Section 1:
Basics

CHAPTER ONE

Introduction and Background

INTRODUCTION

There continues to be a growing awareness about the impact of the built environment on the natural environment. The use of sustainable engineering concepts has evolved quite rapidly in recent years and is now well recognized in HVAC&R and related engineering professions. This in turn is being encouraged by increased client demand for more sustainable buildings, commonly called *green buildings*.

Interest in sustainable or green buildings (the distinction between the two is discussed below) has been particularly evident in the concern about energy and water resource consumption, but also includes broader concerns such as indoor environmental air quality, material use, and "smart" development and planning. Many countries in the world now have green-building rating systems (voluntary) and/or codes (mandatory) in some form or other. Organizations devoted to green buildings now exist in most countries. Even as the concept of green design is reaching mainstream acceptance, these organizations continue to promote these concepts, exhort the industry and society to action, strive to motivate industry practitioners and building owners, warn of consequences from ignoring these concepts, and instruct how to achieve green design.

ASHRAE identified a need for guidance on green building concepts specifically directed toward practicing professionals involved on a day-to-day basis in the mechanical/electrical/plumbing (MEP) building system design process. However, readers may find that this guide may also serve other needs—for example, as the basis for a university course in sustainable building design. From a survey conducted in 2011, a wider range of people now use the *ASHRAE GreenGuide*, including students and other professionals in related disciplines. The topics covered in this guide are global and thus there has been an effort to keep this guide applicable internationally.

Green is one of those words that can have many meanings, depending on the circumstances. One of these is the greenery of nature in the flora around us. This symbolic reference to nature is the meaning this term relates to in this publication. The difference between a green and sustainable design is the degree to which the design helps to minimize the building impact on the environment while simultaneously providing a healthy, comfortable indoor environment. When the term *green* is used, is commonly is thought of as focusing on the energy and resources involved, while *sustainable* is broader in scope and considers the three Ps: people, profit and planet. However, some may not recognize a difference between the two terms and use them interchangeably; this is also the general approach taken in this book. This guide is not intended to cover the full breadth of sustainability, as this would require and extensive series of volumes, but it is a good overview of the main topics and issues involved. For additional key characteristics and detailed discussion of sustainability in buildings and the built environment, refer to the "Sustainability" chapter in the *ASHRAE Handbook—Fundamentals* (ASHRAE 2017a).

It is important to note that the definition of *green buildings* places an emphasis on integrated design of mechanical, electrical, architectural, and other systems. Specifically, a green/sustainable building design is one that achieves high performance, over the full life cycle, in the following areas:

- Minimizing natural resource consumption through more efficient utilization of nonrenewable energy and other natural resources, land, water, and construction materials, including utilization of renewable energy resources to strive to achieve net zero energy consumption.
- Minimizing emissions that negatively impact our global atmosphere and ultimately the indoor environment, especially those related to indoor air quality (IAQ), greenhouse gases, global warming, particulates, or acid rain.
- Minimizing discharge of solid waste and liquid effluents, including demolition and occupant waste, sewer, and stormwater, and the associated infrastructure required to accommodate removal.
- Minimizing negative impacts on the building site.
- Optimizing the quality of the indoor environment, including air quality, thermal regime, illumination, acoustics/noise, and visual aspects to provide comfortable human physiological and psychological perceptions.
- Optimizing the integration of the new building project within the overall built and urban environment. A truly green/sustainable building should not be thought of or considered in a vacuum, but rather in how it integrates within the overall societal context.

Ultimately, even if a project does not have overtly stated green/sustainable goals, the overall approaches, processes, and concepts presented in this guide provide a design philosophy useful for any project. Using the principles of this guide, an owner or a team member can document the objectives and criteria to include in a project, forming the foundation for a collaborative integrated project delivery approach. This can lower design, construction, and operation costs, resulting in a lower total cost for the life of the project.

RELATIONSHIP TO SUSTAINABILITY

The related term *sustainable design* is very commonly used, almost to the point of losing any consistent meaning. While there have been some rather varied and complex definitions put forth (see the Digging Deeper sidebar titled "Some Definitions and Views of Sustainability from Other Sources"), a simple one is adapted in this guide: sustainability is providing for the needs of the present without detracting from the ability to fulfill the needs of the future.

The preceding discussion suggests that the concepts of green design and sustainable design have no absolutes—that is, they cannot be defined in black-and-white terms. These terms are more useful when thought of as a mindset: a goal to be sought and a process to follow. This guide is a means of (1) encouraging designers of the built environment to employ strategies for developing a green/sustainable design, and (2) setting forth some practical techniques to help practitioners achieve the goal of green design, thus making a significant contribution to sustainability.

Another method for assessing sustainability is through the concept of the triple bottom line (Savitz and Weber 2006). This concept advances the idea that monetary cost is not the only way to value project design options. The triple bottom line concept advocates for the criteria to include economic, social, and environmental impacts of building design and operations decisions.

COMMITMENT TO GREEN/SUSTAINABLE HIGH-PERFORMANCE PROJECTS

Green projects require more than a project team with good intentions; they require commitment from the owner and the rest of the project team, early documentation of sustainable/green goals recorded by the Owner's Project Requirement (OPR), and the designer's documented basis of design. The most successful projects incorporating green design are ones with dedicated, proactive owners who are willing to examine (or give the design team the freedom to examine) the entire spectrum of ownership—from design to construction to long-term operation of their facilities. These owners understand that green buildings require more planning, better execution, and better operational procedures, requiring a firm commitment to changing how building projects are designed, constructed, operated, and maintained to achieve a lower total cost of ownership and lower long-term environmental impacts.

Implementing green/sustainable practices could indeed raise the initial design soft costs associated with a project, particularly compared to a code minimum building design. First cost is an important issue and often is a stumbling block in moving building design from the code minimum ("good or adequate design") to one that is more truly sustainable. Implementing the commissioning process early in the predesign phase of a project adds an initial budget line item but can often actually reduce overall total design/construction costs and the ultimate cost of ownership.

In addition, significant savings and improved productivity of the building occupants can be realized for the life of the building, lowering the total cost of ownership and/or providing better value for tenants. To achieve lifelong benefits also requires operating procedures for monitoring performance, making adjustments (continuing commissioning) when needed, and appropriate maintenance.

WHAT DRIVES GREEN PROJECTS

Green-building advocates can cite plenty of reasons why buildings should be designed utilizing integrated green concepts. The fact that these reasons exist does not make it happen in routine building projects, nor does the existence of designers—or design firms—with green design experience. The main driver of green-building design is the motivation of the owner—the one who initiates the creation of a project, the one who pays for it (or who carries the burden of its financing), and the one who has (or has identified) the need to be met by the project in question. If the owner does not believe that green design is needed, thinks it is unimportant, or thinks it is of secondary importance to other needs, then it will not happen. In addition, recent trends in the industry are moving toward green-building practices being made mandatory, either through local adoption of new codes and standards or through an organizational policy. These trends are discussed in more detail in Chapter 2.

THE IMPACT OF CARBON CONSIDERATIONS

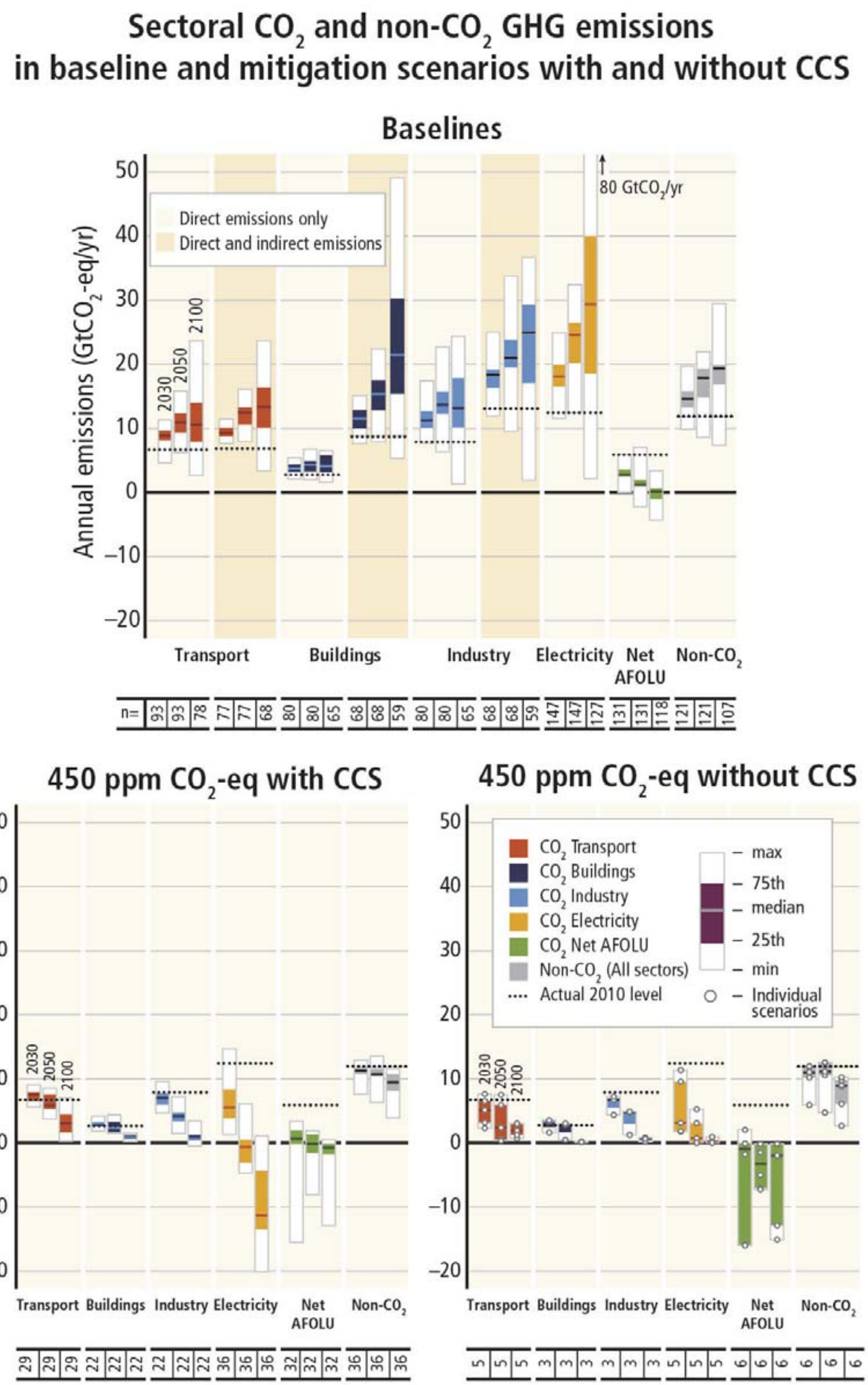
The attention paid to concerns about greenhouse gas emissions has certainly increased in much of the world. During the first decade of the twenty-first century, two organizations issued challenges to the industry to design and implement buildings that had a significantly lower energy consumption compared to current typical designs. The Architecture 2030 Challenge (see the "References and Resources" section at the end of the chapter for more information) is one of these. Architecture 2030 was initiated by Edward Mazria in 2002, setting a goal of net zero energy and net zero carbon buildings by the year 2030. This goal is to be realized by achieving substantially better building energy performance on a sliding scale from 2010 through 2030. The near-term focus of the challenge was adopted by the American Institute of Architects (AIA). The Architecture 2010 Imperative achieved a goal of constructing new buildings that show a 50% improvement in energy efficiency compared to those built using the 1999 version of ANSI/ASHRAE/IES Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*

(ASHRAE 1999). In Europe, there is an ongoing parallel effort to meet an ambitious goal of nearly zero energy buildings after 2020, according to the Energy Performance of Buildings Directive (EPBD) (European Commission 2010).

There is bad news and good news when we look at how buildings are involved with greenhouse gas (GHG) emissions. First, the bad news: buildings (commercial and residential) are responsible for approximately 30% of the GHG emissions in the United States and most developed countries, and the trend is also holding up in key developing nations. The good news is that buildings have also been identified as the economic sector with the best potential for cost-effective mitigation of GHG emissions, as highlighted in Figure 1-1. In this figure, the carbon dioxide (CO_2) emissions by sector and total non-CO_2 GHG emissions across sectors are shown in the baseline scenario at top while the bottom portion of Figure 1-1 shows the net result from mitigation scenarios that reach an average of about 450 ppm (in a range of 430 to 480 ppm) CO_2 equivalent (CO_2-eq) emissions (likely to limit warming to 3.6°F [2°C] above preindustrial levels) with CO_2 capture and storage (CCS, left) and without CCS (right). The difference between the baseline and mitigation scenarios in this figure represent the net emissions decrease possible for each sector, and the buildings sector represents one of the highest potential options. Therefore, the buildings industry can and should take responsibility for reducing GHG emissions, primarily through a reduction in energy consumption for new construction, in refurbishing existing buildings, and planning for the operation and maintenance to maintain the high level of efficiency.

The Conference of the Parties meeting in Paris in late 2015 (COP21) was recognized as a breakthrough event where the first significant changes to a global approach to address climate concerns were made in nearly 25 years. More importantly for the buildings industry, the important role of buildings in addressing this problem was recognized at this conference and a new organization, the Global Alliance for Buildings and Construction, was created. This alliance has a four-step strategic approach to: (1) reduce the energy demand of buildings (in particular, existing buildings), (2) decarbonize the energy and power supply for buildings, and (3) reduce the embodied greenhouse gases in materials and equipment through life cycle analysis, and increase resiliency by adaptations against climate change and associated other risks.

ASHRAE took the lead in meeting these challenges in several ways. To address the Architecture 2010 Imperative, significant effort was put into modifying Standard 90.1 (ASHRAE 1999) to drastically improve energy efficiency. The 2010 version of Standard 90.1, in essence, met the AIA challenge for 2010 by introducing requirement changes that were developed and introduced during that decade. Subsequent versions of Standard 90.1 continue to increase the minimum energy efficiency requirements. Although the specific requirements may differ in some cases, ANSI/ASHRAE/USGBC/IES Standard 189.1, *Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings* (ASHRAE



Source: IPCC (2014)

Figure 1-1 Cross-sectoral mitigation strategies.

2017b) and the *International Green Construction Code* (IgCC) have energy efficiency levels that exceed the minimum code values in Standard 90.1.

Another way this is being accomplished is through the production of the ASHRAE Advanced Energy Design Guide (AEDG) series. The series covers prescriptive measures that result in significant energy efficiency improvements, with the first series dealing with measures that should achieve 30% and 50% savings over Standard 90.1 (ASHRAE 1999) with even more strenuous improvements in the planning process. Additional details on these guides can be found in Chapter 2.

The HVAC&R engineer can provide a significant benefit to society (as well as to the building project's owners) via CO_2 emissions reduction associated with lower energy consumption. All new building projects that wish to comply with green principles should at least estimate the CO_2 equivalent emissions footprint of the building (of which a large part is produced through energy consumption). Using publicized emissions factors, these calculations are not complicated and can provide insight. For existing buildings, the goal is to compute the reduction in emissions associated with proposed energy conservation measures. In both cases, the GHG emissions factor used should be based on source energy and not on energy consumed on site alone. A good initial reference source for emissions factors is a 2007 National Renewable Energy Laboratory (NREL) report (Deru and Torcellini 2007). The emissions factors for site electricity consumption in the United States have been updated by the U.S. Environmental Protection Agency (EPA) to reflect recent trends away from coal-based electricity production to more natural gas and other renewable energy systems such as solar and wind. Along the same lines, the European Commission is reviewing the methodology for the calculation of a primary energy factor in the context of revising the Energy Efficiency Directive (EED) and preparing the upcoming legislative proposals on the 2030 Climate and Energy Framework. Currently, a default coefficient of 2.5 may be used for converting kilowatt-hour electricity (EED 2006/32/EC), although EU Member States may apply a different coefficient provided they can justify it. The ongoing efforts underline the need to regularly revise the conversion factor for electricity and that the methodology adequately reflects the strong efforts of the European power sector to decrease the carbon footprint and increase the share of renewables in the power generation mix. European informative default values for various energy carriers are available in ISO 52000-1, *Energy Performance of Buildings—Overarching EPB Assessment*

SUSTAINABILITY IN ARCHITECTURE

The emergence of green-building engineering is best understood in the context of the movement in architecture toward sustainable buildings and communities. Detailed reviews of this movement appear elsewhere and fall outside the scope of this document. A brief review of the history and background of the green design movement is provided, followed by a discussion of its applicability. Several leading

Digging Deeper

INTERNATIONAL PERSPECTIVE: REGULATIONS AND COMMENTARY

Society has recognized that previous industrial and developmental actions caused long-term damage to our environment, resulting in loss of food sources and plant and animal species, and changes to the Earth's climate. As a result of learning from past mistakes and studying the environment, the international community identified certain actions that threaten the ecosystem's biodiversity, and, consequently, it developed several governmental regulations designed to protect our environment. Thus, in this sense, the green design initiative began with the implementation of building regulations. An example is the regulated phaseout of fully halogenated chlorofluorocarbons (CFCs) and partially halogenated refrigerant hydrochlorofluorocarbons (HCFCs).

In Europe, the main regulatory instrument for tackling the energy consumption of buildings is the Energy Performance of Buildings Directive (EPBD) recast (European Commission 2010), which took effect in 2012 and replaced the original EPBD Directive (European Commission 2002). All EU member states introduced national laws, regulations, and administrative provisions for setting minimum requirements on the energy performance of new and existing buildings that are subject to major renovations and for energy performance certification of buildings. Additional requirements include regular inspection of boilers and air conditioning systems in buildings, an assessment of the existing facilities, and provision of advice on possible improvements and alternative solutions. Moreover, the EPBD recast strengthens the energy performance requirements and clarifies and streamlines some of the original EPBD provisions to reduce the large differences between EU member states' practices. In particular, it requires that EU member states lay down the requirements so that new buildings are nearly zero energy by 2020 (2018 for public buildings) and the application of cost-optimal levels for setting minimum energy performance requirements for both the building's thermal envelope and technical systems.

Energy performance certificates (EPC) are issued when buildings are constructed, sold, or rented out. The EPC documents the energy performance of the building and is expressed as a numeric indicator or a letter grade that allows benchmarking of primary energy consumption. The certificate also includes recommendations for cost-effective improvement of the energy performance, and is valid for up to ten years. National efforts and examples of EPCs are detailed in the works by Arcipowska et al. (2014) and Maldonado (2016).

The Concerted Action EPBD launched by the European Commission provides updated information on the implementation status in the various European countries (www.epbd-ca.org).