book is organized into four parts, each of which describes an aspect of this emerging building delivery system. Part I, "Green Building Foundations," covers the background and history of green buildings, the basic concepts, ethical principles, and ecological design. Part II, "Assessing High-Performance Green Buildings," addresses the important issue of assessing or rating green buildings, with special emphasis on the two major US rating systems, LEED and Green Globes. Part III, "Green Building Design," more closely examines several important subsystems of green buildings: siting and landscaping, energy and atmosphere, carbon accounting, the building hydrologic cycle, materials selection, and indoor environmental quality. Part IV, "Green Building Implementation," addresses the subjects of construction operations, building commissioning, economic issues, and future directions of sustainable construction. Additionally, several appendices containing supplemental information on key concepts are provided. To support the readers, a John Wiley & Sons website contains hyperlinks to relevant organizations, references, and resources. This website also references supplemental materials, lectures, and other information suitable for use in university courses on sustainable construction [18].

BREEAM Case Study: Bloomberg European Headquarters, London

Because of construction industry's acknowledgment that it must dramatically lower the impacts of the built environment on eco- and human systems, the requirements for exemplary, high-performance green buildings are becoming ever more stringent and challenging. For instance, a green building of the 2020s will likely require 50 percent less energy and water compared to a similar structure designed and built in the 1990s. A low- to zero-carbon footprint is becoming the norm for energy infrastructure, and the embodied carbon of the materials constituting the facility is being evaluated to minimize the negative climate change implications of materials selection. Contemporary green building project teams not only assess the toxicity risk of the products and materials being selected as components to the occupants but also are now reaching upstream into the manufacturing and extraction processes. Structures that "default to nature" by synergistically connecting to the local ecosystems are more closely emulating and integrating with natural systems than ever before.

Perhaps no building better demonstrates the progress that has been made in this regard than the Bloomberg Headquarters building designed by Foster + Partners. The 1.2 million square ft (107,000 m^2), \$1.6 billion building, located in Central London near St. Paul's Cathedral, the Bank of England, and the church of St Stephen Walbrook, was completed in 2017 and is considered one of the most ambitious and successful green building projects of all time. In addition to achieving numerous awards for its environmental performance, the Bloomberg Headquarters also demonstrated the full integration of excellence in architecture with the achievement of demanding environmental performance. The Royal Institute of British Architects (RIBA) awarded the project the 2018 Stirling Prize, the most prestigious architecture award in the UK, which is made to the architects that have "made the greatest contribution to the evolution of architecture in the past year." The RIBA's president at the time, Ben Derbyshire, went even further, stating that Foster + Partners had "have not just raised the bar for office design and city planning, but smashed the ceiling" (Wainwright 2018). Some refer to it as the world's most sustainable office block.

The architecture is indeed outstanding. Its unique, eye-catching façade is framed by structural sandstone, with large-scale bronze fins that shade the floor-to-ceiling glazing. The fins vary in scale, pitch, and density across the building sides as a function of the orientation and solar exposure, and are an important component of the building's natural ventilation system. The building consists of two 10-story office blocks connected by a bridge that spans the Bloomberg Arcade. The space between the two office blocks retraces Watling Street, the path of an ancient Roman road that once transited the site. The site also sits on one of the most important archeological sites in the UK, the ancient Roman Temple of Mithras, which was located in the center of Londinium, the settlement founded by the Romans on the banks of the River Thames around 50 AD. Part of the Bloomberg Headquarters building project was to restore this site and to build a museum to display the Temple, which had been rediscovered 60 years earlier. Significant effort was made to ensure the Bloomberg Headquarters building fits in well with its neighbors. The sandstone exterior and bronze window fins make the building friendly and approachable from the street level. To add to its connectivity, three new exterior public spaces were created to integrate the building with its neighbors. Moving from outdoors to indoors is accomplished by passing through the Vortex, a novel artwork formed from three curved timber shells. The result is a dramatic entry experience that signifies the start of a high-tech enterprise equipped with a wide variety of cutting-edge communications technologies, workspaces, offices, and meeting rooms.

The list of green innovations for this project is long and includes extensive refinement and optimization using computational fluid dynamics modeling (see Figure 1.19). Full-scale 1:1 and miniature mock-ups tested the building, from tropical high temperatures to sub-zero arctic conditions (Block 2017) . The design of the building maximizes natural ventilation and integrates roof mounted photovoltaic panels and a combined heating and cooling power system. An absorption chiller delivers cooling to the interior of the building via a specially designed chilled ceiling. In the interior of the building, the ceiling is covered with 3.5 million aluminum petals that provide LED lighting, cooling, and acoustic control. The larger, northern building has deep floor plates that allow the building to be ventilated and cooled via natural ventilation (see Figure 1.20). The outside air needed for this purpose is drawn through the vertical bronze fins that line the building's facade and frame the glazing. The fins are acoustically treated to control exterior noise transmission and open and close to control the rate of airflow. Once the air transits the floor plates, it rises in the central atrium and is exhausted from the building. The southern building does not have an atrium and relies solely on mechanical ventilation. LED lamps are used throughout the building and the petals in the ceiling act as reflectors, thus increasing the efficiency of the lighting system and reducing the lighting

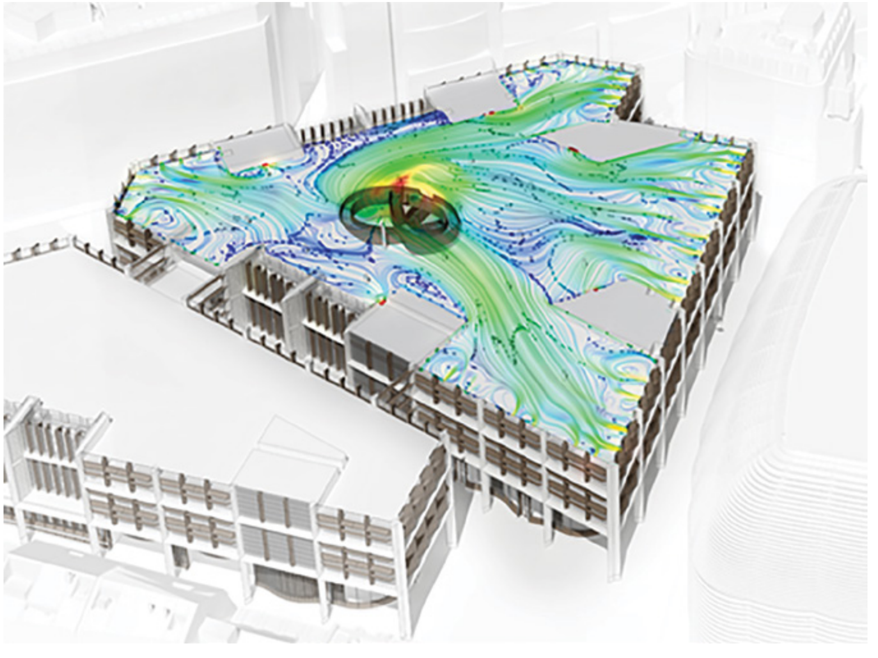

Figure 1.19 Computational fluid dynamics models were used to model the natural ventilation air flows through the Bloomberg European Headquarters. (*Source:* Courtesy of Foster + Partners)

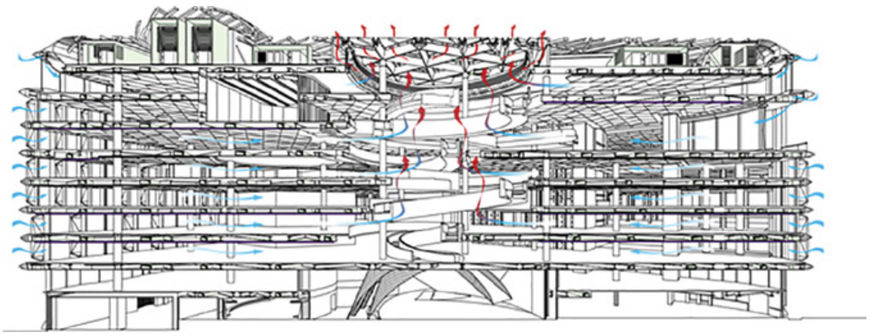

Figure 1.20 Cross-section through the Bloomberg European Headquarters horizontal and vertical airflows. The building has deep floor plates that allow the building to be ventilated and cooled via natural ventilation. (*Source:* Courtesy of Foster + Partners)

power density to an exceptionally low 4.7 watts per m^2. A collateral benefit of the low lighting power density is a reduced cooling load. CO_2 sensors adjust indoor ventilation air based on occupancy, saving an estimated 600–750 megawatt-hours (MWh) of energy per year. The result of these numerous innovations is an office building that is designed to consume 33 percent less energy than a comparable conventional office building.

Water consumption is extremely low, and the facility uses 73 percent less potable water than a conventional office building. An on-site water treatment plant collects and processes rainwater and greywater for reuse, saving an estimated 25 million liters of water per year. The processed water is fed to airline-style vacuum-assisted flush toilets, eliminating the need for potable water for this purpose (Bloomberg 2019).

Summary and Conclusions

The rapidly evolving and exponentially growing green building movement is arguably the most successful environmental movement in the United States today. In contrast to many other areas of environmentalism that are stagnating, sustainable building has proven to yield substantial beneficial environmental and economic advantages. Despite this progress, however, there remain significant obstacles, caused by the inertia of the building professions and the construction industry and compounded by the difficulty of changing building codes. Industry professionals in both the design and construction disciplines are generally slow to change and tend to be risk averse. Likewise, building codes are inherently difficult to change, and fears of liability and litigation over the performance of new products and systems pose considerable challenges. Furthermore, the environmental or economic benefit of some green building approaches has not been quantified scientifically, despite the often intuitive and anecdotal benefits. Finally, lack of a collective vision and guidance for future green buildings, including design, components, systems, and materials, may affect the current rapid progress in this arena.

Despite these difficulties, the robust international green building movement continues to gain momentum, and thousands of construction and design professionals have made it the mainstay of their practices. Numerous innovative products and tools are marketed each year, and, in general, this movement benefits from enormous energy and creativity. Like other processes, sustainable construction may one day become so common that its unique distinguishing terminology may be unnecessary. At that point, the green building movement will have accomplished its purpose: to transform fundamental human assumptions that create waste and inefficiency into a new paradigm of responsible behavior that supports both present and future generations.

Notes

1. The energy consumption figures for buildings in the United States refer to purchased or metered energy.
2. The Architecture 2030 Challenge was started by Ed Mazria in 2002. A parallel effort known as the 2030 Challenge for Products was initiated in 2011 to reduce the contributions of building materials to climate change.
3. The 2030 Challenge is described at the Architecture 2030 website, http://architecture2030.org/2030_challenges/2030-challenge/.
4. The origin of the word *sustainability* is controversial. In the United States, sustainability was first defined in 1981 by Lester Brown, a well-known American environmentalist and for many years the head of the Worldwatch Institute. In "Building a Sustainable Society," he defined a sustainable society as "one that is able to satisfy its needs without diminishing the chance of future generations." In 1987, the Brundtland Commission, headed by then prime minister of Norway, Gro Harlem Brundtland, adapted Brown's definition, referring to sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their needs." Sustainable development, or sustainability, strongly suggests a call for intergenerational justice and the realization that today's population is merely borrowing resources and environmental conditions from future generations. In 1987, the Brundtland Commission's report was published as a book, *Our Common Future*, by the UN World Commission on Environment and Development.
5. The World Business Council for Sustainable Development (WBCSD) promotes sustainable development reporting by its 170-member international companies. The WBCSD is committed to sustainable development via the three pillars of sustainability: economic growth, ecological balance, and social progress. Its website is www.wbcsd.org.
6. In November 1992, more than 1,700 of the world's leading scientists, including the majority of the Nobel laureates in the sciences, issued the "World Scientists' Warning to Humanity." The preamble of this warning stated: "Human beings and the world are on a collision course. Human activities inflict harsh and often irreversible damage on the environment and critical resources. If not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it may be unable to sustain life in the manner we know. Fundamental changes are urgent if we are to avoid the collision our present course will bring about." The remainder of this warning addresses specific issues, global warming among them, and calls for dramatic changes, especially on the part of the high-consuming developed countries, particularly the United States.
7. At the First International Conference on Sustainable Construction held in Tampa, Florida, in November 1994, Task Group 16 (Sustainable Construction) of the CIB formally defined the concept of *sustainable construction* and articulated six principles of sustainable construction, later amended to seven principles.
8. The *Whole Building Design Guide* can be found at www.wbdg.org.
9. Detailed information about Solaire can be found at www.thesolaire.com.
10. Primary energy accounts for energy in its raw state. The energy value of the coal or fuel oil being input to a power plant is primary energy. The generated electricity is metered or purchased energy. For a 40 percent efficient power plant, 1 kWh of purchased electricity requires 2.5 kWh of primary energy.
11. A description of the severe water resource problems beginning to emerge even in water-rich Florida can be found in the May/June 2003 issue of *Coastal Services*, an online publication of the National Oceanic and Atmospheric Administration Coastal Services Center, available at www.csc.noaa.gov/magazine/2003/03/florida.html. A similar overview of water problems in the western United States can be found in Young (2004).
12. An overview of xeriscaping and the seven basic principles of xeriscaping can be found at http://aggie-horticulture.tamu.edu/extension/xeriscape/xeriscape.html.
13. The Adam Joseph Lewis Center for Environmental Studies at Oberlin College was designed by a highly respected team of architects, engineers, and consultants and is a cutting-edge example of green buildings in the United States. An informative website, www.oberlin.edu/envs/ajlc, shows real-time performance of the building and its photovoltaic system.

14. The embodied energy of a product refers to the energy required to extract raw materials, manufacture the product, and install it in the building, and includes the transportation energy needed to move the materials comprising the product from extraction to installation.
15. To support the readers, a website, https://www.wiley.com/en-us/Sustainable+Construction%3A+Green+Building+Design+and+Delivery%2C+4th+Edition-p-9781119055174, contains hyperlinks to relevant organizations, references, and resources. This website also references supplemental materials, lectures, and other information suitable for use in university courses on sustainable construction.

References

BD&C. 2020. “Going Viral: How the Coronavirus Pandemic Could Change the Built Environment. *Building Design & Construction* (June 8). Available at https://www.bdcnetwork.com/going-viral-how-coronavirus-pandemic-could-change-built-environment.

Block. 2017. “Fosters + Partners-Designed Bloomberg Headquarters Is a ‘Vote of Confidence in London.’” Available at https://www.dezeen.com/2017/10/25/fosters-partner-european-bloomberg-headquarters-brexit-vote-of-confidence-london-uk/.

Bloomberg. 2019. “5 Eco-Friendly Features at Bloomberg’s Sustainable New European Headquarters, Bloomberg (August 12). Available at https://www.bloomberg.com/company/stories/eco-friendly-features-bloombergs-new-european-headquarters/.

Brown, Lester. 1981. *Building a Sustainable Society*. New York: W. W. Norton.

City of New York Department of Design and Construction. 1999. “High Performance Building Guidelines.” Available at www.nyc.gov/html/ddc/downloads/pdf/guidelines.pdf.

Dodge Data & Analytics. 2018. *World Green Building Trends 2018*. Smart Market Report. Available at http://images.marketing.construction.com/Web/DDA/%7Bf8b87329-bf5b-4f99-b09b-915be728b796%7D_World_Green_Building_Trends_2018_SMR_FINAL_11–24.pdf.

EveryCRSReport.com. 2019. *Vehicle Fuel Economy and Greenhouse Gas Standards: Frequently Asked Questions*. Available at https://www.everycrsreport.com/reports/R45204.html#_Toc17702020.

Fenner, A. E., C. J. Kibert, J. Li, M. A. Razkenari, H. Hakim, X. Lu, M. Kouhirostami, and M. Sam. 2020. “Embodied, Operation, and Commuting Emissions: A Case Study Comparing the Carbon Hotspots of an Educational Building.” *Journal of Cleaner Production*, 122081.

Griffith, B., N. Long, P. Torcellini, and R. Judkoff. 2007. *Assessment of the Technical Potential for Achieving Net-Zero Energy Buildings in the Commercial Sector.* National Renewable Laboratory Technical Report NREL/TP-550–41957. Available at www.nrel.gov/docs/fy08osti/41957.pdf.

“High Performance Guidelines: Triangle Region Public Facilities,” Version 2.0.2001. Available at www.tjcog.org/docs/regplan/susenerg/grbuild.pdf.

Kibert, Charles J. 1994. “Principles and a Model of Sustainable Construction.” *Proceedings of the First International Conference on Sustainable Construction*, November 6–9, Tampa, Florida, 1–9.

Lewis, Simon, Paulo M. Brando, Oliver L. Phillips, Geertje M. F. van der Heijden, and Daniel Nepstad. 2011. “The 2010 Amazon Drought.” *Science* 331 (6017): 554.

Pennsylvania Governor’s Green Government Council. 1999. “Guidelines for Creating High-Performance Green Buildings.” Available at www.portal.state.pa.us/portal/server.pt/community/green_buildings/13834/high_performance_green_building_guide/588208.

RIBA. 2018. “Bloomberg’s European HQ Named UK’s Best New Building.” RIBA architecture.com 10 October. Available at https://www.architecture.com/knowledge-and-resources/knowledge-landing-page/bloombergs-european-hq-named-uks-best-new-building.

Ritchie, Hannah, and Max Roser. 2019. “Indoor Air Pollution.” Available at https://ourworldindata.org/indoor-air-pollution.

UN World Commission on Environment and Development. 1987. *Our Common Future*. Oxford: Oxford University Press.

US Green Building Council. 2003. *Building Momentum: National Trends and Prospects for High-Performance Green Buildings.* Washington, DC: US Green Building Council. Available at www.usgbc.org/Docs/Resources/043003_hpgb_whitepaper.pdf.

Wainwright, Oliver. 2018. “Norman Foster’s Bloomberg Office in London Wins Sterling Prize.” *The Guardian* (October 10). Available at https://www.theguardian.com/artanddesign/2018/oct/10/norman-fosters-bloomberg-office-in-london-wins-stirling-prize.

Wilson, Alex, with Rachel Navaro. 2007. “Driving to Green Buildings: The Transportation Energy Intensity of Buildings.” *Environmental Building News* 16(9).

Young, Samantha. 2004. *Las Vegas Review Journal* (March 10). Available at www.reviewjournal .com/lvrj_home/2004/Mar-10-Wed-2004/news/23401764.html.

Zabarsky, Marsha. 2002. “Sick Building Syndrome Gains a Growing Level of National Awareness.” *Boston Business Journal* (August 16). Available at www.bizjournals.com/boston/stories/2002/08/19/focus9.html.

Part I

Green Building Foundations

This book is intended to guide design and construction professionals through the process of developing commercial and institutional high-performance green buildings. A green building can be defined as *a facility that is designed, built, operated, and disposed of in a resource-efficient manner using ecologically sound approaches and with both human and ecosystem health as goals*. This book addresses the application of building assessment systems such as LEED[1] and Green Globes[2] in the United States, as well as several noteworthy building assessment systems used in other countries. Part I addresses the background and history of the sustainable construction movement, various green building rating systems, the concept of life-cycle assessment, and green building design strategies. It is intended to provide the working professional with sufficient information to implement the techniques necessary to create high-performance green buildings. This part contains the following chapters:

Chapter 2: Background

Chapter 3: Ecological Design

Chapter 2 describes the emergence of the green building movement, its rapid evolution and growth over the past decade, and current major influences. This chapter also addresses the unusual scale of resource extraction, waste, and energy consumption associated with construction, and it examines the resource and environmental impacts of the built environment. Although this book focuses on the United States, the context, organizations, and approaches of other countries are also mentioned.

General design strategies for green building are covered in Chapter 3. Fundamentally, green design is based on an ecological model or metaphor commonly referred to as ecological design. The work of Sim Van der Ryn and Stuart Cowan, Ken Yeang, and David Orr, along with earlier works by R. Buckminster Fuller, Frank Lloyd Wright, Ian McHarg, Lewis Mumford, John Lyle, and Richard Neutra, are reviewed in this chapter.

In spite of the impulse to apply the highest ecological ideals to the built environment, a vast majority of contemporary designers lack an adequate understanding of ecology. Claims of a building's "ecological design" are often tenuous in fact, and greater participation by ecologists and industrial ecologists is necessary to reduce the gap between the ideal of ecological design and its expression in reality. To that end, the LEED and Green Globes building assessment systems have been the first step in a long process of achieving truly ecological design. The products, systems, techniques, and services needed to create buildings in harmony and synergy with nature are rare. Buildings often are assembled from components produced by a variety of manufacturers that have paid little or no attention to the environmental impacts of their activities. Installation is performed by a workforce largely unaware of the impacts of the built environment and often results in enormous waste. Conventional buildings are designed by architects and engineers who often have little or no training in sustainable construction. In spite of these obstacles, certified green buildings are usually superior to conventional projects in terms of energy and water efficiency, materials selection, building health, waste generation, and site utilization. Of equal importance, the green building process has necessitated a deeper integration of the client, the designer, and the general public. New projects generally are initiated via the charrette, which includes construction and design professionals as well as community members, who together brainstorm the project's initial design.

Exceeding the requirements of the contemporary assessment standards such as LEED and Green Globes is the next rung on the ladder of truly sustainable construction. Some of the features of future sustainable construction include:

- The built environment would fully adopt closed-loop materials practices, and the entire structure, envelope, systems, and interior would be composed of products easily disassembled to permit ready recycling. Waste material throughout the structure's life cycle would be capable of biological (composting) or technological recycling. The building itself would be deconstructable; in other words, it would be possible to disassemble it economically for reuse and recycling. Only materials with future value, either to human or to biological systems, would be incorporated into buildings.
- Buildings would have a synergistic relationship with their natural environment and blend with the surrounding environment. Materials exchanges across the building–nature interface would benefit both sides of the boundary. Building and occupant waste would be processed to provide nutrients to the surrounding biotic systems. Toxic or harmful emissions of air, water, and solid substances would be eliminated.
- The built environment would incorporate natural systems at various scales, ranging from individual buildings to bioregions. The underexplored integration of natural systems with the built environment has staggering potential to produce superior human habitats at lower cost. Landscaping would provide shade, food, amenities, and stormwater uptake for the built infrastructure. Wetlands would process wastewater and stormwater and often eliminate the need for enormous and expensive infrastructure. Currently the integration of nature, which is barely addressed in building assessment systems, is considered under the comprehensive category of design innovation. Ideally, the integration of human and natural systems would be standard practice rather than being considered an innovation.
- Energy use by buildings would be reduced by a Factor 10 or more below that of conventional buildings.[3] Rather than the typical 100,000 BTU/ft^2 (292 kWh/m^2) or more consumed by today's commercial and institutional structures, truly green buildings would be relatively deenergized, using no more than 10,000 BTU/ft^2 (29 kWh/m^2). The source of this energy would be the sun or other solar-derived sources, such as wind power or biomass. Alternatively, geothermal and tidal power, both nonsolar energy sources, also would be employed as renewable forms of energy derived from natural sources.

- The carbon footprint of buildings would be reduced via the selection of low carbon footprint materials, the design of low energy buildings, and a shift to net zero energy buildings, together with carbon offsets that make buildings *carbon neutral* (see Chapter 12).

In summary, the green building movement has come a long way in a short time. Its exponential growth promises its longevity, and numerous public and private organizations support its agenda. It is exciting to contemplate the possibility of extending the boundaries of ecological design and construction as global environmental problems become exigent and as solutions, if not survival itself, demand a radical departure from conventional thinking. The evolution of products, tools, services, and, ultimately, Factor 10 buildings cannot occur soon enough. Only then may we alter the trajectory of the human quality of life from one of certain disaster to one that finally exists within the carrying capacity of nature. Although humanity is halfway through the race, the ultimate question remains unanswered: Can we change the built environment rapidly enough to save both nature and ourselves?

Notes

1. The USGBC (www.usgbc.org) is now the US leader in promoting commercial and institutional green buildings. The greening of single-family-home residential construction and land development is far more decentralized and varies from state to state. An example of an organization leading change at the state level in the residential and land development sectors is the Florida Green Building Coalition (FGBC) (www.floridagreenbuilding.org). The Florida Green Residential Standard and the Florida Green Development Standard can be downloaded from the FGBC website.
2. The genesis of Green Globes was the Building Research Establishment Environmental Assessment Method, which was developed in the United Kingdom in the early 1990s, brought to Canada in 1996, and eventually developed as an online assessment and rating tool. In 2004, the Green Building Initiative (GBI) acquired the rights to distribute Green Globes in the United States. In 2005, the GBI became the first green building organization to be accredited as a standards developer by the American National Standards Institute (ANSI) and began the process of establishing Green Globes as an official ANSI standard. The GBI ANSI technical committee was formed in early 2006, and the ANSI/GBI 01 standard based on Green Globes was published in 2010.
3. Factor 10, a concept developed by the Wuppertal Institute in Wuppertal, Germany (www.wupperinst.org), suggests that long-term sustainable development can be achieved only by reducing resource consumption (energy, water, and materials) to 10 percent of present levels. Another concept, Factor 4, suggests that technology currently exists to reduce resource consumption immediately by 75 percent. The book *Factor Four: Doubling Wealth, Halving Resource Use*, by Ernst von Weizsäcker, Amory Lovins, and L. Hunter Lovins (London: Earthscan, 1997), popularized this concept.

Chapter 2

Background

On May 9, 2013, for the first time in the 200,000 years of existence of the species of bipedal primates known as humans, a pivotal event occurred that now threatens their future on Earth. On that date the Mauna Loa Observatory in Hawaii recorded that, for the first time in human history, atmospheric carbon dioxide (CO_2) levels exceeded 400 parts per million (ppm), an event that had last occurred over 800,000 years ago. In preindustrial times—that is, prior to 1760—CO_2 concentrations had averaged 280 ppm and had slowly increased to 310 ppm by 1958, the year that instruments at the observatory first began measurements (see Table 2.1). As of 2020, CO_2 levels averaged 415 ppm, and they are expected to continue to increase unless dramatic action is taken by the world's nations to limit greenhouse gas emissions from their power generating systems, industries, and transportation systems (see Figures 2.1 through 2.5).

Human activities have been identified as the cause of the shift in Earth's carbon cycle, which is trapping the sun's energy in the planet's atmosphere and oceans, with likely consequences for all life-forms.[1] Dr. Carmen Boening, a scientist with the Climate Physics Group of the NASA Jet Propulsion Laboratory, described the event in this way:

> Reaching the 400 ppm mark should be a reminder for us that CO_2 levels have been shooting up at an alarming rate in the recent past due to human activity. Levels that high have only been reached during the Pliocene era, when temperatures and sea level were higher. However, Earth's climate had never had to deal with such a drastic change as the current increase, which is, therefore, likely to have unexpected implications for our environment.[2]

Climate change, today's dominant environmental issue, is just one of many humans-caused impacts plaguing both the planet and its inhabitants, both human and nonhuman. Eutrophication, acidification, deforestation, loss of biodiversity, and the activities of extractive industries such as mining are forcing countries to either shift onto a cleaner, softer path or face a wide range of negative consequences, among them threats to food and water resources. As the human industry that consumes the most resources and the most energy, construction clearly must undergo the most significant transformation.

TABLE 2.1

Atmospheric CO_2 concentrations are increasing at least 11 times faster from 1958 to the present compared with the period from 1760 to 1958.

Period	Years	Start CO_2 (PPM)	End CO_2 (PPM)	CO_2 (PPM) Change	PPM / Year Change	Factor Increase
1760–1958	198	280	310	30	0.15	———-
1958–2020*	62	310	413	103	1.66	11

*As of March 3, 2020.

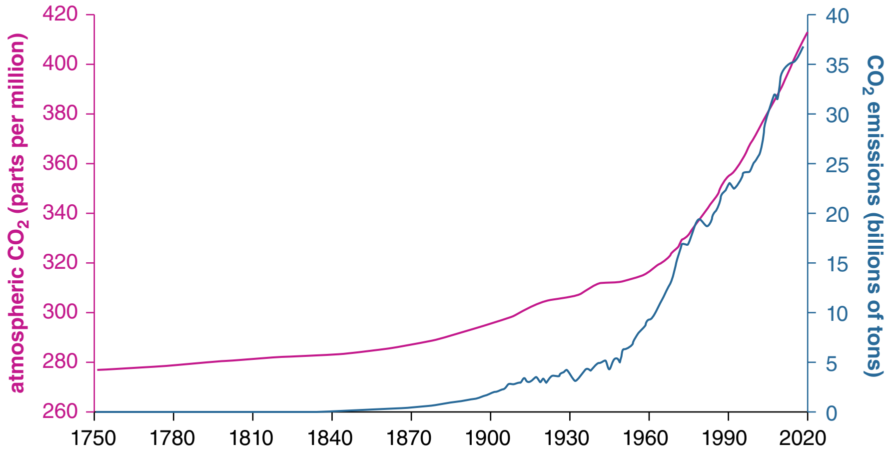

Figure 2.1 Atmospheric CO_2 concentrations are increasing at least 11 times faster from 1958 to the present compared with the period from 1760 to 2020. (*Source:* Climate.gov)

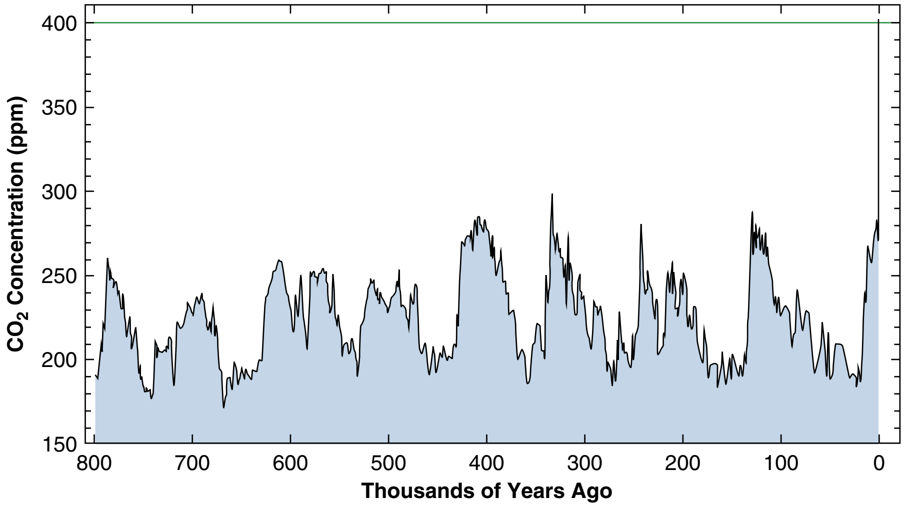

Figure 2.2 Concentration of CO_2 in Earth's atmosphere from the present (Year 0) to 800,000 years ago, the last time Earth's atmosphere experienced concentrations at or above 400 ppm. (*Source:* Courtesy of Scripps Institution of Oceanography)

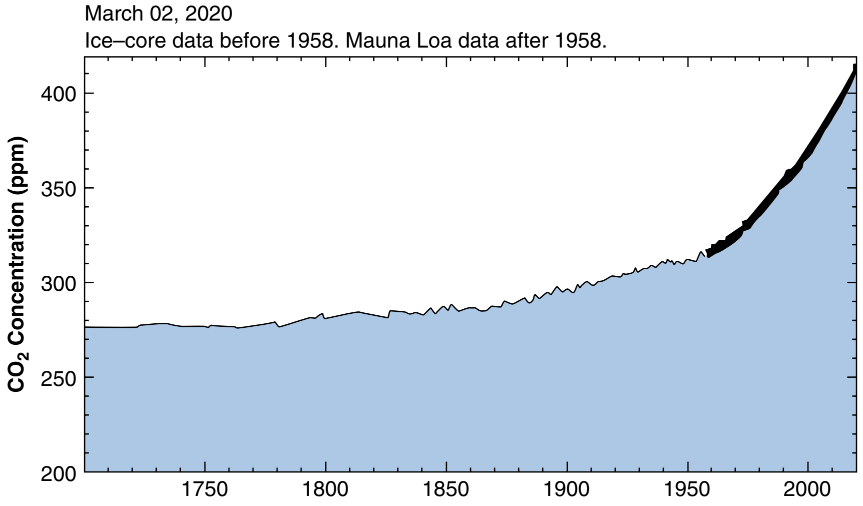

Figure 2.3 CO_2 concentrations in Earth's atmosphere from the year 1700 to the present, showing the increase in levels from about 280 ppm to 400 ppm. Note also the acceleration in CO_2 levels since the 1950s. (*Source:* Courtesy of Scripps Institution of Oceanography)

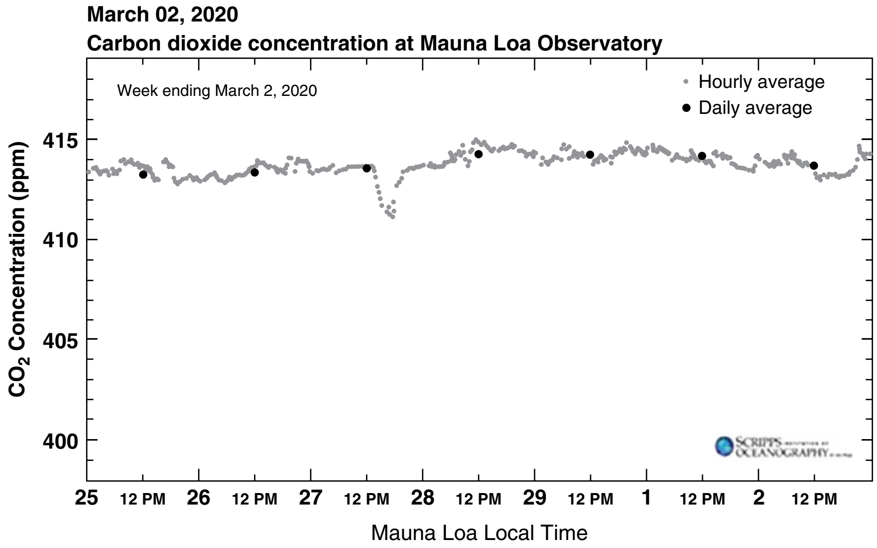

Figure 2.4 Measured CO_2 concentrations for the week ending March 6, 2020, on Mauna Loa exceed 415 ppm during the parts of the day. This has been the case since May 9, 2013, when the first 400 ppm concentrations were detected. (*Source:* Courtesy of Scripps Institution of Oceanography)

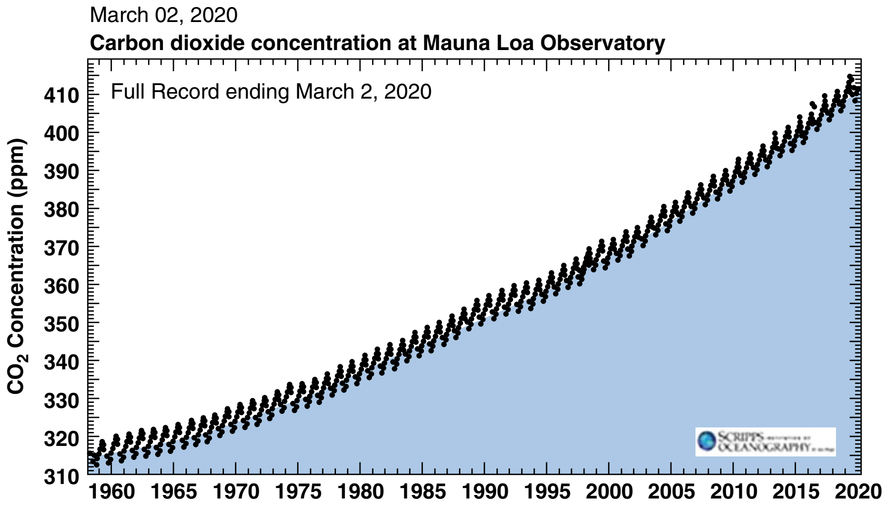

Figure 2.5 In the 60 years since 1960, concentrations of CO_2 in Earth's atmosphere increased from about 310 ppm to 415 or by 115 ppm. In comparison, these concentrations increased just by 30 ppm in the 210 years from the start of the industrial Revolution. (*Source:* Courtesy of Scripps Institution of Oceanography)

The Driving Forces for Sustainable Construction

Sustainable construction is the response of the construction industry[3] response to the rapid negative changes in Earth's environment and its ecosystems. Three major changes are motivating the construction industry to develop an ethical response to several categories of impacts. First, there is growing evidence of accelerated destruction of planetary ecosystems, alteration of global biogeochemical cycles, and enormous increases in population and consumption. Human-caused problems such as climate change, depletion of major fisheries, deforestation, and desertification are the prime cause of what some environmentalists have labeled the *Sixth Extinction*, referring to the human species' massive destruction of life and biodiversity on the planet.[4]

Second, increasing demand for natural resources by both developed and developing countries, such as the so-called BRIC (Brazil, Russia, India, and China) countries, is causing shortages and higher prices for materials and agricultural products. China adds about 8 million people each year to its population of 1.4 billion, and its economy has been expanding at a rate of about 7.0 percent annually. Worldwide economic turbulence in 2016 caused by Chinese overproduction is likely to affect this growth rate. In general, China's growing economy and improving standard of living have increased the demand for, and prices of, meat and grain. The negative consequences of rapid urban expansion in China have included water shortages and increasing desertification, leading to the growth of the Gobi Desert by 4,000 square miles (10,400 km^2) per year.

The growing Chinese economy has a huge appetite for materials, which is contributing to shortages and driving up prices around the world. China produced over 46 percent of the world's steel in 2014 and is increasing production at a prodigious rate, from approximately 12 million tons (11 million metric tons [mt]) per month in 2001 to 69 million tons (60 million mt) per month in 2014, an annual rate increase of 768 million tons (720 million mt) and rising rapidly. In comparison, steel production in the United States has been relatively flat in the past decade, totaling 90 million tons (81 million mt) in 2014, a small fraction of the Chinese level of production. Chinese demand for fossil fuels is growing at a rate of 30 percent per year. Copper prices have increased 10-fold in 10 years. The manufacturing sector is experiencing higher prices for virtually every commodity used in the production system. Rare earths, which, as their name implies, are not abundant materials but indispensable elements such as lanthanum, neodymium, and europium, are essential for the magnets, motors, and batteries used in electric cars, wind generators, hard-disk drives, mobile phones, and other high-tech products. Their short supply is affecting industries worldwide. After prices spiked significantly in 2011–2012, recently prices for rare earths have stabilized.[5] In short, prices for nonrenewable materials and energy resources are on a strong upward trend that shows no sign of abating. The construction industry, a major consumer of these resources, must change in order to remain healthy and solvent.

Third, the green building movement is coinciding with similar transformations in manufacturing, tourism, agriculture, medicine, and the public sector, which have adopted various approaches toward greening their activities. From redesigning entire processes to implementing administrative efforts such as adopting green procurement policies, new concepts and approaches are emerging that deem the environment, ecological systems, and human welfare to be of equal importance to economic performance. For example, the Xerox Corporation has announced the strategic environmental goal of creating "waste-free products and waste-free facilities for waste-free workplaces." Xerox created just such a product, the DocuColor iGen4 EXP Press, which uses nontoxic dry inks and has a transfer efficiency of almost 100 percent. Up to 97 percent of the machine's parts and 80 percent of its generated waste can be reused or recycled. Furthermore, by reclaiming copy machines at the end of their useful life, recovering components for reuse and recycling, and instituting sophisticated remanufacturing processes, Xerox conserves materials and energy, dramatically reduces waste, and limits its potential liability by eliminating hazardous materials.[6]

In the automotive industry, the European end-of-life vehicles (ELV) directive has been in effect since the year 2000 (see Figure 2.6). This legislation requires manufacturers to accept the return of vehicles at the end of their useful life, with no charge to the consumer. The measure requires extensive recycling of the returned vehicles and minimizes the use of hazardous materials in automobile production. Spurred by European efforts, Ford Motor Company is using European engineering expertise at its research center in Aachen, Germany, to develop recycling technologies that will

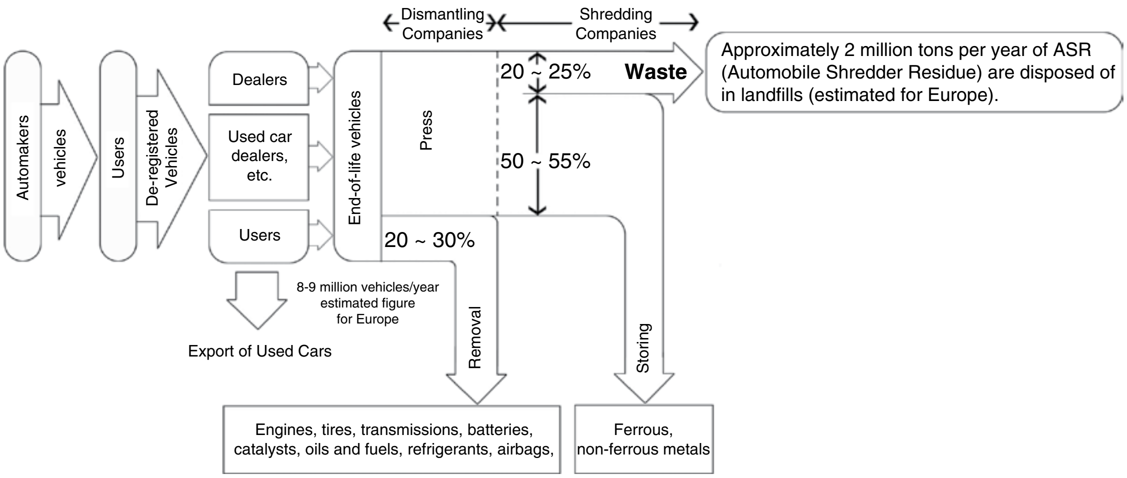

Figure 2.6 The European ELV directive requires manufacturers to accept the return of vehicles at the end of their useful life, with no charge to the consumer. This diagram shows the extensive recycling of returned vehicles and greatly reduced waste generation in automobile production.

raise the recovery yield of recycled materials above their current 85 percent to 95 percent level. Construction is generally seen as a wasteful industry, and efforts to increase the reuse and recycling of building materials are beginning to emerge as part of the high-performance green building movement (see Figure 2.7). The European automobile industry, although a different economic sector, provides ample lessons for reducing waste and closing materials loops in construction.

Figure 2.7 The structural system for Rinker Hall, a Leadership in Energy and Environmental Design (LEED)–certified building at the University of Florida in Gainesville, is steel. Steel is an excellent material due to its high recycled content—almost 100 percent for some building components—and is readily deconstructable and recyclable. Rinker Hall is the only building out of the thousands certified by the US Green Building Council to have been awarded an innovation credit for its deconstructability. Although some would consider metals such as steel to be “green” building materials, their embodied energy—that is, the energy required for resource extraction, manufacturing, and transport—is fairly high and results in the consumption of nonrenewable fossil fuels and the generation of global warming gases and air pollution. Consequently, whether steel can truly be considered a green building material is controversial and depends on the criteria used in the evaluation. Of all the challenges in creating high-performance green buildings, finding or creating truly environmentally friendly building materials and products is the most difficult task facing construction industry professionals.

This chapter describes the effect of these three forces on the green building movement and their influence on defining new directions for design and construction of the built environment. It lays out the ethical arguments supporting sustainability and, by extension, sustainable construction. It explores the relatively new vocabulary associated with various efforts that attempt to reduce human environmental impact, increase resource efficiency, and ethically confront the dilemmas of population growth and resource consumption. Finally, it covers the history of the green building movement in the United States, acknowledging that an understanding of its roots is necessary to appreciate its evolution and current status.

Ethics and Sustainability

In the context of sustainable development and sustainable construction, the idea of ethics must be broadened to address a wide range of concerns that are not usually considered. *Ethics* addresses relationships between people by providing rules of conduct that are generally agreed to govern the good behavior of contemporaries. Sustainable development requires a more extensive set of ethical principles to guide behavior because it addresses relationships between generations, calling for what is sometimes referred to as *intergenerational justice*. The classic definition of sustainable development, from the Brundtland Report, more commonly known as *Our Common Future* (UN World Commission on Environment and Development [WECD] 1987), is “meeting the needs of the present without compromising the ability of future generations to meet their needs.” It is clear that *intertemporal* considerations—the responsibility of one generation to future generations, as well as the rights of future generations vis-à-vis a contemporary population—are fundamental concepts of sustainable development. The result of intertemporal or intergenerational considerations with respect to morality and justice must be an expanded concept of ethics that extends not only to future generations but also to the nonhuman living world and arguably to the nonliving world because the alteration or destruction of nonhuman living and nonliving systems affects the quality of life of future generations by reducing their choices. The result of destroying biodiversity today, for instance, is the removal of important information for future populations that could have been the basis for biomedicines, not to mention the removal of at least some portion of *environmental amenity*, or enjoyment that nature provides because of its many positive effects on human beings. It is clear that the choices of a given population in time will directly affect the quantity and quality of resources remaining for future inhabitants of Earth, affect the environmental quality they will experience, and alter their experience of the physical world. With this in mind, the purpose of this section is to expand on the foundations of classical ethics to provide a robust set of principles that can address questions of intergenerational equity.

THE ETHICAL CHALLENGES

Humans are unique among all species with respect to control over their destiny. Garry Peterson (2002), an ecologist, articulated this very well when he stated:

> Humans, individually or in groups, can anticipate and prepare for the future to a much greater degree than ecological systems. People use mental models of varying complexity and completeness to construct views of the future. People have developed elaborate ways of exchanging, influencing, and updating these models. This creates complicated dynamics based upon access to information, ability to organize, and power. By contrast, the organization of ecological systems is a product of the mutual reinforcement of many interacting structures and processes that have emerged over long periods of

> time. Similarly, the behavior of plants and animals is the product of successful evolutionary experimentation that has occurred in the past. Consequently, the arrangement and behavior of natural systems are based upon what has happened in the past, rather than looking forward in anticipation toward the future. The difference between forward-looking human systems and backward-looking natural systems is fundamental. It means that understanding the role of people in ecological systems requires not only understanding how people have acted in the past, but also how they think about the future. (p. 138)

Following this line of thinking, humans are certain to create materials and develop processes that have not evolved in a natural sense, which have no precedent in nature. The question then becomes: What constraints should society place on the development of new materials, products, and processes? The ongoing debates about genetically modified organisms (GMOs) and cloning are indicative of the uncertainty about the outcomes of human tinkering with the blueprints of life, not to mention the creation of materials that have uncertain long-term impacts. Other major developments such as biotechnology, genetic engineering, nanotechnology, robotics, and nuclear energy, to name but a few, present fundamental challenges to human society. Decisions about implementing technologies with no precedent in nature and with potentially unprecedented negative and irreversible impacts must be considered carefully, especially since, once a technology is deployed, it is extremely difficult to reverse course if negative consequences are discovered. Decisions about how to move forward must be based on (1) an ethical framework that represents society's general moral attitudes toward life and future generations, (2) an understanding of and willingness to accept risk, and (3) the economic costs of implementation and resulting impacts.[7]

INTEGRATIONAL JUSTICE AND THE CHAIN OF OBLIGATION

There is an asymmetry of power between present and future generations because, while today's people can make choices that likely will severely affect people 100 to 200 years into the future—for example, ignoring the long-term impacts of climate change—the same cannot be said of future generations. There is simply no mechanism for future, remote generations to have an effect on the past.[8] Current generations can affect the health and quality of life of these remote generations. The choices of today's generations will directly affect the quality and quantity of resources remaining for future inhabitants of Earth and its environmental quality. This concept of obligation that crosses temporal boundaries is referred to as *intergenerational justice*. Furthermore, the concept of intergenerational justice implies a *chain of obligation* between generations that extends from today into the distant future. Richard Howarth (1992) expressed this obligation by stating that "unless we ensure conditions favourable to the welfare of future generations, we wrong existing children in the sense that they will be unable to fulfill their obligation to their children while enjoying a favourable way of life themselves" (p. 133). Howarth also suggested that the actions and decisions of the current generation affect not only the welfare but also the composition of future generations. He argued that when we create conditions that change resource availability or that alter the environment, future populations will be compositionally different than if the resource base and environmental conditions had been passed on, from one generation to future generations, unchanged. For instance, mutations caused by excessive ultraviolet radiation through an ozone layer depleted by human activities, or by synthetic toxic chemicals used without adequate safeguards, certainly will result in different people and conditions. Consequently, the chain of obligation that underpins the key sustainability concept of intergenerational justice includes parents' responsibility for enabling their offspring to meet their moral obligations to their children and beyond. Clearly, doing this would include educating the offspring about these obligations and the basis for them.

DISTRIBUTIONAL EQUITY

There is an obligation to ensure the fair distribution of resources among people currently alive so that the life prospects of all people are addressed. This obligation can be referred to as *distributional equity* or *distributive justice* and refers to the right of all people to an equal share of resources, including goods and services, such as materials, land, energy, water, and high environmental quality. Distributional equity is based on principles of justice and the reasonable assumption that all individuals in a given generation are equal and that a uniform distribution of resources must be a consequence of *intragenerational equity*. The principle of distributional equity can be extended to relationships between generations because a given generation has a moral responsibility to provide for their offspring, which is referred to as *intergenerational equity*. Thus, distributional equity also underpins the chain of obligation concept. Distributional equity is a complex concept, and a number of principles underpin and are related to it: (1) the difference principle, (2) resource-based principles, (3) welfare-based principles, (4) desert-based principles, (5) libertarian principles, and (6) feminist principles.

THE PRECAUTIONARY PRINCIPLE

The *precautionary principle* requires the exercise of caution when making decisions that may adversely affect nature, natural ecosystems, and global biogeochemical cycles. According to the Center for Community Action and Environmental Justice (CCAEJ), the precautionary principle states that "when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically." Global climate change is an excellent example of the need to act with caution. Notwithstanding debate about the effects of man-made carbon emissions on future planetary temperature regimes, the potentially catastrophic outcomes should motivate humankind to behave cautiously and attempt to limit the emissions of carbon-containing gases such as methane and CO_2. On its website (www.ccaej.org) the CCAEJ proposes four tenets of the precautionary principle:

1. People have a duty to take anticipatory action to prevent harm.
2. The burden of the proof of harmlessness of a new technology, process, activity, or chemical lies with the proponents, not the general public.
3. Before using a new technology, process, or chemical or starting a new activity, people have an obligation to examine a full range of alternatives including the alternative of not doing it.
4. Decisions applying the precautionary principle must be open, informed, and democratic and must include the affected parties.

As an example, a hypothetical danger of *nanotechnology* is the creation of so-called gray goo. Nanotechnology is an approach to building machines at the submicrometer level—that is, on an atomic scale. K. Eric Drexler (1987) suggested that one of the hallmarks of nanotechnology will be the ability of these invisible machines to self-replicate, with enormous potential benefits to humanity, but with the attendant danger that the replication will bring an out-of-control conversion of matter into machines. Drexler warned that "we cannot afford certain kinds of accidents with replicating assemblers," which can be restated as "we cannot afford the irresponsible use of powerful technologies." Thermodynamics and energy requirements will limit the effects of the gray goo conversion process, but significant harm still may be the consequence. This type of scenario requires consideration of the precautionary principle, even if the full consequences of self-replicating machines are not known, because of the potential catastrophic outcome if Drexler is correct. Similar concerns exist with regard to genetic engineering and nuclear engineering: They have a high probability of putting future generations at risk. Clearly, the precautionary principle should be applied to each of these scenarios to eliminate as much as possible risks to future populations, both human and nonhuman, from the consequences of technologies that are not fully understood.

Despite the wisdom of exercising caution when addressing complex issues that may have unknown, far-reaching effects, the precautionary principle is controversial and sometimes is perceived as a threat to progress, since it fails to consider the negative consequences of its application. For example, refusing to use new drugs because society has not fully established their effects on nature and people may foreclose options for advancing human health. Nonetheless, the consequences of not applying the precautionary principle are becoming apparent in several areas. Most notably, the widespread use of estrogen-mimicking chemicals is believed to damage the reproductive systems of animal species and probably of humans. With these concerns in mind, in 1999 the National Science Foundation developed the Biocomplexity in the Environment Priority Area to address the interaction of human activities with the environment and on climate change and biodiversity.[9] At least the debate surrounding the application of the precautionary principle has focused greater attention on the environmental impacts of technology and has pressured technologists to acknowledge the potential consequences of their efforts on humans and nature.

THE REVERSIBILITY PRINCIPLE

Making decisions that can be undone by future generations is the foundation of the *reversibility principle*. Renowned science fiction author Arthur C. Clarke (1965, cited in Goodin 1983) suggested a rule that well describes this principle: "Do not commit the irrevocable." At its core, this principle calls for a wider range of options to be considered in decision-making. Addressing the issue of energy choices is an excellent example because a rapidly growing global economy is faced with looming energy shortages, exacerbated by the depletion of finite oil supplies. In the United States, a shift is under way to reconsider nuclear plants as a major source of energy because they probably can generate electricity at an acceptable cost and also be a source of thermal energy for producing hydrogen from water for use in fuel cells. The reversibility principle would force today's society to confront the issue of whether the choice of nuclear energy as an option is reversible by a future society. Two questions would immediately emerge from this consideration. First, is the technology safe enough for widespread use? The nuclear industry suggests that over the past two decades of a national hiatus from building new plants, the technology has advanced to the point where a Chernobyl, Three Mile Island, or Fukushima Daiichi incident can be eliminated. The second question is: How would a future society cope with the nuclear waste from these plants? Converting the waste into harmless materials via a new technology is highly unlikely, and the power plants built today would force future generations to store and be put at risk by the radionuclides in the spent fuel rods. A subset of questions on this same subject would result as a consequence of assuming that, if storage of the radioactive waste for periods of time in the 10,000-year range is feasible, what are the storage options? (See Figure 2.8.) In addressing this question, Gene I. Rochlin (1978) suggested that there are two options. One is to deposit the waste deep in a stable rock formation where it could be recovered if, for example, leaks in the storage containers were detected by future generations. A second option is to

Figure 2.8 Yucca Mountain Nuclear Waste Repository: The project was halted indefinitely in 2009. In 2019, Illinois Rep. John Shimkus reintroduced a bill in the House for the site.[2] However the Appropriation Committee killed an amendment by Rep. Mike Simpson of Idaho to add $74 million in Yucca Mountain funding to an Energy Department appropriations bill.

deposit it in inaccessible locations—for example, by placing the waste deep in the ocean, where sliding continental plates would gradually cover it. The former solution allows future generations access to the waste to take corrective action, while the latter does not allow that option.

The reversibility principle is related to the precautionary principle because it lays out criteria that must be observed prior to the adoption of a new technology. It is less stringent than the precautionary principle in some respects because it suggests reversibility as the primary criterion for making a decision to employ the technology; the precautionary principle, by contrast, requires that a technology not be implemented if its effects are not fully understood and if the risks are unacceptable.

THE POLLUTER PAYS PRINCIPLE AND PRODUCER RESPONSIBILITY

The fundamental premise of the precautionary and reversibility principles is that those who are responsible for implementing technologies must be prepared to address the consequences of their implementation. The precautionary principle suggests that technologists should demonstrate the efficacy of their products and processes prior to allowing them to affect the biosphere. The reversibility principle permits implementation despite some level of risk as long as any negative effects can be undone. The *polluter pays principle* addresses existing technologies that have not been subject to these other principles and places the onus for mitigating damage and consequences on the individuals causing the impacts. The polluter pays principle originated with the Organisation for Economic Co-operation and Development in 1973 and is based on the premise that polluters should pay the costs of dealing with pollution for which they are responsible. Historically, the polluter pays principle has focused on retrospective liability for pollution; for example, an industry causing pollution would have to pay for the cleanup costs arising from it.

More recently, the focus of the polluter pays principle has shifted toward avoiding pollution and addressing wider environmental impacts through producer responsibility. Producer responsibility is an example of the extended version of the polluter pays principle, as it applies to waste and resource management, placing responsibility for the environmental impact associated with a product on the producers of that product. Producer responsibility is intended to address the whole life-cycle environmental problems of the production process, from initial minimization of resource use, through extended product life span, to recovery and recycling of products once they have been disposed of as waste. Producer responsibility is used increasingly throughout the world to address the environmental impacts of certain products. The European Union has applied producer responsibility through directives on packaging and packaging waste, waste electronics and electrical equipment, and ELV.

PROTECT THE VULNERABLE

There are populations, including those of the animal world, that are vulnerable to the actions of portions of the human species, due to the destruction of ecosystems under the guise of development, introduction of technology (including toxic substances, endocrine disruptors, and GMOs), and general patterns of conduct (war, deforestation, soil erosion, eutrophication, desertification, and acid rain, to name a few). People who are essentially powerless due to governing and economic structures are vulnerable to the decisions of those who are powerful because of their wealth or influence. This asymmetrical power arrangement is governed by moral obligation. Those in power have a special obligation to *protect the vulnerable*, those dependent on them. In a family, children's dependence on their parents gives them rights against their parents. Future generations are also vulnerable because they are subject to the effects of decisions we make today. In a technological society, many portions of the human population and certainly the animal world can be exposed to harm by the actions of individuals or companies performing medical research or because the government that is charged with protecting them fails in its responsibilities when it comes to pollution, the use of toxic substances, and a wide variety of other poorly controlled actions. Breaches of ethics are not uncommon when it comes to vulnerable populations, such as prisoners, people with mental disabilities, women, and people in developing countries. And, as noted earlier, today's actions have consequences for future generations that have been considered only recently. Future people are certainly vulnerable to our actions, and both their existence and their quality of life are potentially compromised by short-term thinking and decisions based solely on the comfort and wealth of past populations. The ethical principle of protecting the vulnerable places an enormous responsibility on Earth's current population, one made even more difficult due to rampant global poverty.

PROTECTING THE RIGHTS OF THE NONHUMAN WORLD

The *nonhuman world* refers to plants and animals and could be extended to include bacteria, viruses, mold, and other living organisms. The principle of protecting this world is an extension of the principle of protecting the vulnerable, particularly animals but also plants that are in danger of extinction. Animal rights fall under this principle. The nonliving portion of Earth is essential in supporting life, and a set of sustainability principles should address the requirements for protecting this key element of the life support system. Some would argue that ethics should require the character of beautiful places, such as the Grand Canyon, be protected in perpetuity. This principle is an important one because humans have become disconnected from both the living and the nonliving nonhuman worlds when, in fact, we are utterly dependent on them for our survival. Indeed, the *biophilia hypothesis*, described later in this chapter, states that humans crave a connection with nature and that our health, at least in part, is dependent on being able to connect with nature on a routine basis. Human ingenuity in the form of technology is having quite the opposite effect. As noted by Andrew J. Angyal (2003):

> [T]his destructive myth of a technological wonderland in which nature is bent to every human whim is turning the Earth into a wasteland and threatening human survival. Western spiritual traditions have not been able to impede these lethal tendencies, but have encouraged them as part of God's plan for human domination of the Earth, and these traditions have understood human destiny as primarily involving a heavenly spiritual redemption. . . With their preoccupation with redemption and their neglect of creation, modern religious traditions are unable to offer a spirituality adequate to experience the divine in ordinary life or in the natural world.

Thomas Berry (2002) described ten precepts based on nature deriving its rights from universal law, and not human law, which provide an ethical framework for the rights of the nonhuman world:

1. Rights originate where existence originates. That which determines existence determines rights.

2. Since it has no further context of existence in the phenomenal order, the universe is self-referent in its being and self-normative in its activities. It is also the primary referent in the being and activities of all derivative modes of being.
3. The universe is a communion of subjects, not a collection of objects. As subjects, the component members of the universe are capable of having rights.
4. The natural world on the planet earth gets its rights from the same source that humans get their rights, from the universe that brought them into being.
5. Every component of the Earth community has three rights: the right to be, the right to habitat, and the right to fulfill its role in the ever-renewing processes of the Earth community.
6. All rights are species-specific and limited. Rivers have river rights. Birds have bird rights. Insects have insect rights. Difference in rights is qualitative, not quantitative. The rights of an insect would be of no value to a tree or a fish.
7. Human rights do not cancel out the rights of other modes of being to exist in their natural state. Human property rights are not absolute. Property rights are simply a special relationship between a particular human "owner" and a particular piece of "property" so that both might fulfill their roles in the great community of existence.
8. Since species exist only in the form of individuals, rights refer to individuals and to their natural groupings of individuals into flocks, herds, packs, not simply in a general way to species.
9. These rights as presented here are based upon the intrinsic relations that the various components of Earth have to each other. The planet Earth is a single community bound together with interdependent relationships. No living being nourishes itself. Each component of the Earth community is immediately or mediately dependent on every other member of the community for the nourishment and assistance it needs for its own survival. This mutual nourishment, which includes the predator-prey relationships, is integral with the role that each component of the Earth has within the comprehensive community of existence.
10. In a special manner humans have not only a need for but a right of access to the natural world to provide not only the physical need of humans but also the wonder needed by human intelligence, the beauty needed by human imagination, and the intimacy needed by human emotions for fulfillment.

Clearly, putting nature on an equal footing with humans is a difficult leap for many people, but vigorously protecting nature is in the best interests of humanity. Indeed, simply protecting nature does not quite meet the imperatives of the principle of protecting the rights of the nonhuman world. Rather, humans should consider restoring nature in all activities, righting the wrongs of the past, and in the process restoring the badly damaged link between humans and nature.

RESPECT FOR THE NATURE AND THE LAND ETHICS

Respect for nature follows from acknowledging the rights of the nonhuman world described in the previous sections. An ethics of respect for nature is based on the fundamental concepts that (1) humans are members of Earth's community of life, (2) all species are interconnected in a web of life, (3) each species is a teleological center of life pursuing good in its own way, and (4) human beings are not superior to other species. This last concept is based on the other three and shifts the focus from *anthropocentrism*, or a human-centered viewpoint, to a *biocentric* outlook (Taylor 1981).

Humans are part of precisely the same evolutionary process as all other species. All other species that exist today faced the same survival challenges as humans. The same biological laws that govern other species—for example, the laws of genetics, natural selection, and adaptation—apply to all living creatures. Earth does not depend on humans for its existence. On the contrary, humans are the only species that has ever threatened the existence of the Earth itself. As relative latecomers, humans appeared on a planet that had contained life for 600 million years. Not only do humans have to share the planet with other species, but they are totally dependent on those species for survival. Human beings threaten the soundness and health of Earth's ecosystems by their behavior. Technology results in the release of toxic chemicals, radioactive materials, and endocrine disruptors. Forestry and agriculture destroy biologically dense and diverse forests. Emissions pollute land, water, and air. Unlike natural extinctions of the past from which Earth recovered, the current human-induced extinction is causing disruption, destruction, and alteration at such a high rate that, even if the human species causes its own extinction, the planet may never recover. An ethics based on biocentrism would result in humans realizing that the integrity of the entire biosphere would benefit all communities of life, humans and nonhumans. It is debatable whether this concept is merely an ethical one because it is also a biological fact that humans cannot survive without the ecosystems on which they depend. However, human beings have the capability to act and change behavior based on knowledge, in this case the awareness of the causal relationship of behavior to the survival of other species. An ethics of respect for nature consists not only of realizing this causal relationship but also of adopting behaviors that respect the rights of nonhuman species to both exist and thrive.

In addition to respecting the rights to survival of other species, as a consequence of careful observation and the application of scientific principles and the scientific method, humans understand the unique qualities and aspects of other organisms. These observations allow us humans to see these organisms as unique teleological centers of life, each struggling to survive and realize its good in its own way. This does not mean that organisms need to have the characteristic of consciousness, that is, self-awareness, to be "good," because each is oriented toward the same ends: self-preservation and well-being. The ethical concept here is that because each species is a teleological center of life, its universe or world can be viewed from the perspective of its life. Consequently, good (finding food), bad (being injured or killed), and indifferent (swimming in the ocean) events can be said to occur in each species' life, as is the case for the human species. Having respect for nature means that humans can view life events for nonhuman species in much the same fashion as they would for other humans.

Aldo Leopold (1949) suggested that there should be an ethical relationship with the land and that this relationship should and must be based on love, respect, and admiration for the land. Furthermore, this ethical relationship, referred to as the *land ethic*, should exist not only because of economic value but should also be based on value in the philosophical sense (see Figure 2.9). The land ethic makes sense because of the close relationship and interdependence of humans with land, which provides food and amenities and contributes to good air and water quality. Humans have tended to become disconnected from the land because of technological developments that give us apparent (but not actual

Figure 2.9 Aldo Leopold advocated a relationship between humans and the land that he referred to as the land ethic. (*Source:* Courtesy of The Aldo Leopold Foundation)