

SUSTAINABLE BUILDING TECHNICAL MANUAL

Green Building Design, Construction, and Operations



Produced by Public Technology Inc. ■ US Green Building Council

Sponsored by U.S. Department of Energy ■ U.S. Environmental Protection Agency

Project Managers

Annette Osso

Business Director, Environmental Programs
Public Technology, Inc.
Project Manager

David A. Gottfried

President
Gottfried Technology Inc.
Managing Editor

Taly Walsh

Communications Director
Public Technology, Inc.
Project Design Manager

Lynn N. Simon

Gottfried Technology Inc.
Senior Editor

Editorial and Production Staff and Consultants

Mark Graef, Production Consultant
Fran Haselsteiner, Editing Consultant
Kathleen Lundy, Editing Consultant
Christopher Marshall, Production Consultant
Patrick McCarthy, Production/Research Consultant
Kristen Mosbaek, Graphic Design/Production Consultant
Shaden Tageldin, PTI Writer/Editor
Jack Werner, PTI Energy Director

Copyright © 1996 by Public Technology, Inc.
All rights reserved.

Printed in the United States of America
Printed on recycled paper.

Acknowledgments

Funding for development of the Sustainable Building Technical Manual was provided to Public Technology, Inc., by the U.S. Department of Energy (DOE), with supplemental funding from the U.S. Environmental Protection Agency (EPA). The DOE and EPA principals involved with the manual's development are listed below.

DOE principals

William Becker

Director
Denver Support Office, U.S. DOE

Mary-Margaret Jenior

Senior Program Manager,
Office of Building Technologies, State and Local
Programs, U.S. DOE

Louis Divone

Acting Deputy Assistant Secretary
Office of Building Technologies, State and Local
Programs, U.S. DOE

EPA principals

David Scott Smith

Associate Director
Safety, Health and Environmental Management Divn.
Office of Administration, U.S. EPA

Lawrence Martin

Project Officer
Office of Research and Science Integration, U.S. EPA

Julius C. Jimeno

Director
Safety, Health and Environmental Management Divn.
Office of Administration, U.S. EPA

John C. Chamberlin

Director
Office of Administration, U.S. EPA

Public Technology, Inc. developed this manual to address the growing demand for information on the design and construction of green buildings. The manual was jointly sponsored by PTI's Urban Consortium Environmental and Energy Task Forces. The U.S. Green Building Council (USGBC) worked with PTI to develop the manual. David Gottfried of Gottfried Technology Inc., served as managing editor. An Advisory Committee of local-government and private-sector representatives assisted in developing the manual. The manual underwent a consensus review process by members of the USGBC and was peer reviewed by U.S. DOE and U.S. EPA officials.

Public Technology, Inc.

Public Technology, Inc., is the non-profit technology research and development organization of the National League of Cities, the National Association of Counties, and the International City/County Management Association. PTI's mission is to bring technology to local and state governments. Through the collective R&D work of its membership, PTI spreads the use of technology to effectively serve communities. PTI uses strong, dynamic public-private partnerships to offer to local and state government cost-saving technology services and products.

PTI is committed to a sustainable environment. Its Urban Consortium (UC) Environmental and Energy Task Forces unite cities and counties behind that goal to explore, test, and promote technologies that maintain the critical balance between healthy development and a healthy environment. Many of its members' innovative programs are highlighted in the annual PTI *SOLUTIONS* publication series.

The UC Environmental Task Force is chaired by Randy Johnson, Commissioner, Hennepin County, Minnesota. The UC Energy Task Force is chaired by Michael Lindberg, Commissioner of Public Utilities, City of Portland, Oregon.

U.S. Green Building Council

The U.S. Green Building Council (USGBC) is a balanced, nonprofit coalition of the building industry promoting the understanding, development, and accelerated implementation of green building policies, programs, technologies, standards, and design practices on a national basis. Since its formation in 1993, the council has attracted more than 100 leading national organizations to its ranks, including product manufacturers, environmental groups, building owners, utilities, state and local governments, research institutions, professional societies, and colleges and

universities. USGBC has also established effective and ongoing liaisons with the White House, federal agencies, standards organizations, and organizations representing state and local governments. Issues being addressed by the council include economic analysis, full-cost accounting, green building rating systems, product certification, life-cycle analysis, environmental policies, standards development, and education of the building industry.

U.S. Department of Energy

The mission of the U.S. Department of Energy (U.S. DOE) is to assure that the nation has adequate and stable supplies of energy. The department is also committed to helping the nation discover and adopt cleaner and more sustainable energy resources and technologies—in other words, technologies that improve energy efficiency, prevent pollution, and make use of renewable resources to diversify the nation's energy mix. U.S. DOE's Office of Energy Efficiency and Renewable Energy (OEERE) operates a number of technical and financial assistance programs to improve the resource efficiency of America's buildings. Among them are Building America, which brings the diverse elements of the building industry together to practice a systems approach to building design and construction, improving cost, durability, indoor air quality, and energy efficiency. In addition, the Office encourages green building practices through its Center of Excellence for Sustainable Development, which helps communities create and implement sustainable development programs. The center will help communities adopt a comprehensive approach to planning—an approach that recognizes the links between energy, environment, economy, and community livability. Information and a "tool kit" on sustainable development is available on the Center's Internet home page, <<http://www.crest.org/doe/sustainable>>, or by calling (800) 357-7732.

U.S. Environmental Protection Agency

The Safety, Health and Environmental Management Division (SHEMD) of U.S. EPA is responsible for developing and implementing the agency's internal policies, programs, and infrastructure for environmental management and public and occupational safety and health. SHEMD works closely with all U.S. EPA operating units to provide management support and technical assistance. Through collaborative relationships with other federal, state, and local government agencies and organizations, business and industry, educational and research institutions, and other entities, SHEMD jointly develops products and services that have widespread public- and private-sector application. A particular emphasis is placed upon learning, information, and performance-support systems, especially those employing new technologies, to help advance the nation's objectives for a sustainable future.

Producing a manual that covers all disciplines involved in the design, construction, and operation of a building is an enormous challenge. Early in the process it was decided that this book, like a building project, would best be designed and constructed via a collaborative, integrated effort of practitioners in the field. Many individuals across the building professions provided a great deal of assistance and deserve thanks for making the manual a success.

A special thanks to Annette Osso, PTI, who provided overall project coordination and management and to David Gottfried of Gottfried Technology Inc., who managed the USGBC's work on the manual. He developed the outline for the manual, identified authors, and worked with Lynn Simon to organize the authors' drafts and reviewers' comments to develop a cohesive document. The individual authors also deserve special thanks for working with the USGBC and PTI, contributing additional information, and reviewing material throughout the process. The Advisory Committee and additional reviewers read and commented on the manual manuscript through several review processes. PTI staff and contractors provided many hours of work to edit and produce the final document. All have worked together to provide building professionals in public and private organizations with a document that will further their green building initiatives.

A final note of thanks goes to Lou Divone, Bill Becker, and Mary-Margaret Jenior of U.S. DOE and to David Scott Smith of U.S. EPA for their support of green building initiatives in communities around the country.

Authors

Loren E. Abraham, AIA, IDSA, Environmental Research Group
Sal Agnello, Johnson Controls
Stephen P. Ashkin, Rochester Midland Corporation
Lucia Athens, University of Georgia, School of Environmental Design
Anthony Bernheim, AIA, Simon Martin – Vegue Winkelstein Moris
Clark C. Bisel, P.E., Flack & Kurtz Consulting Engineers
William Burke, AIA, University of California, Berkeley, Center for Environmental Design and Research
Nicholas T. Dines, FASLA, University of Massachusetts, Department of Landscape Architecture and Regional Planning
Bruce K. Ferguson, University of Georgia, School of Environmental Design
Daniel J. Goldberger, International Council for Local Environmental Initiatives
David A. Gottfried, Gottfried Technology Inc.
Gerard Heiber, Sigal Environmental, Inc.
Lisa Heschong, Heschong Mahone Group
Phillip Jessup, International Council for Local Environmental Initiatives
Barbara Lippiatt, National Institute of Standards and Technology
John D. Longman, Cerami & Associates
Dru Meadows, AIA, BSW International
Michael Myers, U.S. Department of Energy
William G. Reed, AIA, Hillier Group
David Rousseau, Archemy Consulting Ltd.
Kim Sorvig, University of New Mexico, School of Architecture and Planning
Dr. James A. Tshudy, Armstrong World Industries

Advisory Committee

Susan Anderson, city of Portland Energy Office
Joseph Azzarello, Herman Miller, Inc.
Kathy Bakin, American Society of Interior Designers
Larry Blackstad, Hennepin County, Minnesota
William Bobenhausen, Steven Wintor Associates
Helen English, Passive Solar Industries Council
Susan Everett, American Society of Landscape Architects
Richard Fedrizzi, Carrier Corporation
David Gottfried, Gottfried Technology Inc.
Richard Hays, city of San Diego, California
Gerard Heiber, Sigal Environmental, Inc.
Mary-Margaret Jenior, U.S. DOE
Randy Johnson, Hennepin County, Minnesota
Dimitrios Laloudakis, city of Phoenix, Arizona
Steven J. Piguett, Armstrong World Industries
William G. Reed, AIA, Hillier Group
Douglas Seiter, city of Austin, Texas
David Scott Smith, U.S. EPA
Wade Smith, Honeywell Inc.
Ross Spiegel, Construction Specifications Institute
Alan Traugott, Flack & Kurtz Consulting Engineers
Paul Tseng, Montgomery County, Maryland
Doug Yoder, Metro-Dade County, Florida

Additional Reviewers

Loren E. Abraham, AIA, IDSA, Environmental Research Group
Anthony Bernheim, AIA, Simon Martin – Vegue Winkelstein Moris
William Burke, AIA, Architect
Nancy Carlisle, National Renewable Energy Laboratory
Anne Sprunt Crawley, U.S. DOE
Michael O'Reilly, U.S. EPA
Patricia Plympton, National Renewable Energy Laboratory
Adam Saling, San Diego, California
Dr. James A. Tshudy, Armstrong World Industries
Donald Watson, FAIA, Architect
Phil Wirdzek, U.S. EPA

DISCLAIMER: This document was developed by Public Technology, Inc. and the U.S. Green Building Council with funding provided by the U.S. DOE and U.S. EPA. These entities do not make any warranty, expressed or implied, or assume any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product, or process disclosed, or represent that its use would not infringe upon privately owned rights. The parties involved do not assume any liability for the use of any information, methods, or materials contained herein or for damages arising from such use; nor do they assume any responsibility for any injury to individuals or property, or for any loss, sustained as a result of the use or application of contents of this document.

This document was prepared with the assistance and participation of representatives from many organizations. The views and opinions expressed represent general consensus and available information, but unanimous approval by all organizations is not implied. The views and opinions do not necessarily state or reflect those of the United States government.

The information in this document is not a substitute for professional advice, as evidenced by architectural stamps and engineering seals, regarding its use in the design, construction, and renovation of buildings; nor is it a substitute for the adherence to applicable law and sound professional practices, and procedures for sound design, engineering, and construction, including sustainable design, engineering, and construction.

In consideration of the permission given by PTI and USGBC to use this document and in consideration for the value received through the use of this document, the purchaser and user of the document (and his or her heirs, representatives, and assignees) covenant not to sue, and waive and release PTI, the USGBC, and the United States government from any and all claims, demands, and causes of action for any injury to individuals or property, and from any and all financial loss or economic damages sustained by or arising from the purchaser's use of or reliance on this document. Use of this document does not relieve the purchaser from complying with all applicable laws and regulations and proper analysis and monitoring in the design and operation of buildings.

Introduction

Foreword

Author
David A. Gottfried

Since the Industrial Revolution, the world has witnessed incalculable technological achievements, population growth, and corresponding increases in resource use. As we enter a new century, we are recognizing the “side effects” of our activities: pollution, landfills at capacity, toxic waste, global warming, resource and ozone depletion, and deforestation. These efforts are straining the limits of the Earth’s “carrying capacity”—its ability to provide the resources required to sustain life while retaining the capacity to regenerate and remain viable.

As the world’s population continues to expand, implementation of resource-efficient measures in all areas of human activity is imperative. The built environment is one clear example of the impact of human activity on resources. Buildings have a significant impact on the environment, accounting for one-sixth of the world’s freshwater withdrawals, one-quarter of its wood harvest, and two-fifths of its material and energy flows. Structures also impact areas beyond their immediate location, affecting the watersheds, air quality, and transportation patterns of communities.¹

Within the United States, buildings represent more than 50 percent of the nation’s wealth. In 1993, new construction and renovation activity amounted to approximately \$800 billion, representing 13 percent of the Gross Domestic Product (GDP), and employed ten million people.² The resources required to create, operate, and replenish this level of infrastructure and income are enormous, and are diminishing. To remain competitive and continue to expand and produce profits in the future, the building industry knows it must address the environmental and economic consequences of its actions.

That recognition is leading to changes in the way the building industry and building owners approach the design, construction, and operation of structures. With the leadership of diverse groups in the public and private sectors, the building industry is moving toward a new value in its work: that of environmental performance.

The industry's growing sustainability ethic is based on the principles of resource efficiency, health, and productivity. Realization of these principles involves an integrated, multidisciplinary approach—one in which a building project and its components are viewed on a full life-cycle basis. This “cradle-to-cradle” approach, known as “green” or “sustainable” building, considers a building's total economic and environmental impact and performance, from material extraction and product manufacture to product transportation building design and construction, operations and maintenance, and building reuse or disposal. Ultimately, adoption of sustainable building practices will lead to a shift in the building industry, with sustainability thoroughly embedded in its practice, products, standards, codes, and regulations.

Understanding the specifics of sustainable building and determining effective sustainable practices can be confusing. Local governments and private industry often do not have the resources to perform the necessary research to assemble information on sustainable practices, assuming such information is readily available.

The *Sustainable Building Technical Manual* was written to fill that void. In its pages, noted private practitioners and local government experts extract, consolidate, and prioritize—from their own experience and expertise—the scattered and growing volume of information pertaining to sustainable buildings. The manual's primary intent is to provide public and private building industry professionals with suggested practices across the full cycle of a building project, from site planning to building design, construction, and operations.

We hope that you will find this technical manual a useful and vital resource in advancing your organization's adoption and daily practice of sustainable building principles—a necessary and important step toward recognizing the Earth's finite carrying capacity and addressing the depletion of its natural resources.

NOTES

- 1 David Rodman and Nicolas Lenssen, “A Building Revolution: How Ecology and Health Concerns Are Transforming Construction,” *Worldwatch Paper 124* (Washington, D.C., March 1996).
- 2 National Science and Technology Council, Subcommittee on Construction and Buildings, *Preliminary Report* (Washington, D.C., 1993).

The Role of Local Governments

Local governments own and maintain a wide range of buildings and facilities, including administrative and office buildings, park facilities, health clinics and hospitals, fire and police stations, convention centers, wastewater treatment plants, and airports.

At their disposal are a variety of administrative, regulatory, and financing tools that can help local governments develop and operate these building resources in a sustainable manner. Local governments can create policies for municipal procurement, contract specifications, building performance, and building codes regulating community standards; enact resolutions, training and education programs, and ordinances that focus attention on sustainable development; create community boards and commissions to study local sustainable issues; and provide economic incentives for sustainable development.

Finally, many local governments have the experience and capability to create model programs and buildings, which set examples for resource-efficient guidelines and support green building programs elsewhere in their communities. Green building programs can be a first step to helping local stakeholders—policymakers, businesses, citizens, financiers, homeowners, and building owners—understand the economic and environ-

mental wisdom of adopting sustainable principles for their communities.

Many successful green building initiatives are being developed and implemented at the local level across the United States.

The city of Austin, Texas, has consistently demonstrated leadership and vision in this area. Over the last decade, the city of Austin developed its Green Builder Program to support green practices in the residential sector. More recently, it passed a resolution encouraging environmentally sound development within the residential, municipal, and commercial building sectors. Austin's ultimate goal is to be a model sustainable city.

The city of Portland, Oregon, passed an ordinance requiring the recycling of construction waste, along with a set of city-wide principles that promote a sustainable future. Metro-Dade County, Florida, is working with Habitat for Humanity and other partners to plan and develop an energy-efficient and environmentally sound low-cost housing development. Some communities, such as San Francisco, California; Seattle, Washington; San Diego, California; Hennepin County, Minnesota; and New York, New York, are developing their own green building guidelines for municipal and private buildings, or launching demonstration projects that incorporate green building principles.

Communities may also address sustainability from an overall quality-of-life perspective, as Jacksonville, Florida, did. Jacksonville, which has tracked quality indicators since 1985, involves citizens in setting targets and reports annually on progress in education, economy, public safety, health, natural environment, social environment, government, recreation, and mobility. Other communities, such as Chattanooga, Tennessee, have sought to address environmental damage in the process of redesigning their communities. In Chattanooga, more than 2,600 citizens participated in the ReVision 2000 planning process to identify specific environmental improvement goals and recommendations for future city development. Some of the cities efforts to become a model sustainable city include developing a network of greenways and eco-industrial parks, renovating and constructing new public facilities to be model green buildings, and proposing an expansion of the city's trade center to include a variety of green technologies.

Green building initiatives, as well as sustainable development activities, offer many opportunities to local governments and communities. The key to success for local governments is to take the first step toward sustainability, working initially within areas that are most likely to succeed, such as a green building project. A few possible starting points include the following:

- Examine local government policies and procurement procedures for inclusion of green building measures.
- Develop a demonstration green building project or local sustainable building design competition.
- Require that government building projects incorporate renewable energy and energy efficient systems, indoor-air-quality guidelines, and waste and water-efficiency measures.
- Survey and review other cities with green building projects, programs, and standards.
- Assemble a multidisciplinary team within the community to discuss the possibility of developing a green building program.
- Develop a green building awards program; co-sponsor the program with the local utility and local chapters of design, engineering, and property-management societies.
- Survey and publish the community's green building resources.
- Initiate a conference or series of lectures on green building issues.
- Assemble a green building resource library within an existing library or municipal office.
- Initiate a green building computer-based bulletin board or Internet site.
- Publish case studies of local green building projects or develop a green building

Overview

Sustainable Building Technical Manual: Green Building Practices for Design, Construction, and Operations is intended to meet the building industry's need for a comprehensive manual of sustainable building practices. Its goal is to provide clear, easily applied guidelines and useful practices that can be readily introduced into new construction, renovation, and building operations. The manual is designed to synthesize the large volume of available information on green buildings and direct the reader to more detailed resources for further review and reference.

The manual focuses on commercial-size building projects in both the public and private sectors. Building professionals who will find this manual a useful resource include landscape architects, planners, architects, interior designers, engineers, contractors, property managers, building owners and developers, product manufacturers, utility companies, building tenants, maintenance staff, and code officials.

Organization of the Manual

The manual is organized in seven parts, along with an Introduction and Appendix. Part I discusses the economic and environmental significance of sustainable buildings. Parts II through VI describe the sequential design, construction, and operational process for a building project, and Part VII reviews sustainable building financing issues and opportunities for local governments, as well as future green building issues and trends.

Introduction

This section contains a foreword by managing editor David Gottfried, a discussion of the role of local governments in promoting green building practices, and the manual overview.

Part I: Economics and Environment

Part I outlines the financial benefits and environmental ramifications of green building practices. It focuses on energy and water efficiency, waste reduction, construction costs, building maintenance and management savings, insurance and liability, employee health and productivity, and building value. It also reviews the local economic development potential of green building initiatives and presents a methodology for environmental life-cycle assessment and its application to green buildings.

Part II: Pre-Design Issues

This section reviews pre-design environmental issues such as design team selection, environmental guidelines, and “whole-building” design integration—the first and essential steps in creating and implementing a successful green building project.

Part III: Site Issues

Site issues chapters provide detailed information on sustainable site design, water use, and site materials. Discussed are design issues such as assessment and selection of building sites, development of landscaping that preserves natural vegetation and maintains watershed integrity, and consideration of green site materials.

Part IV: Building Design

Building design is divided into three subsections that provide information on passive solar design strategies; building systems, indoor environmental quality, and building commissioning; and building materials and specifications.

Part V: The Construction Process

Environmentally sound construction methods are outlined and the section discusses site management issues, indoor air quality, and resource efficiency as they relate to construction processes.

Part VI: Operations and Maintenance

This section reviews environmental operations and maintenance issues including indoor environmental quality, energy efficiency, resource efficiency, and renovation. Housekeeping and custodial practices that help maintain high environmental standards are also discussed.

Part VII: Issues and Trends

The first chapter in this section discusses financing options and cost issues for local governments seeking to implement green building practices. The last chapter presents green building issues such as building standards, rating systems and product certification, and green business trends such as performance contracting and product “environmental” leasing.

Appendices

The Appendices contain a comprehensive listing of information resources for local government; a glossary of terms, acronyms, and abbreviations used in this manual; and biographies of the manual’s contributing writers. They also contain the PTI Advisory Committee of public and private experts, and other manual reviewers, including members of the U.S. Green Building Council and American Institute of Architects, and representatives from the U.S. Department of Energy and the U.S. Environmental Protection Agency.

Format of the Manual Chapters

Sections of this manual that discuss green building practices—Parts II through VI—are organized according to the traditional project phases of building design, construction, and operations. The chapters in each section focus on sustainable issues and green practices relevant to the specific processes that occur in each of these phases. Parts II through VI also include chapters on local government information, which provide the local government perspective on implementation issues, give examples of action taken by jurisdictions, and include lists of local options. Readers may choose to add other relevant information and resources about local green building experts, products, or regulations to these local government chapters.

Most of these chapters are organized in the following standard format:

★ SIGNIFICANCE

This section summarizes the sustainability issues relevant to the chapter’s topic. It also provides background information on the subject.

👉 SUGGESTED PRACTICES AND CHECKLIST

This section suggests action-oriented, environmentally based practices that design and construction professionals may apply directly to their projects. Brief discussions accompany the practices which are presented in a checklist format.

→ RESOURCES

Resource lists accompanying chapters direct the reader to publications with additional information on the subject. These lists are not exhaustive, and are intended generally as starting points.

NOTES

The numbered citations at the end of each chapter are endnotes related to information cited in the text.

Chapter Presentation and Approach

Successful sustainable design requires an integrated approach; green building systems and operational practices are dependent on siting, solar access and light penetration, architectural design, and product specification. Green buildings must take all of these factors into consideration on a “whole-building,” integrated basis. This approach is not linear; rather it is circular and multi-dimensional.

Given this level of complexity and the interrelationships between different parts of the design process, chapters cross-reference pertinent information in other chapters. Each chapter, however, can stand on its own. As a result, some of the material in a given chapter may echo information provided elsewhere. For example, topics covered in the chapter on the design of heating, ventilating and air-conditioning (HVAC) systems may be repeated, to some extent, in the chapter on operations and maintenance. The goal of this approach is to allow professionals from different fields—design, engineering, products, and operations—to use the relevant parts of this manual independently. To further this goal, we have published the manual in a notebook format, allowing easier concurrent use by several practitioners as well as additions and updates to the information contained therein.