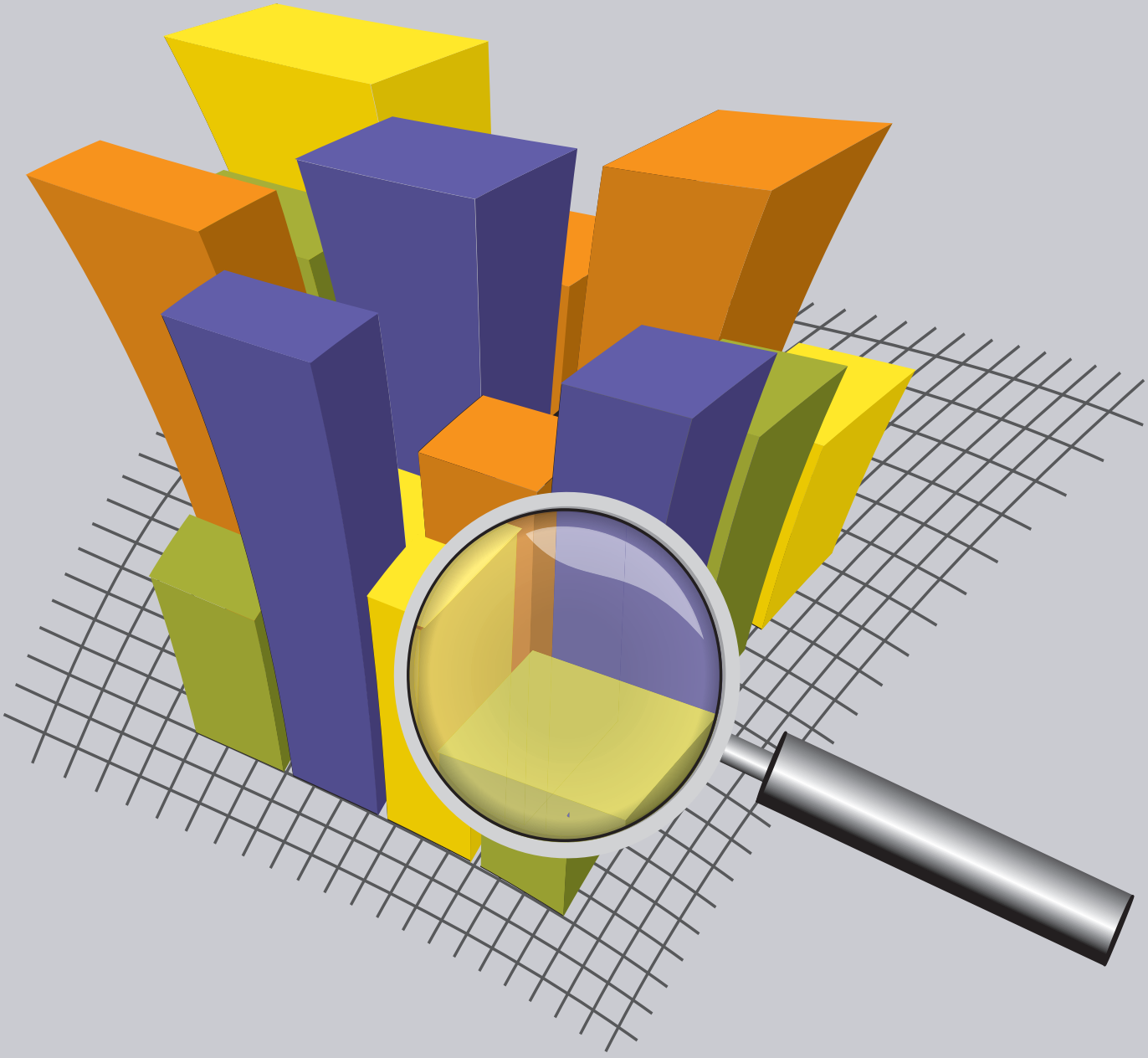
Performance Measurement Protocols
for Commercial Buildings



American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

U.S. Green Building Council

The Chartered Institution of Building Services Engineers

This publication was developed under ASHRAE's Special Publication procedures and is not a consensus document. This publication was developed under the auspices of ASHRAE Special Project 115.

ASHRAE acknowledges the contributions of USGBC and CIBSE to the preparation of this special publication.

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ISBN 978-1-933742-79-3

1791 Tullie Circle, NE
Atlanta, GA 30329
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Printed in the United States of America on 30% post-consumer waste using soy-based inks.

Cover design by Tracy Becker.

Library of Congress Cataloging-in-Publication Data

Performance measurement protocols for commercial buildings / American Society of heating, Refrigerating, and Air-Conditioning Engineers, Inc., U.S. Green Building Council, [and] The Chartered Institution of Building Services Engineers.
p. cm.
Includes bibliographical references.
Summary: "Provides three levels of standardized protocols for assessing building performance that identify what, how, and how often to measure in six performance categories: energy, water, thermal comfort, indoor air quality, lighting, and acoustics. Such protocols give feedback when performance does not match design intent and lend credibility to performance claims"--Provided by publisher.
ISBN 978-1-933742-79-3 (softcover)
1. Buildings--Performance--Measurement. 2. Commercial buildings--Evaluation. I. American Society of Heating, Refrigerating and Air-Conditioning Engineers II. U.S. Green Building Council. III. Chartered Institution of Building Services Engineers.
TH453.P46 2010
696--dc22
2010008223

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Executive Summary

THE NEED FOR STANDARDIZED PERFORMANCE MEASUREMENT PROTOCOLS

To provide secure energy supplies, reduce energy demand and costs, and reduce carbon emissions, the energy and water use of new and existing buildings needs to be very significantly reduced. At the same time, buildings need to be comfortable, at an appropriate temperature, well ventilated and lit, and have appropriate acoustics.

Although there are many buildings in the United States, United Kingdom, and elsewhere that are claimed to be "green," "low energy," or "high performance," it is rarely clear on what evidence or data these claims are based. Such claims of high performance cannot be credible without standardized protocols that are applied consistently to the assessment of building performance, both in the United States and internationally. If claims of superior building performance are to be believed, it is essential that a common set of measurements be used and the results reported against meaningful and consistent benchmarks. Such protocols are also needed to give usable feedback to building designers and operators when measured performance does not match design intent and expectations.

Thus this book provides a standardized, consistent set of protocols, for a range of costs/accuracies, to facilitate the appropriate and accurate comparison of measured energy, water, and indoor environmental quality (IEQ)—thermal comfort, indoor air quality (IAQ), lighting, and acoustics—performance of commercial buildings. Energy and water savings need to be accomplished while maintaining acceptable levels of building service for the occupants. Benchmarks are included to facilitate appropriate comparison to peer buildings.

SCOPE OF PROTOCOLS

The protocols identify what to measure, how it is to be measured (instrumentation and spatial resolution), and how often it is to be measured for inclusion in the building's operation and maintenance (O&M) plan. For each of the six performance categories (energy, water, thermal comfort, IAQ, lighting, and acoustics), protocols are developed at three levels—Basic, Intermediate, and Advanced—providing realistic choices for consis-

tent performance characterization of the building stock and comparison to appropriate benchmarks. Basic protocols are intended to be simple, low-cost measures to gain an initial insight into performance at the annual, whole-building level. Where these reveal cause for further measurement, Intermediate protocols provide further data on the building performance, typically at a monthly frequency and major system level. Advanced protocols offer a more detailed and comprehensive analysis for those building owners or managers wishing to gain even deeper insights into the performance of a building, typically at a daily or weekly frequency at the system or equipment level.

BACKGROUND AND SUMMARY OF PROTOCOLS AT THREE LEVELS

Presentation of the protocols begins with an overview of this book and a description of how it is to be used (Chapter 1). Background and history are then given on the six performance measure categories. This information describes the measurement foundation (including definitions of measurement parameters), instrumentation types (both subjective, e.g., occupant surveys, and metered), analysis and evaluation methods for characterizing and quantifying the set of measures, standards and benchmarks, and limitations as to application of the measurement tools. While the focus is primarily on procedures and methods used in the United States, those used internationally (e.g., ISO standards), especially in Europe (e.g., CIBSE and CEN literature and standards), are also discussed.

Chapter 2 provides a high-level summary of the key measurement methods and metrics for the six performance categories at the Basic, Intermediate, and Advanced levels, presented in Table 2-1. For each category, the methods and metrics are described by the three subtypes of

- descriptive information,
- subjective measures (e.g., occupant surveys), and
- instrumented (physical) measures.

A range of costs for staff time and instrumentation is also given for each category. This table serves as a quick reference guide to all of the protocols presented in this book and is of greatest use to the casual reader.

Chapter 3 presents the Basic protocols in the six measure categories. In each category are presented the objective(s) (the purpose of the measurement), measurement methods and cost (how the measurements are to be made), metrics (what is to be measured), and performance evaluation/benchmarking (to what the measurements should be compared).

- For energy, the required data are of three types: basic building characteristics needed for performance expression and comparison, annual whole-building energy use and costs of all electricity and fuels used, and annual energy and cost indices.
- Water use at the Basic level involves periodic and total water usage and cost utility water meter data, including annual data per build-

ing and per occupant. Benchmarks are provided by building type for buildings in the United States, United Kingdom, and Europe.

- Basic data to measure thermal comfort are based on analysis of complaint logs, occupant surveys, operator surveys, and, in cases where problems have been identified, spot measurements of the thermal environment using handheld instruments with immediate readout.
- Evaluation of IAQ at the Basic level requires determining whether the building is in an Environmental Protection Agency (EPA) non-attainment zone (EPA 2008a), site assessment, surveying occupant satisfaction and rating it against benchmarks, and verifying compliance with the Ventilation Rate Procedure in *ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality* (ASHRAE 2007b).
- Lighting quality at the Basic level involves surveying occupant satisfaction, identifying problems with the lighting and clues to their causes, and spot measurements of illuminance in representative spaces.
- Evaluation of acoustics at the Basic level includes descriptions of spaces, room finishes, and locations of noise sources; an occupant survey to identify acoustical problems in the building; and measurement of the A-weighed sound pressure level in the occupied spaces.

Chapters 4–9 present the Intermediate and Advanced protocols in the six measurement categories; these are for those building owners or managers wishing to gain deeper insights into the performance of a building and a higher level of confidence in the building's performance. At these levels, performance is measured more frequently and with greater spatial resolution than the annual whole-building measurements of the Basic level. As is the case for the Basic level protocols, each category presents the objectives, measurement methods and cost, metrics, and performance evaluation/benchmarking.

- Chapter 4 presents the higher-level protocols for energy performance. The objective is to characterize, analyze, and understand end-use energy patterns so as to identify where performance improvement can best be made. The Intermediate level focuses on monthly or weekly energy use data for occupied versus unoccupied periods for major building systems and makes use of whole-building inverse models. In contrast, the Advanced level focuses on daily or hourly data at the system and equipment level. Advanced diagnostic techniques, such as whole-building calibrated simulations, coupled with measured end-use and equipment energy data, may be used to establish a self-reference benchmark.
- Higher level evaluation of water use is the subject of Chapter 5. The Intermediate level measurement provides improved feedback by separating the landscape water flow from the building water flow

using the utility water meter and a separate landscape water meter. The objective of the Advanced level is to measure as many separate water-using components as possible to better determine usage patterns for occupants, landscaping, and wastewater streams; meters are usually read monthly, with the peak month noted.

- Chapter 6 presents the higher-level protocols for thermal comfort. The Intermediate level monitors the physical environment coupled with concurrent "right-now" occupant perceptions of the thermal environment with the objectives of optimizing the environmental control system operation to minimize the effect of failures and matching occupant responses with simultaneous physical measurements so they can be compared to results in existing occupant comfort databases and to predictive model simulations of thermal comfort. Advanced measurement covers detailed quantification of complex comfort environments and environmental control systems affecting the occupants, including tests of asymmetrical and transient environments.
- IAQ at the higher levels is the subject of Chapter 7. Objectives at the Intermediate level include those of the Basic level as well as determining whether ventilation quantities are adequate in all conditioned zones and whether potential contaminant sources are local or distributed. At the Advanced level, the measurements establish baseline and long-term assessment of pollutants and to identify potential contaminants of concern (CoC).
- Chapter 8 addresses higher-level protocols for lighting quality. Intermediate measurements include a diagnostic survey of occupant lighting satisfaction, studying full-grid illuminance and luminance, and determination of discomfort glare. The Advanced level includes high-resolution measurements of illuminance, luminance, and discomfort glare using high dynamic range (HDR) photography.
- Chapter 9 presents the protocols for acoustics. At the Intermediate level, detailed measurements are made of background noise for comparison with single-number ratings such as noise criteria (NC), room criteria (RC), and balanced noise criteria (NCB), and spot measurements are made of reverberation time for general assessment of speech communication issues. At the Advanced level, measures include speech privacy and speech communication for special-purpose rooms and measures of sound and vibration isolation from outside sources and between interior rooms.

Appendices are included to cover additional details such as measurement and instrumentation and to provide examples, and a compendium of definitions and acronyms and a list of references used throughout this book are also included.

Preface

BACKGROUND

In the spring of 2005, the U.S. Green Building Council (USGBC) approached the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) to inquire about the development of performance measurement protocols. In response to this inquiry, ASHRAE formed a working group to develop a Scoping Study to conduct a preliminary survey of the relevant documents and develop recommendations to ASHRAE Technology Council regarding how to proceed. In January 2006, the Scoping Study was completed. It identified the need to provide guidance regarding the measurement and reporting of the performance of new and existing commercial buildings and proposed short-term and long-term efforts to accomplish this. For the short-term it was proposed that an ASHRAE protocol be developed for rapid dissemination in an ASHRAE Special Publication.

Then, for the long-term, an ASHRAE standard or guideline was recommended that would be based on existing ASHRAE standards, guidelines, and other documents to provide a consistent method of measuring, expressing, and comparing the energy use, water use, and indoor environmental quality (IEQ) of buildings. These documents would be immediately useful to other organizations, including the USGBC, The Chartered Institution of Building Services Engineers (CIBSE), American Institute of Architects (AIA), Illuminating Engineering Society of North America (IES), U.S. Environmental Protection Agency (EPA), U.S. Department of Energy (DOE), U.S. General Services Administration (GSA), the U.S. Military, International Energy Agency (IEA), the European Union, and other organizations interested in sustainable design and performance.

In August 2007, ASHRAE joined with USGBC and CIBSE to complete an extensive literature evaluation, which surveyed more than 400 documents that were analyzed and, with the help of expert interviews, were ranked according to their relevance to the protocols. Based on that survey of the literature, this book has been written by a committee of industry experts to develop protocols, or procedures, for the performance measurement of commercial buildings, including energy use, water use, and the following elements of IEQ: thermal comfort, indoor air quality (IAQ), lighting, and acoustics.

This book addresses the short-term needs described above and will be revised and updated as experience in its use is gained. Later versions are likely to become an ASHRAE standard or guideline. While this book has been developed by a group of experts in building performance, it will inevitably generate constructive feedback as user experience is gained. As this occurs, the protocols will be revised and updated to reflect user application.

PURPOSE/SCOPE

The purpose of this book is to provide protocols for the operational performance measurement of occupied commercial buildings. To reduce energy use and carbon emissions in existing buildings, it is necessary to measure energy and water use to provide a systematic basis for the management of the buildings so as to achieve that end. This must be accomplished while maintaining acceptable levels of building service for the occupants.

This book provides standardized and consistent protocols for measuring energy, water, and IEQ performance of commercial buildings. For building owners, these protocols provide clear procedures for the evaluation of the real, on-the-ground effectiveness of building operational management and cost savings as well as benchmarks for appropriate comparison to peer buildings to show how well a building is performing. For facility managers, details of what is to be measured and how it is to be measured are included for incorporation into the operation and maintenance (O&M) plan for the building. The result will be to establish verified operating performance of the owner's portfolio through the tracking of actual operating cost savings over time.

This book provides an overview of protocols, or procedures, for the operational performance measurement of commercial buildings including energy use, water use, and IEQ. The energy protocols apply to all forms of energy, including electricity, gas, oil, district heating/cooling, and renewables; the water use protocols apply to individual facilities or meters; and the IEQ protocols apply to thermal comfort, IAQ, lighting, and acoustics. Cost and resource information will also be discussed in each section, as appropriate.

These protocols do not cover the following:

- Sampling methodologies used in large-scale demand-side management programs
- Asset performance determination based on calculations or simulations
- Metering standards
- Major industrial loads
- Forensics, audit procedures, or commissioning procedures
- Campuses or groups of buildings
- Carbon or other emission impacts

With the standardized, consistent building performance protocols presented here, a firm basis is provided to assess claims of a building's high performance. Such a basis benefits building owners, tenants, designers, financiers, and analysts alike.

1 Introduction and Overview

INTRODUCTION TO PERFORMANCE MEASUREMENT PROTOCOLS

Buildings in the United States, Europe, and most developed economies are responsible for over 40% of their respective national energy uses. To secure our energy supplies, reduce energy demand and costs, and reduce carbon emissions, the energy use of existing buildings needs to be very significantly reduced. At the same time, buildings must perform effectively the functions for which they are built. They need to be comfortable, at an appropriate temperature, well ventilated and lit, and have appropriate acoustics. They also need to use water efficiently, both because it is itself an increasingly scarce resource and because the processing, distribution, and disposal of water is energy intensive.

In addition, there are many buildings in the United States, United Kingdom, and elsewhere that are claimed to be "green," low energy," or "high-performance" buildings. It is never entirely clear on what evidence or data these claims are based. Such claims of high performance cannot be credible without standardized protocols that are applied consistently to the assessment of building performance. These protocols should be consistent across the United States and internationally. It is essential that a common set of measurements is used and that results are reported against meaningful and consistent benchmarks if claims of superior building performance are to be believed, whether they be "green," "sustainable," or "high performance." Furthermore, such protocols are also needed to give usable feedback to building designers and operators when measured performance does not match design intent and expectations. Thus, the goal of this book is to provide a standardized, consistent set of protocols, for a range of costs/accuracies, to facilitate the appropriate and accurate comparison of measured performance of buildings.

Experience also shows (Cohen et al. 2001; Ruyssevelt et al. 1995) that there is a major credibility gap between design intent, the potential performance of the building as initially constructed, and the reality of everyday practical operation. There is therefore an urgent need for a set of measures that enable the performance of our building stock to be measured. Better management of buildings, and hence reduced operating costs, requires better measurements of their performance. As is often said, "you can't manage what you can't measure."