Procedures for

Commercial Building Energy Audits

Second Edition

ASHRAE

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Contents

Also included is online access to sample data collection forms and templates in Microsoft® Excel® spreadsheet format that may be downloaded and used as the bases for data collection and reporting results from energy audits and pdfs of an energy auditor checklist and a list of energy efficiency measures (EEMs) to consider when performing an energy audit.

List of Sidebars

Acknowledgments

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The primary authors and reviewers of this document include Steve Carlson, David Eldridge, Keith Emerson, Michele Friedrich, Dakers Gowans, Bruce Hunn, Michael Levinson, Kendra Tupper, and Megan Van Wieren. Reviews and supporting content were provided by Adrienne Thomle, Bernt Askildsen, Dave Moser, Ron Nelson, Rob Risley, Mark Case, Eric Harrington, Fredric Goldner, Stanton Stafford, and Greg Towsley.

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Preface—How to Use this Book

The goals of this edition of *Procedures for Commercial Building Energy Audits* are to

- define levels of effort for energy audits;
- provide a reference guide for building owners, managers, government entities, and other consumers illustrating best practices for conducting energy assessments and the associated deliverables; and
- serve as an introductory guide to best practices for energy auditors.

The intended scope of this volume is for existing commercial and institutional buildings. However, many of the procedures herein will be applicable to industrial or multifamily residential facilities as well.

Part 1 of this book discusses Level 1, Level 2, and Level 3 energy audits as defined by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). The procedures outlined are the minimum requirements for the levels. These definitions have changed only slightly from the first edition of this book.

Part 2 outlines recommended audit procedures and best practices. This section is intended only as a reference and does not define required audit procedures. The intent of this section is to provide guidance to auditors and those who would like to hire professional energy assessors.

Part 3 includes additional useful resources, such as sample data collection forms and templates, unit conversions, a list of abbreviations and acronyms, and a references section.

The sample data collection forms and templates included in Part 3 may be downloaded and used as the bases for data collection and reporting results from energy audits from the supplemental files online. The forms and templates are in Microsoft Excel® spreadsheet format. The Web site also includes pdfs of an energy auditor checklist reprinted with permission from Washington State Uni-versity and a list of energy efficiency measures (EEMs) to consider when per-forming an energy audit.

Energy Audit Sample Forms and Templates

Gathering the right data with the appropriate amount of detail is a key component to achieving the maximum benefits of an energy audit. However, the

process for audit data collection is not standardized and, often, crucial data may be overlooked.

To facilitate the data collection effort, sample energy audit forms and templates are provided in Part 3. These include data collection forms for all components of a commercial building that contrib-ute to heating and cooling loads or consume energy and are organized by build-ing system (e.g., glazing, cooling towers, etc) and template procedures for completing the Preliminary Energy-Use Analysis (PEA), end-use breakdowns, and EEM summary tables. The purpose of these sample forms and templates is to assist building energy auditors in collecting the data required to complete comprehensive energy and financial analyses of proposed modifications to a building.

How to Use The Forms and Templates

The data collection forms, which are best suited to Level 2 and Level 3 audits, may be used to aid the auditor in gathering data at the site. They are very comprehensive and are intended to support the collection of data needed for a detailed audit of a facility. It may not be necessary to collect all the data covered by the forms for every facility; therefore, auditors will need to use their judgment as to what data is and what level of investigation are appropriate for each specific site. Auditors can use the following guidelines to determine which forms to use:

- Identify which information listed in the sample forms is needed for a specific project.
- Identify the anticipated source for each piece of data. Typical data sources include
  - facility managers,
  - as-built drawing sets,
  - utility bills,
  - building automation system (BAS) trend data,
  - on-site spot measurements,
  - temporary logger data, and
  - occupant surveys.
- Collect and organize as much data as possible prior to a site visit.
- Print the sample forms (sometimes multiples of each) and take them to the site (or take the electronic versions).

Some of the forms contain “guidance” sample forms and show examples and potential data sources of information that should be collected.

The sample template procedures for completing the PEA, end-use breakdowns, and EEM summary tables include basic unit conversion calculations and financial calculations that are consistent with the guidelines in this book. See the following sample spreadsheets:

- The file "ASHRAE PEA Template.xls" includes a sample format for the PEA methods in the Preliminary Energy-Use Analysis sections of Part 1 and 2.
- The file "ASHRAE Sample End-Use Breakdown.xls" includes a sample end-use breakdown consistent with the methods of the Level 2—Energy Survey and Engineering Analysis section of Part 1 and the Energy End-Use and Cost Allocation section of Part 2.
- The file "ASHRAE EEM Summary Table.xls" is a sample EEM summary table for reporting energy audit results with common financial performance metrics and economics consistent with the Level 2—Energy Survey and Engineering Analysis section of Part 1 and the Audit Reports section of Part 2.

Note that the forms and templates available on the Web site may be revised from time to time, so users should refer to the Web site for the most up-to-date version of any form or template they wish to use for their audit projects. When a file is revised, it will be posted online with a new date at the end of the file name; this revised file will replace any versions previously available on the Web site.

The Term *Energy Audit*

The term *energy audit* is an established term within the industry. It is widely used and understood by many. Ultimately we decided to retain the word *audit* for this publication because of its wide industry usage and to maintain a consistent title for the book, which is referenced in multiple publications and standards. However, we have chosen to use the terms *energy audit* and *energy assessment* interchangeably throughout. Also in popular use are the terms *energy analysis*, *energy survey*, *energy evaluation*, *energy investigation*, *energy assessment*, and others. We have used these terms within this publication as well. Many of these terms have achieved some common use in the industry and they may be more descriptive than the term *energy audit*.

For many reasons, *assessment* is preferable to *audit—assessment* carries none of the negative connotations of the word *audit*, which is commonly associated with an involuntary investigation of finances or taxes, where the perceived goal is to uncover mistakes and assess monetary penalty, and is often seen as a precursor to some kind of enforcement action or punishment. If we are to gain market acceptance for energy assessment, such negative connotations are best avoided. *Assessment* also conveys more accurately the activity at hand—that is, assessing the current state of a building and making recommendations to improve its performance. Our hope is to move toward a wider use of *assessment* yet maintain reference to the term *audit*.

Similarly, throughout this book we've used the terms *auditor*, *analyst*, and *assessor* interchangeably.

Part 1

Defining the Levels of Effort of Commercial Building Energy Audits

Levels of Effort

Overview

A commercial building energy analysis can generally be classified into the following three levels of effort:

- Level 1—Walk-Through Analysis
- Level 2—Energy Survey Analysis
- Level 3—Detailed Analysis of Capital Intensive Modifications

In addition, there is a Preliminary Energy-Use Analysis (PEA), which is a prerequisite for any audit, and there are targeted audits, which do not have a strictly defined level of effort bu t may be useful or necessary for some situations.

This section contains a brief overview of the PEA, each audit level, and targeted audits. More rigorous definitions for each level also follow in this section.

Preliminary Energy-Use Analysis (PEA)

The PEA precedes an audit of the building. During the PEA the analyst analyzes the historic utility use, peak demand, and cost; develops the Energy Cost Index (ECI) of the building (expressed in dollars per floor area per year); and develops the Energy Utilization Index (EUI) of the building (expressed in kBtu/ft^2 [MJ/m^2] per year). The analyst then compares the building EUI to similar buildings' EUIs to assess the potential for improved energy performance and to determine whether further engineering study and analyses are likely to produce significant energy savings. Monthly energy use and peak demand or, if available, interval billing data (such as 15 minute data), are reviewed to identify efficiency or behavioral modification opportunities.

Use the PEA Template found in Part 3 to assist with developing and comparing the ECI and EUI and analyzing monthly energy use.

A PEA provides necessary background data for Levels 1, 2, or 3 analyses.

Level 1—Walk-Through Survey

First, the building's energy cost and efficiency are assessed by analyzing energy bills, compiled in the PEA, and conducting a brief on-site survey of the building. A Level 1 energy survey will identify low-cost/no-cost measures for

improving energy efficiency and provide a listing of potential capital improvements that merit further consideration. Because calculations at this level are minimal, savings and costs are approximate.

A Level 1 analysis is applicable when the desire is to establish the general energy savings potential of a building or to establish which buildings in a portfolio have the greatest potential savings. Level 1 results can be used to develop a priority list for conducting Level 2 and 3 audits.

Level 2—Energy Survey and Analysis

A Level 2 audit involves a more detailed building survey, including energy consumption and peak demand analysis. A breakdown of energy end uses within the building is developed.

A Level 2 energy analysis will identify and provide the savings and cost analyses of all practical energy efficiency measures (EEMs) that meet the owner's/operator's constraints and economic criteria, along with proposed changes to operation and maintenance (O&M) procedures. It may also provide a listing of potential capital-intensive improvements that require more thorough data collection and engineering analysis as well as an assessment of potential costs and savings. This level of analysis will provide adequate information for the owner/operator to act upon recommendations for most buildings and for most measures.

Level 3—Detailed Analysis of Capital-Intensive Modifications

The third level of engineering analysis focuses on potential capital-intensive projects identified during a Level 2 analysis. It requires more detailed field data gathering as well as more rigorous engineering and economic analyses, often including modeling (simulation) of the annual energy performance of the building and vendor pricing. It provides detailed project cost and savings calculations with a high level of confidence sufficient for major capital investment decisions. It often goes beyond the economic analysis of a Level 2 audit and uses a comprehensive life-cycle cost analysis (LCCA) as a decision-making tool.

Targeted Audits

A targeted audit is an investigation with a limited scope, typically a single energy-using system, central plant, or area of the building. Some examples include lighting-only audits, cooling tower replacements, boiler control assessments, and tenant improvement projects.

A targeted audit will identify and provide savings and cost analyses for retrofits and control strategy improvements for the systems of interest. The level of effort may be tailored to the needs of the facility. Because the audit is limited to a portion of the building, whole-building approaches such as end-use allocation and comparisons with historical utility bills cannot be used to provide a check on analytical methods. Similarly, whole-building simulation is typically not a cost-effective approach except for large systems. For this reason, targeted audits rely on measurements, data logging, and trend data to provide a check on the energy use estimates in the base case.

Discussion

There are not sharp boundaries between these levels. The levels are general categories for identifying the type of information that can be expected and an indication of the level of confidence in the results. While performing an energy analysis in a particular building, various measures may be subjected to different levels of analysis based on their savings potential or expected implementation costs.

The matrix presented in Table 1 is a general representation of the tasks required for each level of effort.

Table 1 — Energy Audit Required Tasks

Process	Level		
	1	2	3
Conduct PEA	•	•	•
Conduct walk-through survey	•	•	•
Identify low-cost/no-cost recommendations	•	•	•
Identify capital improvements	•	•	•
Review mechanical and electrical (M&E) design and condition and O&M practices		•	•
Measure key parameters		•	•
Analyze capital measures (savings and costs, including interactions)		•	•
Meet with owner/operators to review recommendations		•	•
Conduct additional testing/monitoring			•
Perform detailed system modeling			•
Provide schematic layouts for recommendations			•
Report	**Level**		
	1	2	3
Estimate savings from utility rate change	•	•	•
Compare EUI to EUIs of similar sites	•	•	•
Summarize utility data	•	•	•
Estimate savings if EUI were to meet target	•	•	•
Estimate low-cost/no-cost savings		•	•
Calculate detailed end-use breakdown		•	•
Estimate capital project costs and savings		•	•
Complete building description and equipment inventory		•	•
Document general description of considered measures		•	•
Recommend measurement and verification (M&V) method		•	•
Perform financial analysis of recommended EEMs		•	•
Write detailed description of recommended measures			•
Compile detailed EEM cost estimates			•

For ease of reading, an executive summary should be the first section of an energy analysis report. Some readers of such a report may be unable to comprehend the technical analyses involved, while others may demand a full presentation of the analyses for critique. Consequently, technical material should be presented in an appendix to the report, while the body of the report should guide the reader through the technical material and summarize the findings.

Information presented in this book outlines the engineering procedures that should be followed while performing an energy analysis. It is assumed that the analyst is a knowledgeable and competent individual. No attempt is made in this publication to prescribe specific methods of data gathering or data analysis, although recommendations for best practices are described in Part 2 of this book.

To assist with the organization of the data collected and the calculation procedures, this publication contains guideline forms that suggest the types of data to be gathered and their organization. It is recommended that the analyst develop and use appropriate data collection and organization forms specific to the size and type of the building(s) being analyzed.

The engineering services performed and the reports provided after performing Level 1, 2, and 3 analyses are progressively more specific and complex. The descriptions provided in Figure 1 are intended for the work and deliverables required in each level to build upon the previous level.

Preliminary Energy-Use Analysis (PEA)

Before any level of energy analysis has begun, it is valuable to perform a PEA to determine a building's current energy and cost efficiencies relative to other, similar buildings. This is normally done by calculating the energy use and cost per unit area per year, which can indicate the potential value of further levels of analysis. This preliminary analysis generally includes the following steps:

1. Determine the building's gross conditioned floor area and record this on the basic building characteristics form (use the PEA Template in Part 3). Classify the primary use of the building. Ensure that the standard definition of *gross floor area* is used, which is:

   > the sum of the floor areas of all the spaces within the building with no deductions for floor penetrations other than atria. It is measured from the exterior faces of exterior walls or from the centerline of walls separating buildings, but it **excludes** covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, roof overhangs, parking garages, surface parking, and similar features.

2. Assemble copies of utility bills and summarize them for at least a one-year period, preferably for a two- or three-year period. Review the monthly bills for opportunities to lower costs by taking advantage of

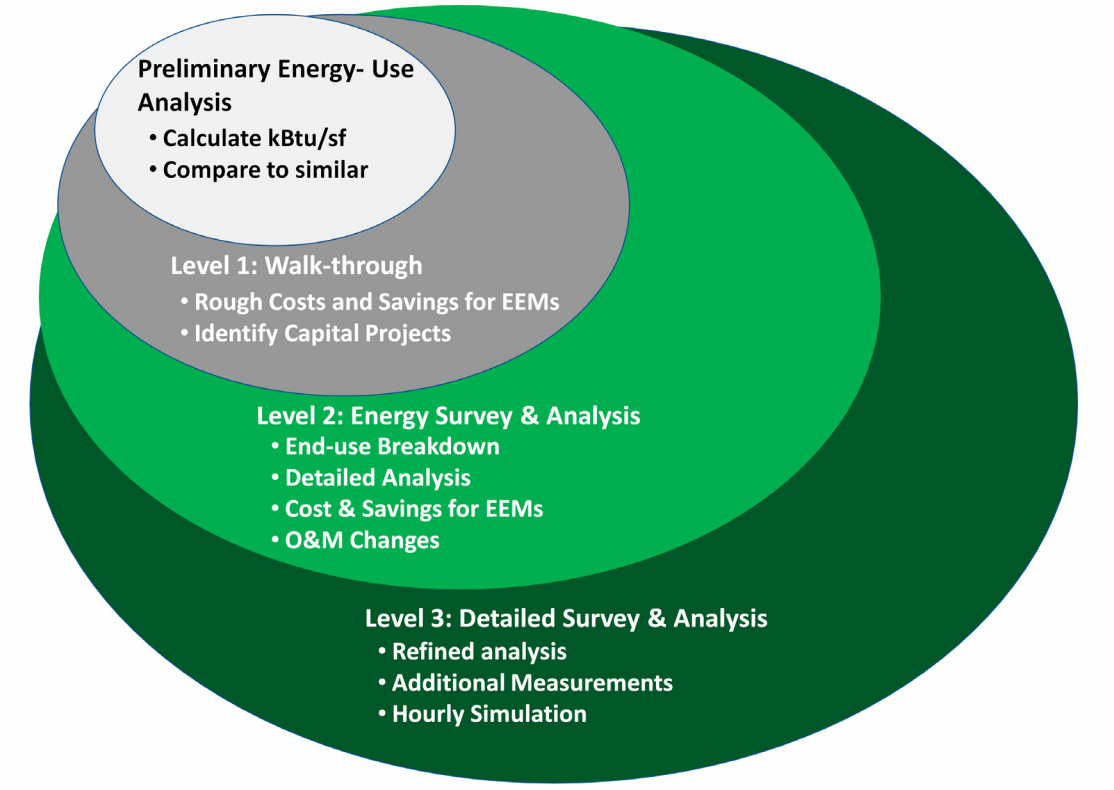

Figure 1 — Relationships of ASHRAE Energy Audit Levels 1, 2, and 3

different utility rate classes, taking into account peak electric demand patterns. Review the monthly patterns for irregularities. Note if a bill is missing or if it is estimated rather than an actual consumption value.

3. Complete the energy performance summary to develop the EUI and the ECI for each fuel or demand type and their combined total using methods outlined in ASHRAE Standard 105 (ASHRAE 2007a).
4. Compare the EUI and ECI with those of buildings having similar characteristics. A common benchmark comparison for peer buildings is the ENERGY STAR Portfolio Manager of the U.S. Environmental Protection Agency (EPA) (2011a). The owner/operator of the subject building may have similar buildings for this comparison. Comparison should also be made with publicly available energy indices of similar buildings. In all cases, care should be taken to ensure that comparison is made with current data, using consistent definitions of building usage and floor area.
5. Derive target energy, demand, and cost indices for a building with the same characteristics as the building being analyzed. A range of methods are available for this work, including
   - choosing from any database of similar buildings those buildings with the lowest energy index and

- choosing an index based on the knowledge of an energy analyst experienced with this type of building.

6. Compare the energy and cost savings for each fuel type if the building were to reach the target EUI. Using these values, determine whether further engineering analysis is recommended.

Use the PEA Template found in Part 3 to assist with developing and comparing the ECI and EUI and analyzing monthly energy use.

Level 1—Walk-Through Analysis

The Level 1 process includes all of the work performed for the PEA plus the following steps:

1. Perform a brief walk-through survey of the facility to become familiar with its construction, equipment, operation, and maintenance.
2. Meet with the owner/operator and occupants to learn of special problems or planned improvements (e.g., HVAC equipment replacements, aesthetic upgrades, etc.) of the facility and any operation or maintenance issues. Determine whether any maintenance problems and/or practices affect efficiency.
3. Perform a space function analysis, guided by sheet 1.12 in the PCBEA Sample Forms in Part 3. Determine whether efficiency may be affected by functions that differ from the original functional intent of the building.
4. Identify low-cost/no-cost changes to the facility or to O&M procedures and estimate the approximate savings that will result from these changes.
5. Identify potential capital improvements for further study and provide an initial rough estimate of potential costs and savings.

The report for a Level 1 analysis should contain the building characteristics and energy use summary as well as the following items:

- Quantification of any savings potential from changing to a different utility rate structure.
- Discussion of irregularities found in the monthly energy use patterns, with suggestions about their possible causes.
- The EUIs of similar buildings. Report the source, size, and date of the sample used in this comparison. The names of comparable buildings should be given if known.
- The target EUI and the method used to develop the target index. Where comparison is made to other buildings, state their names or the source of the database. Where the experience of someone other than the report author is used to develop the target, provide the source. Where the target is developed by calculation, show the calculation or

quote the name and version of the software used and include both input and output data.
- Total energy and demand costs by fuel type for the latest year and preceding two years, if available. Show potential savings in dollars using the energy index format of ASHRAE Standard 105 (ASHRAE 2007a).
- The fraction of current costs that would be saved if the energy index were brought to the target level.
- A summary of any special problems or needs identified during the walk-through survey, including possible revisions to O&M procedures.
- A listing of low-cost/no-cost changes with estimated savings for these improvements.
- The potential capital improvements, with an initial rough estimate of potential costs and savings

Level 2—Energy Survey and Engineering Analysis

The Level 2 analytical procedure is guided by Level 1 analysis and includes the following additional steps:

1. Review mechanical and electrical system design, installed condition, maintenance practices, and operating methods.
2. Describe and analyze the energy-using systems of the building, resulting from on-site observation, measurement, and engineering calculations. Use the PCBEA Sample Forms found in Part 3 to document the building systems, including the following systems:

    - Envelope
    - Lighting
    - Plug loads
    - HVAC
    - Domestic hot water
    - Laundry
    - Food preparation
    - Refrigeration
    - Conveying
    - Pools/saunas/spas
    - Process loads
    - Others

3. Review existing O&M problems and logs. Review planned building changes or improvements and estimate their costs.
4. Measure key operating parameters and compare them to design levels, for example, operating schedules, heating/cooling water temperatures, the supply air temperature, the space temperature and humidity, ventilation quantities, and task lighting levels. Such measurements may be taken on a spot basis or logged manually or electronically.

5. Prepare a breakdown of the total annual energy use into end-use components, as illustrated in Part 2 of this book in the section Energy End-Use and Cost Allocation. A number of calculation methods are available, ranging from simplified manual calculations to fully detailed computer simulation of hour-by-hour building operations for a full year.
6. List all possible modifications to equipment and operations that will save energy. Select those that might be considered practical by the owner/operator. Perform preliminary cost and savings estimates.
7. Review the list of practical modifications with the owner/operator and select those that will be analyzed further. Prioritize the modifications in the anticipated order of implementation.
8. Create integrated bundles of measures where successive efficiency measures have significant interactive effects. Measures should be packaged together to achieve different levels of whole-building energy use reduction and financial performance. Package measures together to reduce loads to lower equipment capital costs and increase interactive energy savings. Capture interactions in at least one package that meets the project's financial criteria or savings goals.
9. For each practical measure, estimate the potential savings in energy costs and the building EUI. To account for interaction between modifications, assume that modifications with the highest operational priority and/or best return on investment will be implemented first. A number of calculation methods are available, ranging from simplified manual calculations to iterative computer simulations.
10. Estimate the implementation cost of each practical measure.
11. Estimate the impact of each practical measure on building operations, maintenance costs, and nonenergy operating costs.
12. Estimate the combined energy savings from implementing recommended bundles of measures and compare the estimated savings to the potential savings derived in the Level 1 analysis. It should be clearly stated that savings from each modification are based on the assumption that all previous modifications have already been implemented and that the total savings account for all of the interactions between the modifications.
13. Prepare a financial evaluation of the estimated total potential investment using the owner's/operator's chosen techniques and criteria. These evaluations may be performed for each practical measure or for combinations of practical measures.
14. During the development of the report of the Level 2 analysis, meet with the owner/operator to discuss priorities and to help select measures for implementation or further analysis.

The report for a Level 2 analysis should contain at least the following items:

- A summary of the current energy use and cost associated with each end use. Show calculations performed or quote the name and version of software used and include both input and output data. For ease of reading, present end-use data in pie charts or other graphic formats. Further details and examples are presented in the Billing Data Review section of Part 2 of this book. Provide interpretation of differences between actual total energy use and calculated or simulated end-use totals.
- A description of the building, including typical floor plans and inventories of major energy-using equipment. (This information may be included as an appendix.)
- For each practical measure, provide
  - a discussion of the existing situation and how excess energy is being consumed;
  - a description of the measure, including its impact on occupant health, comfort, and safety;
  - a description of any repairs that are required for a measure to be effective;
  - the impact of the measure on occupant service capabilities, such as ventilation for late occupancy or year-round cooling;
  - an outline of the impact of the measure on operating procedures, maintenance procedures, and costs;
  - the expected life of new equipment and the impact on the life of existing equipment;
  - an outline of any new skills required of operating staff and training or hiring recommendations;
  - calculations performed, or the name and version of the software used (including both input and output data); and
  - nonenergy benefits, especially improvements to health, safety, and environment, and decreases in equipment runtime and labor hours.
- A table listing the estimated costs for all practical measures and recommended bundles of measures, the savings, and a financial performance indicator (for example, simple payback period). For the cost of each measure, show the estimated accuracy of the value quoted. This table should spell out the assumed sequence of implementation and state that savings may be quite different if a different implementation sequence is followed.
- A list of measures considered but deemed to be impractical, with brief reasons for rejecting each.
- A discussion of any differences between the savings projected in this analysis versus any savings projected in a prior Level 1 analysis.
- Overall project economic evaluation.

- Recommended measurement and verification methods that will be required to determine the actual effectiveness of the recommended measures.
- Discussion of feasible capital-intensive measures that may require a Level 3 analysis.

Level 3—Detailed Analysis of Capital-Intensive Modifications

The Level 3 analytical procedure is guided by Level 1 and 2 analyses and the owner's/operator's selection of measures for greater definition. It follows Level 1 and 2 work and also includes the following additional steps:

1. Expand the definitions of all modifications requiring further analysis. Consider system interactions to create integrated packages of recommendations.
2. Review measurement methods and perform additional testing and monitoring as required to allow determination of feasibility.
3. Perform accurate modeling of proposed modifications. Ensure that modeling includes system interaction.
4. Prepare a schematic layout of each of the modifications.
5. Estimate the cost and savings of each modification and each integrated bundle of modifications. Perform a LCCA to inform decision making.
6. Meet with the owner/operator to discuss/develop recommendations.

The report for a Level 3 analysis should include the following items, as a minimum:

- The text, schematics, equipment lists, and manufacturer's cut sheets necessary to completely describe all proposed changes to physical equipment. Matters of a final design nature may be left to subsequent engineering as long as the cost of such engineering is included in the budget. Firm price contractor quotations for key parts of any measure may be included. Cost estimates should show contingencies separately and report the expected accuracy of the budget.
- A description of system interactions and explanations of why certain efficiency measures should be bundled together.
- A financial evaluation of the estimated capital investment and projected savings. Use LCCA along with the owner's/operator's chosen techniques and criteria.

Targeted Audits

A targeted audit is an energy assessment of a specific system or end use at a facility. Whereas the Level 1, 2, and 3 audits provide a comprehensive approach to energy savings, a targeted audit focuses more narrowly on an area of particular interest to a customer.

For example, in a building with a chiller at the end of its useful life, an owner may want to take advantage of the need for replacement to investigate efficiency options, review sizing specifications, and examine alternative operating strategies. Given the owner's system-specific focus, a full audit would be excessive and costly, so an energy assessment provider could recommend a targeted audit to study only the chiller replacement and control options.

Other common examples of systems where a targeted approach may be used include the following:

- Packaged equipment replacements
- Compressed air systems
- Building additions
- Lighting system upgrades

A targeted energy audit has the advantage of allowing a more in-depth approach to a specific area or system. Because the scope is limited, the auditor can focus on the details of the system under study. With a reduced scope, a more detailed study of the equipment or system can be achieved at lower cost compared to comprehensive energy audits.

The targeted audit approach provides unique challenges for the energy auditor. Because only a specific area or end use is under study, an end-use breakdown or energy balance of the facility is not an option, so it may be more difficult to attribute the correct portion of the utility bill to the system under study. This makes additional measurement and monitoring of the existing system particularly important to ensure an accurate picture of the base-case conditions, loads on the system, and existing control methods. Targeted approaches also typically cannot rely on whole-building hourly simulation tools (e.g., DOE-2 [JJH 2009a] and Energy Plus [EERE 2011a]) because the information needed to create these models involves the entire building and its systems and is therefore outside the scope of the investigation. Targeted audits commonly rely on engineering analysis performed via spreadsheets to estimate energy and demand requirements for different equipment and operating scenarios. For some technologies, specialized software may be used to supplement or replace simple engineering analysis, for example, the use of AirMaster+ (EERE 2011b) for air compressors.

Targeted Audit Methods

The following approaches will help ensure that energy and cost savings estimates for targeted audits are comparable to more comprehensive strategies:

- Clearly define the scope of the audit and the systems to be studied.
- Interview building O&M personnel to determine their opinions of how equipment is operated and maintained and whether there are other factors to be considered in any decision, such as special needs or maintenance issues.
- Reduce uncertainty in assumptions by using measurements and data logging.

- Use spot measurements to verify key inputs such as full-load power requirements and equipment efficiencies.
- Monitor performance over time to observe control sequences, system performance, and occupant behavior.
- Calibrate base-case energy use estimates to measured data when possible. This may require extrapolation of short-term data to a full year with proper accounting for weather and occupancy over time.
- Perform "reality checks" on end-use energy estimates. For instance, in a lighting-only audit, check whether the calculated energy use of the lighting systems as a percentage of billed energy use aligns with industry norms. Use end-use-specific averages for your building type when possible.

Part 2

Best Practices for Conducting Energy Audits

The Energy Audit Process

This section of the book provides guidance on best practices for conducting commercial building energy assessments. This guidance is informative only and not intended to alter the level-of-effort definitions of Part 1 of this book.

ASHRAE and other entities have defined *energy audits* as processes in which engineering service providers identify and recommend efficiency opportunities to clients. The objectives of an energy audit are to identify and develop measures that will reduce the energy use and/or cost of operating a building and/or will improve the indoor environmental quality experience by the occupants. The results should be presented in a format that provides complete information needed by an owner/operator to decide whether or not to implement the recommended measures. As a general overview, an energy audit includes the following steps:

1. Collect and analyze historical energy use.
2. Study the building and gather data on its operational characteristics and indoor environmental quality (use the PCBEA Sample Forms found in Part 3).
3. Identify potential measures that will reduce the energy use and/or cost and/or will improve the occupants' indoor environmental quality.
4. Perform an engineering and economic analysis of potential modifications.
5. Prepare a list of appropriate measures and group measures into bundles that will capitalize on potential synergies and cost reductions.
6. Prepare a report to document the analysis process and results.

The energy audit may also include additional steps toward implementation of the recommended measures. These steps may include additional engineering and design, construction administration and management, commissioning (Cx), or measurement and verification (M&V) of energy savings.

Overview

A team approach helps ensure that an energy audit results in recommendations that can be implemented at the site. By involving multiple parties, the audit takes advantage of each team member's strengths. By actively involving building staff, the process can ensure that their concerns are heard, that their observations about the building add value, and that those who will be left to

maintain the building are familiar with recommended equipment and controls. This section describes who should be involved in a building audit, their roles, and the requirements.

Selecting team participants depends on the type of project and building under consideration. Regardless of the project delivery method, the audit process will require experienced, committed, eager, and innovative minds carefully selected by the building owner. When selecting team members, it is important for the owner to define shared goals. While definitive quantitative or contractual goals should be explored once the entire team is selected, the building owner should develop high-level goals and communicate them to the project team as members are interviewed and selected.

An energy audit of a facility should provide sufficient information for the owner/operator and/or manager of a facility to understand the energy use characteristics of the building. When feasible, this analysis breaks down the total energy use and cost for the facility into various end uses, such as heating, air conditioning, lighting, etc., and shows the potential for energy and cost savings for each end use.

The engineering analysis should also provide the owner/operator with all the information needed to allocate necessary resources to reduce the building's energy use and/or cost. This includes outlining any changes in the facility's operation and maintenance (O&M), including different personnel requirements, as well as presenting an economic analysis of any capital improvement projects.

The engineering analyst is encouraged to follow a systematic approach in identifying, selecting, ranking, and grouping recommended measures. While it is useful to have a procedure to follow, consider factors beyond technical issues, such as the regulatory environment, financing options, and occupant requirements. An efficiency measure that is highly effective under some conditions may have little or no effect under others.

The key elements of a commercial building energy audit/analysis are described in Figure 2.

Different levels of energy audit can be performed on any given building, or group of buildings, providing information that may be used for widely varying purposes. A building owner contemplating major energy-saving capital improvements will need a significantly higher level of confidence in the analysis than an owner who simply wishes to compare the level of efficiency of the building to that of other, similar buildings.

As a result, the levels of effort have been organized into the following categories:

- Preliminary Energy-Use Analysis (PEA)
- Level 1—Walk-Through Analysis
- Level 2—Energy Survey and Analysis
- Level 3—Detailed Analysis of Capital-Intensive Modifications
- Targeted Audits