

# ASHRAE GreenGuide

Design, Construction, and Operation  
of Sustainable Buildings

Fourth Edition



- Comprehensive guidance on sustainable buildings
- Major revisions to all chapters
- GreenTips with detailed insights for design and operation



# **ASHRAE GreenGuide**

**Design, Construction,  
and Operation  
of Sustainable Buildings**

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*This publication was developed under the auspices of TC 2.8, Building Environmental Impacts and Sustainability. TC 2.8 is concerned with the impacts of buildings on the local, regional, and global environment; means for identifying and reducing these impacts; and enhancing ASHRAE member awareness of the impacts.*

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**Tom Lawrence**, PhD, PE, LEED-AP, is the chair of the editorial revision committee and coeditor of *ASHRAE GreenGuide*, Fourth Edition. He is a senior public service associate with the University of Georgia and has over 30 years of experience in engineering and related technical fields. He is a past chair of ASHRAE Technical Committee (TC) 2.8 and is a member of the committee that wrote ANSI/ASHRAE/USGBC/IES Standard 189.1, *Standard for the Design of High-Performance Green Buildings*. Dr. Lawrence is also a member of ASHRAE's Technical Activities Committee. As an ASHRAE Distinguished Lecturer, he gives seminars on green building design at venues around the world.

**Abdel K. Darwich**, PE, CEng, LEED-AP, HFDP, is a coeditor of *ASHRAE GreenGuide*, Fourth Edition. He is an associate principal with Guttman and Blaevoet Consulting Engineers in their Sacramento office. Darwich has more than 15 years of experience in the design of mechanical systems for healthcare, commercial, industrial, K-12, mixed-use, and high-end residential uses with emphasis on low-energy and zero-energy design. He is a member of ASHRAE TC 2.8 and Standing Standard Project Committee 62.1, an ASHRAE certified Healthcare Facility Design Professional, and a recipient of a 2013 ASHRAE Technology Award.

**Janice K. Means**, PE, LEED-AP, is the third coeditor of *ASHRAE GreenGuide*, Fourth Edition. She is an associate professor in the College of Architecture and Design at Lawrence Technological University in Southfield, Michigan. Means has over 25 years of experience in the industry. She is a trained presenter for ANSI/ASHRAE/IESNA 90.1 2001 and 2004, a voting member of ASHRAE TC 2.8, Chair of ASHRAE TC 6.7, and was a contributing author to Chapter 36 of the 2008 *ASHRAE Handbook—HVAC Systems and Equipment*.

**Sarah Boyle**, assistant editor in ASHRAE Special Publications, served as staff editor for *ASHRAE GreenGuide*, Fourth Edition.

---

ASHRAE STAFF

SPECIAL PUBLICATIONS

**Mark S. Owen, Editor/Group Manager of Handbook and Special Publications**  
**Cindy Sheffield Michaels, Managing Editor**  
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**W. Stephen Comstock**

**Updates/errata for this publication will be posted on the ASHRAE Web site at [www.ashrae.org/publicationupdates](http://www.ashrae.org/publicationupdates).**

# **ASHRAE GreenGuide**

## **Design, Construction, and Operation of Sustainable Buildings**

Fourth Edition



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## Tomorrow's Child

Without a name, an unseen face,  
And knowing not the time or place,  
Tomorrow's Child, though yet unborn,  
I saw you first last Tuesday morn.  
A wise friend introduced us two,  
And through his shining point of view  
I saw a day, which you would see,  
A day for you, and not for me.  
Knowing you has changed my thinking,  
Never having had an inkling  
That perhaps the things I do  
Might someday threaten you.  
Tomorrow's Child, my daughter-son,  
I'm afraid I've just begun  
To think of you and of your good,  
Though always having known I should.  
Begin I will to weigh the cost  
Of what I squander, what is lost,  
If ever I forget that you  
Will someday come to live here too.

by Glenn Thomas, ©1996

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Sustainable Enterprise:  
The Interface Model*  
by Ray Anderson.  
Chelsea Green  
Publishing Company, 1999.



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## FOREWORD

by William Coad

*Mechanical engineering* has been defined as “the applied science of energy conversion.” ASHRAE is the preeminent technical society that represents engineers practicing in the fields of heating, refrigeration, and air conditioning—the technology that utilizes approximately one-third of the global nonrenewable energy consumed annually.

ASHRAE membership has actively pursued more effective means of utilizing these precious nonrenewable resources for many decades from the standpoints of source availability, efficiency of utilization, and technology of substituting with renewable sources. One significant publication in *ASHRAE Transactions* is a paper authored in 1951 by G.W. Gleason, Dean of Engineering at Oregon State University, titled “Energy—Choose it Wisely Today for Safety Tomorrow.” The flip side of the energy coin is the environment and, again, ASHRAE has historically dealt with the impact that the practice of the HVAC&R sciences have had upon both the indoor and the global environment.

However, the engineering community, to a great extent, serves the needs and desires of accepted economic norms and the consuming public, a large majority of whom have not embraced an energy/environmental ethic. As a result, much of the technology in energy effectiveness and environmental sensitivity that ASHRAE members have developed over this past century has had limited impact upon society.

In 1975, when ASHRAE published ASHRAE Standard 90-75, *Energy Conservation in New Building Design* (ASHRAE 1975), that standard served as our initial outreach effort to develop an awareness of the energy ethic and to extend our capabilities throughout society as a whole. Since that time, updated revisions of Standard 90 have moved the science ahead. In 1993, the chapter on “Energy Resources” was added to the 1993 *ASHRAE Handbook—Fundamentals*. In 2002, ASHRAE entered into a partnering agreement with the US Green Building Council, and it is intended that this and future editions of this design guide will continue to assist ASHRAE in its efforts at promoting sustainable design, as well as



the many other organizations that have advocated for high-performance building design.

The consuming public and other representative groups of building professionals continue to become more and more aware of the societal need to provide buildings that are more energy resource effective and environmentally compatible. This publication, authored and edited by ASHRAE volunteers, is intended to complement those efforts.

The reader is cautioned that a successful green design, like any other successful design, must achieve a high level of environmental comfort and air quality. In addition, the building must be designed so that it can be operated and maintained in such a way as to keep the high level of performance expected.

## PREFACE TO THE FOURTH EDITION

by Tom Lawrence

This new and fourth edition of *ASHRAE GreenGuide* represents another update and revision to what has become one of ASHRAE's primary products and contributions toward sustainable design of the built environment. In early 2012, ASHRAE introduced a major rebranding effort for the society. The Society President at this time was Ron Jarnagin, and in his letter to the members he gave the following summary of this effort: "For more than 100 years, ASHRAE has provided guidance for HVAC&R. As time and technology have changed, so has ASHRAE, moving from focusing solely on HVAC&R to providing guidance for total building design, reconstruction, construction and operation" ([www.ashrae.org/news/ashrae-announces-rebranding](http://www.ashrae.org/news/ashrae-announces-rebranding)).

This new fourth edition is being released at the ten year anniversary of the release of the very first edition in January 2004. It has been ASHRAE's general plan to update and maintain this document on a regular basis, because the technology and entire concept of how green building practices are done and considered within the industry is rapidly changing.

Since the release of the previous third edition of the *GreenGuide*, a number of developments have occurred in the green building arena. ASHRAE has continued to refine and modify Standard 189.1, with a new release of that standard occurring in late 2011. ASHRAE also partnered with the International Code Council for the release of the *International Green Construction Code*<sup>™</sup> (IgCC) in March of 2012. Adoption and use of these codes and standards is beginning to pick up pace, and other organizations and jurisdictions are using these as the basis for their own codes and design standards. Thus, the industry is witnessing the continued evolution of green building programs from strictly voluntary to being both more in the industry mainstream as well as being mandatory in jurisdictions that have adopted these for their building codes.

The fourth edition features new information and GreenTips. This follows the example set by ASHRAE's rebranding in 2012. For example, there is a new chapter that outlines the key components for designing for sustainable sites. A nonessential chapter that reviewed engineering fundamentals was removed to

make room for additional material. New GreenTips were created for topics such as condensing boilers, rain gardens, green roofs, and a Building-Type GreenTip for data centers. Many of the chapters were extensively rewritten, in particular the chapter on indoor environmental quality and the chapter on architectural design and planning impacts.

One of the goals for the editorial committee for this revision was to bring in a large number of additional outside reviewers. In this process, it is likely that we have missed giving credit to the individuals that contributed their time and effort in reviewing and editing as well as the creation of new material for this edition; for this I do apologize. The revision process spread out through a wide number of channels and distributions as ASHRAE members and the dedicated volunteers all pitched in to help create the best product possible. Finally, the current version could not have been possible without all the hard work and dedication put into it by others who created the previous three editions. This book truly represents the collaborative nature of the work done by dedicated volunteers within ASHRAE. All work performed—by the authors, editors, developing subcommittees, other reviewers, and TC participants—was voluntary.

## **WHO SHOULD USE ASHRAE GREENGUIDE**

*ASHRAE GreenGuide* is primarily for HVAC&R designers, but it is also a useful reference for architects, owners, building managers, operators, contractors, and others in the building industry who want to understand some of the technical issues regarding high-performance design from an integrated building systems perspective. Considerable emphasis is placed on teamwork and close coordination between parties.

The *GreenGuide* was originally intended for use by younger engineers or architects or more experienced professionals about to enter into their first green design projects. However, a survey taken of those who purchased one of the earlier editions of this publication revealed that it was being used by more experienced individuals primarily. The survey also indicted a higher percentage of the readership from countries outside of North America, perhaps reflecting the growing internationalization of ASHRAE.

## **HOW TO USE ASHRAE GREENGUIDE**

This document is intended to be used more as a reference than as something one would read in sequence from beginning to end. The table of contents is the best place for any reader to get an overall view of what is covered in this publication. Throughout the *GreenGuide*, numerous techniques, processes, measures, or special systems are described succinctly in a modified outline or bullet form. These are called ASHRAE GreenTips. Each GreenTip concludes with a listing of other sources that may be referenced for greater detail. (A list of GreenTips and Digging Deeper sidebars can be found in the Table of Contents.)

All readers should take the time to read Chapter 1, “Introduction and Background,” which provides some essential definitions and meanings of key terms. Chapter 2, “Sustainable Sites” provides a brief overview of the relationship of the building project to the site and surroundings. Some may question the need for this, but since a successful green building project is the collaboration of many disciplines, it is felt that this topic should not be overlooked.

Chapter 3 provides an overview of project strategies. Chapter 4 covers the early stages of the design process, and Chapter 5 highlights architectural design and planning impacts. These chapters are essential reading for all who are interested in how the green design process works. Building-Type GreenTips are included at the end of Chapter 5. Chapter 6 provides an overview of the commissioning process, a critical component that needs to be addressed from the beginning on all truly successful high-performance building projects. Chapter 7 describes green rating systems and the relevant standards and paths to compliance as they relate to the work of the mechanical engineers.

The next nine chapters deal with virtually all of the practical suggestions for possible strategies and concepts to be appropriately incorporated into a green building design. Chapters 17 and 18 cover what happens after the design documents for the project have been completed—that is, during construction, final commissioning, and the postoccupancy phases of a building project.

At the end of the guide is a comprehensive “References and Resources” section, which compiles all the sources mentioned throughout the guide, and an index for rapid location of a particular subject of interest.

## **BACKGROUND ON ASHRAE GREENGUIDE**

The idea for the publication was initiated by 1999–2000 ASHRAE President Jim Wolf and carried forward by then President Elect (and subsequently President) William J. Coad. Members of that first subcommittee were David L. Grumman, Fellow ASHRAE, chair and editor; Jordan L. Heiman, Fellow ASHRAE; and Sheila Hayter, chair of TC 1.10 (the precursor to TC 2.8 of today).

The *GreenGuide* subcommittee responsible for the second and third editions consisted of John Swift, Tom Lawrence, and the people noted in the Acknowledgments section. Work on the fourth edition was overseen by a subcommittee of TC 2.8 chaired by Tom Lawrence and also including Janice Means and Abdel Darwiche.



## ACKNOWLEDGMENTS

The following individuals served as coeditors on this edition of *ASHRAE GreenGuide*, provided written materials and editorial content, and formed the Senior Editorial Group of the ASHRAE TC 2.8 *GreenGuide* Subcommittee for the second and third editions:

**Thomas Lawrence**

*University of Georgia  
Athens, GA*

**Abdel K Darwich**

*Guttman and Blaevoet Consulting  
Engineers, Sacramento, CA*

**Janice K. Means**

*Lawrence Technological University  
Southfield, MI*

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**Constantinos A. Balaras**

*Institute for Environmental Research &  
Sustainable Development,  
National Observatory of Athens (NOA)  
Athens, Greece*

**Steven Guttman**

*Guttman and Blaevoet Consulting  
Engineers  
San Francisco, CA*

**Jason Bedgood**

*Student, University of Georgia  
Athens, GA*

**R. Ryan Hammond**

*Formerly with Guttman and  
Blaevoet Consulting Engineers  
Sacramento, CA*

**Daniel Faoro**

*Lawrence Technological University  
Southfield, MI*

**Michael Meteyer**

*Erdman Company  
Madison, WI*

**Ashish Rakheja**

*AECOM  
New Delhi, India*

**Nadia Sabeh**

*Guttman and Blaevoet Consulting  
Engineers  
Sacramento, CA*

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*Cannon Design  
Boston, MA*

**Jennifer Wehling**

*Lionakis  
Sacramento, CA*

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**Robert Baker**

*BBJ Environmental Solutions  
Riverview, FL*

**Terry Brennan**

*Camroden Associates  
Westmoreland, NY*

**David Grimsrud**

*University of Minnesota  
Minneapolis, MN*

**Roger Hedrick**

*Architectural Energy Corporation  
Boulder, Colorado*

**Martha Hewett**

*Center for Energy and Environment  
Minneapolis, MN*

**Josephine Lau**

*University of Nebraska-Lincoln  
Lincoln, Nebraska*

**Hal Levin**

*Building Ecology Research Group  
Santa Cruz, CA*

**Dennis Lovejoy**

*Loughborough University  
Loughborough, UK*

**Chandra Sekhar**

*National University of Singapore  
Singapore, Singapore*

**Zuraimi Sultan**

*National Research Council of Canada  
Ottawa, Canada*

**Lily Wang**

*University of Nebraska-Lincoln  
Lincoln, Nebraska*

**Pawel Wargocki**

*Technical University of Denmark  
Lyngby, Denmark*

**Jianshun Zhang**

*Syracuse University  
Syracuse, NY*

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**Ainul Abedin**

**Jerry Ackerman**

**John Andrepont**

**Kimberly Barker**

**Steven Baumgartner**

**David Bearg**

**Bill Becker**  
**James Benya**  
**James Bones**  
**Dean Borges**  
**Gail S. Brager**  
**Stu Brodsky**  
**Amy Butterfield**  
**Stephen Carpenter**  
**Daryn Cline**  
**Dimitri Contoyannis**  
**Kevin Cross**  
**Len Damiano**  
**Michael Deru**  
**Kevin Dickens**  
**Rand Ekman**  
**H. Jay Enck**  
**Michael Forth**  
**Guy S. Frankenfield**  
**Glenn Friedman**  
**Michael Gallivan**  
**Krishnan Gowri**  
**David L. Grumman**  
**Michael Haggans**  
**Jordan L. Heiman**  
**Mark Hertel**  
**Bion Howard**  
**Mark Hydemann**  
**Brad Jones**  
**James Keller**  
**John Kokko**

**Wladyslaw Jan Kowalski**  
**John Lane**  
**Nils L. Larsson**  
**Eddie Leonardi**  
**Malcolm Lewis**  
**Mark Loeffler**  
**Dunstan Macauley**  
**Garrick Maine**  
**Blair McCarry**  
**Paul McGregor**  
**Mark Mendell**  
**Neil Moiseev**  
**Vikas Patnaik**  
**Ron Perkins**  
**Jason Perry**  
**B. Andrew Price**  
**Douglas T. Reindl**  
**Wayne Robertson**  
**Brian A. Rock**  
**Steven Rosen**  
**Marc Rosenbaum**  
**Sara Schonour**  
**Mick Schwedler**  
**Eugene Stamper**  
**Karl Stum**  
**E. Mitchell Swann**  
**John M. Swift, Jr.**  
**Paul Torcellini**  
**Stephen Turner**  
**Charles Wilkin**





# **Section 1: Basics**



## CHAPTER ONE

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# 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 green engineering concepts has evolved quite rapidly in recent years and is now a legitimate and spreading movement in the HVAC&R and related engineering professions. Much of this recent work has been driven by the emergence of green architecture, also commonly referred to as sustainable or environmentally conscious architecture. This, in turn, is being encouraged by increased client demand for more sustainable buildings.

Interest in green buildings has been particularly evident in the concern about energy and water resource consumption, but also includes broader concerns such as material use, “smart” development and planning, etc. Many countries in the world now have green-building rating systems (voluntary) and/or codes (mandatory in some form or other). Organizations devoted specifically to this issue are now in existence in most countries. Not only have the messages contained in this outpouring of information attempted simply to explain what this issue is, they have promoted the concept of green design, exhorted to action, strived to motivate, warned of consequences from ignoring it, and instructed how to do it.

While this vast amount of promotion has been helpful, much has not been directly useful to the practicing designer for buildings (i.e., to the ASHRAE member involved on a day-to-day basis in the mechanical/electrical building system design process). ASHRAE identified a need for guidance on the green-building concept specifically directed toward such practitioners. One key motivation for the development of this guide is that it contains information that has direct practical use. This guide is ASHRAE's way to provide information and guidance to the industry and practicing professionals.

*Green* is one of those words that can have many meanings, depending on the circumstances. One of these is the greenery of nature (e.g., grass, trees,

and leaves). 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. This guide is not intended to cover the full breadth of sustainability, but it is a good overview of many of the main topics. For key characteristics and more detailed discussion of sustainability, refer to the “Sustainability” chapter in the 2013 *ASHRAE Handbook—Fundamentals* (ASHRAE 2013).

The definition of *green buildings* inevitably extends beyond the normal daily concerns of HVAC&R designers alone, since the very concept places an emphasis on integrated design of mechanical, electrical, architectural, and other systems.

Specifically, the viewpoint held by many is that 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 member of his or her team 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 operational 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 sidebar titled “Some Definitions and Views of Sustainability from Other Sources”), we prefer a simple one (very similar to the third one in the sidebar). 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 that can be used in 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 the sustainability of the planet.

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 documented by the Owner's Project Requirement document, 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 the 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 design”)