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30%

Advanced Energy Design Guide for Highway Lodging

Achieving 30% Energy Savings Toward a Net Zero Energy Building

Developed by:
American Society of Heating, Refrigerating and Air-Conditioning Engineers
The American Institute of Architects
Illuminating Engineering Society of North America
U.S. Green Building Council
U.S. Department of Energy

Advanced Energy Design Guide for Highway Lodging

This is an ASHRAE Design Guide. Design Guides are developed under ASHRAE's Special Publication procedures and are not consensus documents. This document is an application manual that provides voluntary recommendations for consideration in achieving greater levels of energy savings relative to minimum standards.

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ADVANCED ENERGY DESIGN GUIDE—HIGHWAY LODGING COMMITTEE

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Mick Schwedler
Consultant (ASHRAE Standard 90.1)

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

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Acknowledgments

The *Advanced Energy Design Guide for Highway Lodging* (AEDG-HL) is the fifth in a series of Guides that address building types that represent major energy users in the commercial building stock. A huge debt of gratitude is extended to the authors of the previous Guides because they paved the way and defined the basic structure, content, and format of the books as well as the procedures for the reporting and the reviews. Following in their footsteps has provided consistency among these five Guides in addition to being a tremendous time saver. Building upon the previous work also allowed the Project Committee to finish its work in a very short period of time.

Continuity with the previous Guides was further maintained because many of the same organizational partners were involved, as were many of the project committee members. American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. (ASHRAE) was again the lead organization, with full support from the American Institute of Architects (AIA), the Illuminating Engineering Society of North America (IESNA), the United States Department of Energy (DOE), and the United States Green Building Council (USGBC). Individuals from each of these organizations served as members of the Steering Committee under the leadership of 2002–2003 ASHRAE President Don Colliver. Their contributions were significant in terms of the direction and oversight they provided to the ASHRAE Special Project 113 Committee (SP 113).

Members on the project committee came from the partner organizations, ASHRAE Standing Standards Project Committee 90.1, several ASHRAE Technical Committees, and the Hilton Corporation. These members served not only on the project committee but also as liaisons to their respective organizations where they coordinated the multiple technical reviews. This group of project committee members consisted of mostly veterans of previous Guides and demonstrated what can be accomplished when people have a good working relationship and are given a very short timeline to complete a very large task. From the first organizational meeting in early March 2008 to the final document approval in September 2008, these folks remained focused and dedicated to the task at hand.

In addition to the voting members on the committee, there were a number of other individuals who contributed to the success of this Guide. The specific individuals and their contributions were: Bing Liu, Wei Jiang, and Krishnan Gowri of the Pacific Northwest National Laboratory for the simulation runs and results; Lilas Pratt of ASHRAE for her assistance, organizational skills, and dedication to the project as well as serving as a gracious host at all meetings at ASHRAE Headquarters; and Elisabeth Parrish and Amelia

Sanders of ASHRAE Special Publications for the editing and layout of the book. This Guide could not have been developed without all of their contributions.

I am very proud of the Guide that the project committee developed and am amazed at the accomplishment in such a short time period. Each project committee member as well should be proud of their individual contributions to this most worthwhile document.

Ronald E. Jarnagin
SP 113 Chair
January 2009

Abbreviations and Acronyms

A	=	area, ft^2
ACCA	=	Air Conditioning Contractors of America
AEDG-HL	=	*Advanced Energy Design Guide for Highway Lodging*
AFUE	=	annual fuel utilization efficiency, dimensionless
AIA	=	American Institute of Architects
ASHRAE	=	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	=	American Society for Testing and Materials
ANSI	=	American National Standards Institute
Btu	=	British thermal unit
Cap	=	cooling capacity in Btu/h at 95°F outdoor dry-bulb temperature
CA	=	census area
CD	=	construction documents
c.i.	=	continuous insulation
Cx	=	commissioning
CxA	=	commissioning authority
CFL	=	compact fluorescent lamp
cfm	=	cubic feet per minute
CM	=	construction manager
CMH	=	ceramic metal halide
CO_2	=	carbon dioxide
COP	=	coefficient of performance, dimensionless
CRI	=	Color Rendering Index
CRRC	=	Cool Roof Rating Council
CZ	=	climate zone
D	=	diameter, ft
DCV	=	demand control ventilation
DL	=	*Advanced Energy Design Guide* code for “daylighting”
DOE	=	U.S. Department of Energy
DX	=	direct expansion

E_c	=	efficiency (combustion), dimensionless
E_t	=	efficiency (thermal), dimensionless
EER	=	energy efficiency ratio, Btu/W·h
EF	=	energy factor
EIA	=	Energy Information Administration
EL	=	*Advanced Energy Design Guide* code for "electric lighting"
EN	=	*Advanced Energy Design Guide* code for "envelope"
EX	=	*Advanced Energy Design Guide* code for "exterior lighting"
F	=	slab edge heat loss coefficient per foot of perimeter, Btu/h·ft·°F
G(G force)	=	gravitational force
GC	=	general contractor
GCHP	=	*Advanced Energy Design Guide* code for "ground coupled heat pump"
Guide	=	*Advanced Energy Design Guide for Highway Lodging*
HC	=	heat capacity, Btu/ft^2·°F
HSPF	=	heating season performance factor, Btu/W·h
HV	=	*Advanced Energy Design Guide* code for "HVAC systems and equipment"
HVAC	=	heating, ventilating, and air-conditioning
IESNA	=	Illuminating Engineering Society of North America
in.	=	inch
IPLV	=	integrated part-load value, dimensionless
IR	=	infrared reflecting
kBtuh	=	thousands of British thermal units per hour
kW	=	kilowatt
LBNL	=	Lawrence Berkeley National Laboratory
LED	=	light-emitting diode
LEED	=	Leadership in Energy and Environmental Design™
Low-e	=	low emissivity
LPD	=	lighting power density, W/ft^2
ls	=	linear systems
N/A	=	not applicable
NEMA	=	National Electrical Manufacturers Association
NFRC	=	National Fenestration Rating Council
NR	=	no recommendation
NZEB	=	net zero energy buildings
O&M	=	operation and maintenance
OPR	=	Owner's Project Requirements
PC	=	project committee
PF	=	projection factor, dimensionless
PL	=	*Advanced Energy Design Guide* code for "plug loads"
ppm	=	parts per million
psf	=	pounds per square foot
PV	=	photovoltaic
QA	=	quality assurance
R	=	thermal resistance, h·ft^2·°F/Btu
SEER	=	seasonal energy efficiency ratio, Btu/W·h
SHGC	=	solar heat gain coefficient, dimensionless
SP	=	special project
SRI	=	Solar Reflectance Index, dimensionless

SSPC	=	standing standards project committee
Std.	=	standard
SWH	=	service water heating
TAB	=	test and balance
TC	=	technical committee
U	=	thermal transmittance, Btu/h·ft^2·°F
UPS	=	uninterruptible power supply
USGBC	=	U.S. Green Building Council
VAV	=	variable air volume
VC	=	*Advanced Energy Design Guide* code for "ventilation control"
VT	=	visible transmittance
W	=	watts
WC	=	*Advanced Energy Design Guide* code for "water conservation"
w.c.	=	water column
wg	=	water gauge
WH	=	*Advanced Energy Design Guide* code for "water heating systems and equipment"

Introduction 1

The *Advanced Energy Design Guide for Highway Lodging* (AEDG-HL; the Guide) is intended to provide a simple approach for contractors and designers who create small hotels and motels. Application of the recommendations in the Guide should result in hotels with 30% energy savings when compared to those same hotels designed to the minimum requirements of *ANSI/ASHRAE/IESNA Standard 90.1-1999, Energy Standard for Buildings Except Low-Rise Residential Buildings*. This document contains recommendations and is *not* a minimum code or standard. It is intended to be used in addition to existing codes and standards and is not intended to circumvent them. This Guide represents *a way*, but *not the only way*, to build energy-efficient hotels that use significantly less energy than those built to minimum code requirements. The recommendations in this Guide provide benefits for the owner while maintaining quality and functionality of the space as well as a pleasant guest experience.

This Guide has been developed by a committee representing a diverse group of energy professionals drawn from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the American Institute of Architects (AIA), the Illuminating Engineering Society of North America (IESNA), the U.S. Green Building Council (USGBC), and the Hilton Hotels Corporation. To quantify the expected energy savings, these professionals selected potential envelope, lighting, HVAC, and service water heating (SWH) energy-saving measures for analysis. These included products that were deemed to be both practical and commercially available. Although some of the products may be considered premium, products of similar performance are available from multiple manufacturers. Each set of measures was simulated using an hourly energy analysis program for two hotel prototype buildings in representative cities in various climates. Simulations were run for reference buildings (buildings designed to ASHRAE/IESNA Standard 90.1-1999 criteria) compared to buildings built using recommendations contained in this Guide to determine whether the expected 30% savings target was achieved. The analysis showed an average energy savings of 39.3% from the ASHRAE/IESNA Standard 90.1-1999 baseline.

In general, this Guide addresses typical hotels found along highways. The scope specifically covers hotels of up to 80 rooms, typically four stories or fewer, that use unitary heating and air-conditioning equipment. Buildings of this type with these HVAC system configurations represent a significant amount of commercial hotel space in the United States. This Guide provides straightforward recommendations and guidance to facilitate its use by anyone in the construction process who wants to produce more energy-efficient buildings.

The Guide excludes certain hotels (i.e., those with significant commercial cooking or refrigeration equipment and those with "built-up" HVAC systems that utilize chillers and chilled-water systems). The Guide is primarily intended for new construction, but it may also be applicable to renovation, remodeling, and modernization projects.

As an added value for designers and contractors, this Guide features case study examples of energy-efficient buildings. The case studies demonstrate that effectively addressing environmental challenges can also result in the creation of good, often excellent, architecture. The case studies illustrate how energy considerations have been incorporated in various design strategies and techniques. However, the example buildings may incorporate additional features that go beyond the scope of the recommendations of the Guide.

It is hoped that the Guide will result in a more sustainable environment for society. The energy savings target of 30% is the first step in the process toward achieving a net zero energy building (NZEB), which is defined as a building that, on an annual basis, draws from outside sources equal or less energy than it provides using on-site, renewable energy sources. ASHRAE/IESNA Standard 90.1-1999, the energy conservation standard published at the turn of the millennium, provides the fixed reference point for all the Guides in this series. The primary reason for this choice as the reference point is to maintain a consistent baseline and scale for all the 30% AEDG series documents. A shifting baseline between multiple documents in the AEDG series would lead to confusion among users about the level of energy savings achieved. However, it is interesting to see what the energy savings of the Guide would be relative to ASHRAE/IESNA Standard 90.1-2004, which reduced lighting power densities and improved efficiency levels for cooling equipment. Using ASHRAE/IESNA Standard 90.1-2004 as the basis, the recommendations in this Guide would produce an average energy savings of 33%.

Plans are in place for development of additional AEDG documents in this decade that will assist users in achieving 50% and 70% energy-saving levels as milestones toward the NZEB goal. The ultimate goal of the participating organizations is to assist in the design and construction of NZEBs.

CONTENTS

Chapter 2 of this Guide contains a chart that walks the user through the design process of applying the recommendations in this Guide, while Chapter 3 provides the actual recommendations for a way to meet the 30% energy savings goal. Chapter 3 includes eight recommendation tables, which are broken down by building component and organized by climate according to the eight climate zones (and specific counties within each climate zone) identified by the U.S. Department of Energy (DOE). The user should note that the recommendation tables do not include all of the components listed in ASHRAE/IESNA Standard 90.1-1999 since the Guide focuses only on the primary energy systems within a building. Chapter 4 provides case studies of actual energy-efficient buildings and systems. Chapter 5 provides essential guidance in the form of concise how-to tips to help the user understand and apply the recommendations from this Guide. Additional "bonus savings" strategies are also found in Chapter 5. Three appendices are included for reference. Appendix A provides thermal performance factors for alternate opaque envelope construction. Appendix B provides climate zone information for a variety of locations in Mexico and Canada. Appendix C provides a list of additional resources.

This Guide includes specific recommendations for energy-efficient improvements in the following technical areas to meet the 30% energy savings goal:

- Building Envelope
  - Roofs
  - Walls
  - Slabs
  - Doors
  - Vertical Glazing
- Lighting
  - Interior Electric Lighting
  - Exterior Electric Lighting
- HVAC Equipment and Systems
  - Cooling Equipment Efficiencies
  - Heating Equipment Efficiencies
  - Supply Fans
  - Ventilation Control
  - Ducts
- Service Water Heating
  - Equipment Efficiencies
  - Pipe Insulation

In addition, “bonus savings” strategies to improve energy efficiency beyond the 30% energy savings level are included for:

- Ventilation Control
- Ground Coupled Heat Pump Systems
- Water Conservation
- Plug Loads
- Daylighting

Quality assurance (QA) and commissioning (Cx) are also covered in Chapter 5.

HOW TO USE THIS GUIDE

There are numerous ways to use this Guide effectively that are consistent with the background and knowledge of the user—some may turn immediately to the climate-specific recommendations; others may choose to first understand how energy goals fit into the design process. In addition, this Guide provides recommendations that would assist the user in achieving energy efficiency credits for LEED® or other building energy rating systems. The authors of this Guide suggest the following approach:

- Review Chapter 2 to understand how energy efficiency goals relate to the stages of building design. The flow charts, tables, and checklists in Chapter 2 can be used to lead, communicate, and manage the design and construction of energy-efficient buildings.
- Review Chapter 3 for specific recommendations to achieve the 30% energy savings level in your climate zone. These criteria provide *a way* to achieve the 30% savings goal and also serve as a starting point to further refine the energy design. The authors realize that designers typically don’t receive sufficient design fees to perform energy design optimization. Therefore, the contents of this chapter can serve as a starting point to meet specific requirements of a particular project.
- Review the Chapter 4 case studies to assure you and your team that other designers and builders have successfully used these and similar techniques to build energy-efficient buildings in the real world. Most of the case study buildings have won awards or achieved peer recognition for their energy-efficiency attributes.

- Use Chapter 5 to detail how the Chapter 3 recommendations are applied. Use the how-to tips, cross-referenced to the recommendation tables, to apply best practices (as well as cautions to avoid known problems in energy-efficient construction) to the specific circumstances of your project. Also, consider the recommendations for "bonus savings."

Integrated Process for Achieving Energy Savings 2

This chapter of the AEDG-HL provides resources for those who want to understand and adopt an overall *process* for designing, constructing, and operating energy-efficient hotel buildings. The resources listed below are above and beyond the straightforward presentation of recommendations in Chapter 3 and the how-to tips in Chapter 5 that lead to energy savings of 30% beyond ASHRAE/IESNA Standard 90.1-1999. The resources are:

- *A narrative discussion of the design and construction process that points out the opportunities for energy savings in each phase.* It further explains the steps that each team member or discipline should take to identify and implement energy savings concepts and strategies. It also includes a discussion on how the quality assurance (QA) measures are worked into the process at each phase and how some of these measures can be used by the owner to maintain energy performance for the life of the facility.
- *A reference table or matrix that leads the Guide's user through the process of identifying and selecting energy-saving measures to meet major energy design goals.* This information is presented in Table 2-5, which ties together detailed strategies, recommendations for meeting the 30% energy use reduction target, and related how-to information.

The following presentation of an integrated process for achieving energy savings in hotel buildings is valuable for designers and builders who want to augment and improve their practices so that energy efficiency is deliberately considered at each stage of the development process from project conception through building operation. Commissioning (Cx) begins in the early stage of design and continues through operation and is an integral part of each phase. These stages are shown in Figure 2-1.

The key benefits of following this integrated process include:

- Understanding the specific step-by-step activities that owners, designers, and construction team members need to follow in each phase of the project's delivery, including communication of management, design, construction, QA, Cx, operation and maintenance (O&M), and occupancy functional requirements an owner should follow to maintain the specified energy performance of the facility.

Figure 2-1. Stages of design.

- Identifying energy efficiency goals and selecting design strategies to achieve those goals.
- Incorporating QA, including building Cx procedures, into the building design and delivery process to ensure that energy savings of recommended strategies are actually achieved and that specific documentation needed to maintain energy performance is provided to the owner.
- Owner understanding of the ongoing activities needed to help ensure continued energy performance for the life of the facility, resulting in lower total cost of ownership.

Users of this Guide who follow the recommended process in their design and construction practice will benefit from achieving the goals of enhanced energy savings.

1. DESIGN (INCLUDING PLANNING AND PRE-DESIGN)

Documentation of the adopted energy goals and general strategies begins in the design phase. In a hotel, this typically involves identifying and documenting the objectives and criteria for the hotel project that form the Owner's Project Requirements (OPR), a brief, two-page description that includes the project's energy and sustainable development goals (see QA3 in Chapter 5). The OPR guides the team and provides a guide to be used during the design, construction, and operation of the project.

This Guide emphasizes goals that relate to the energy uses that can produce the largest savings. Achieving energy efficiency in hotels is based on a combination of strategies that include higher building envelope insulation and glazing, lower lighting power densities (LPDs) through more efficient lighting design, and higher-efficiency heating and air-conditioning systems. Hotels are built in a variety of configurations and may include occupancies such as meeting rooms, exercise rooms, and dining rooms, in addition to lobby spaces.

Interior lighting plays a major role in hotel energy use. Both ASHRAE/IESNA Standard 90.1-1999 and this Guide recognize differences between lighting requirements for different functional areas within a property (e.g., public areas, back of house, guest rooms, etc.).

In addition to lighting, differences in building application, climate, and even orientation will impact the selection of various energy goals and strategies. As an example, Figures 2-2 and 2-3 show energy use mixes for hotels located in a hot, humid climate (Miami) and a cold climate (Duluth). These figures demonstrate that cooling and lighting energy predominates in Phoenix; thus, in that climate zone, the goals and strategies relating to cooling and lighting should receive the highest priority. Conversely, in Chicago, the goals and strategies relating to heating and lighting should receive the highest priority. In the "Bonus Savings" section of Chapter 5, specific examples provide methods to achieve savings above the Chapter 3 requirements.

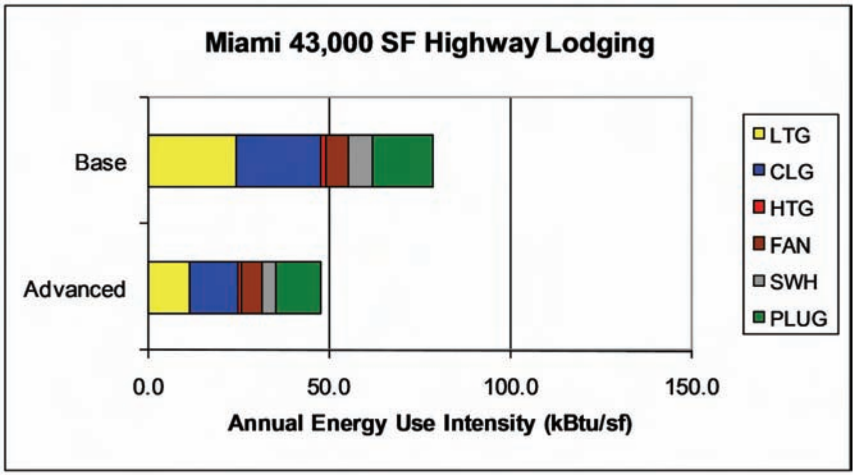


Figure 2-2. Hotel energy use in Miami.

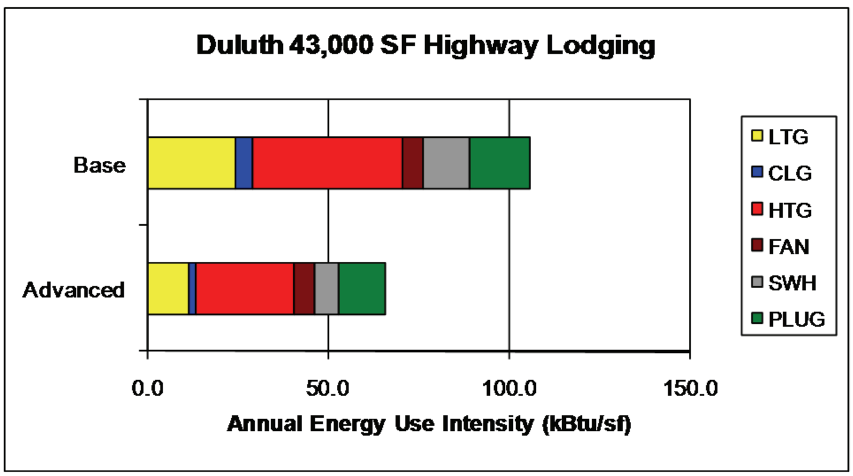


Figure 2-3. Hotel energy use in Duluth.

In the design phase, the team integrates the energy goals into building plans, sections, details, and specifications. The sequence of many design decisions, such as building and glazing orientation as well as other strategies identified in this chapter, has a major impact on energy efficiency. These decisions must, therefore, be made much sooner in the process than is typically done. The steps listed in Table 2-1, presented in sequence, identify the appropriate time in the process to apply specific recommendations from this Guide.

This Guide is designed to help achieve energy savings of 30% without the use of energy modeling, but energy modeling programs make evaluating energy-saving trade-offs faster and far more precise. Although these programs have learning curves of varying difficulty, the use of energy modeling for highway lodging design is highly encouraged and is considered necessary for achieving energy savings beyond 30%. See the U.S. Department of Energy's Building Energy Software Tools Directory for links to current energy modeling programs (www1.eere.energy.gov/buildings/commercial_initiative/modeling_software.html).

Table 2-1. Energy Goals in the Context of the Design Phase Process
A typical "integrated" design process includes the following steps in sequence, with energy-related actions flagged (*).

Activities	Responsibilities	Where to Find Information
1. Select Team a. Design Team b. QA Provider c. Construction Team	Owner evaluates potential service providers and selects team.	Chapter 5, QA1 and QA2
2. Owner's Project Requirements (OPR)[a]* a. Choose Recommendation Table Items b. Codes/Standards Requirements	Owner and CxA define the OPR and goals.	Chapter 2, Table 2-5[b] Chapter 3 Recommendations
3. Define Budget a. Develop and Review Design Budget b. Develop and Review Construction Budget c. Develop and Review QA Budget	Owner, GC, Designer Owner, Designer Owner, GC, Estimator Owner, CxA	Chapter 5, QA4
4. Select Implementation Recommendations * a. Specify System Preferences b. Update OPR c. Check for Rebate/Incentive Programs	Owner, Designer, GC	Chapter 5, QA3 Chapter 3 Recommendations
5. Develop Design and Construction Schedule	Owner, GC, Designer	Chapter 5, QA5
6. Design Development * a. Develop Building Plans, Sections, and Details Incorporating above Strategies b. Determine Ventilation Requirements c. Develop HVAC Load Calculations d. Size HVAC Equipment e. Integrate QA Specifications into Project Manual f. Specify ENERGY STAR® Appliances	Designer, CxA	Chapter 5
7. Construction Documents a. Develop Lighting and Equipment Details b. Develop Outdoor Air Management Details	Designer	Chapter 5, Lighting Chapter 5, Outdoor Air
8. Design Review * — Verify That Project Meets Original Goals	Owner, Designer, CxA, GC	Chapter 3 Chapter 5
9. Perform Final Coordination and Integration of Architectural, Mechanical, and Electrical Systems	Designer	Chapter 3 Chapter 5
10. Perform Final Cost Estimates	GC, Estimator	
11. Review Final Design Documents	Owner, Designer, CxA	Chapter 3 Chapter 5, QA6

a. The OPR is a written document that details the owner's intentions for the project's energy efficiency, measurable performance criteria, sustainability, functional requirements, and expectations of how the facility will be used and operated. See Chapter 3 for specific recommendations for each of the building components. Lists of implementation examples are shown in Chapter 5.

b. Table 2-5 presents four goals in addition to specific strategies for achieving energy savings in hotel construction. Reducing both internal and external loads (Goal 1) is the most basic. Matching the capacity of energy-using systems to the reduced loads (Goal 2) is also important. Oversized systems cost more and do not operate at optimum efficiency. Higher-efficiency equipment (Goal 3) will use less energy to meet any given load. Thus, high-efficiency equipment, in systems whose capacity matches peak loads, serving a building designed and constructed to the lowest practical loads, will result in the lowest energy use and cost. Goal 4 addresses the integration of building systems to increase energy savings potential.

QUALITY ASSURANCE: IN-HOUSE OR THIRD PARTY?

Users of this Guide may debate whether to use in-house staff or outside third parties as the Commissioning Authority (CxA) to perform the quality assurance (QA) tasks in the design, construction, and acceptance phases of the project. A case can be made for either approach depending on project budget, design complexity, capabilities of the design and construction team, and availability of local Cx expertise.

While both approaches can be effective, building owners should insist that the QA tasks be carried out by a party who is independent from the design and construction team, especially if complex and critical systems are installed. Independent review ensures that “fresh eyes” are applied to energy performance QA.

Where the in-house approach is deemed to be in the best interests of the building owner, the QA tasks are best accomplished by personnel with no direct interest in the project. For example, qualified staff working on other projects could be assigned as disinterested parties to check and verify the work of their colleagues. However, building owners can expect to get the most independent QA review from outside third parties. Indeed, most of the literature on building Cx and energy performance QA recommends or requires independent outside reviews. In either case, building owners should expect to bear the cost of approximately 12–50 professional staff hours to carry out the Suggested Commissioning Scope (see next page) depending on project specifics. Additional information can be found in Chapter 5.

Quality Assurance: Prior to design, an OPR should be developed that documents the owner’s objectives and criteria for the project in pre-programming. Combined with programming, the OPR provides the design team the guidance needed to successfully meet the needs of the owner. During the design process, the design team documents its design assumptions (Basis of Design) and includes them in the OPR. A party other than the installing contractor, architect, or engineer of record should review the contract document and verify that it incorporates the OPR and the associated strategies contained in this Guide before the start of construction. The owner’s agent, if qualified, can provide the required review. This review, along with subsequent inspection, testing, and reporting, is referred to as *commissioning*. The Commissioning Process is a quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria.

The reviewer provides the owner and designers with written comments outlining where items do not comply with these defined objectives and criteria selected from this Guide. Comments should be resolved and any required changes should be completed before start of construction. The owner may choose to use an outside third party to perform this review.

Once the design phase is completed, the party that is independent of the design and construction team fulfils the QA role to ensure that the goals, strategies, and recommendations are actually installed and achieved. This Guide provides recommendations to ensure that the goals, strategies, and actions selected are properly executed during the later stages of the building life cycle in Chapter 4 under “Quality Assurance.”

SUGGESTED COMMISSIONING SCOPE

- Review the OPR and the designers' Basis of Design documentation for completeness and clarity. The information provided by the design team for review should include project and design goals, measurable performance criteria, budgets, schedules, success criteria, and supporting information.
- Develop project-specific commissioning/quality assurance (Cx/QA) specifications and construction checklists for building envelope and lighting, mechanical, and plumbing systems that will be verified during the delivery of the project. The specifications will incorporate Cx/QA activities into the construction process and, with the accompanying construction checklists, provide a clear understanding to all participants of their specific roles, responsibilities, and effort. The Guide specifications will be reviewed, modified, and blended into the construction documents by the designers.
- Conduct one design review of the construction documents before 100% completion. A review before construction document completion (around 90% completion recommended) allows any changes to be incorporated. The review will focus on ensuring the design is consistent with the OPR and that all construction requirements are clear and well coordinated. It is also intended to ensure that the specifications describe the roles and responsibilities of all parties to the Cx process so that contractors have a clear understanding of their responsibilities. Prepare a report identifying concerns and opportunities, and use it in working with the owner and designers to develop a collaborative partnership that will ensure the building performs as intended. Provide a report that tracks issues to resolution and follow a collaborative process to facilitate resolution.
- Conduct one meeting or teleconference to discuss review comments and, if necessary, to adjudicate issues with the design team using owner input, and issue a final report illustrating the disposition of each issue raised. Use the report to verify during construction site visits that issues were corrected.
- If a pre-bid meeting is held with bidding contractors, participate in it to emphasize the inclusion of Cx and describe the Cx process for the specific project.
- Conduct a brief meeting with the project team reviewing QA procedures, roles, and responsibilities and establishing a tentative schedule of Cx/QA activities.
- Review submittal information for systems being commissioned and provide appropriate comments to team and owner for action. Based on the submittal information, develop test procedures that will be used to verify system performance and distribute to the team.
- Conduct two site visits: one during construction to observe construction techniques and to identify issues that may affect performance and one after construction is completed to verify identified issues/concerns were resolved. Review issues with appropriate team members at the end of each site visit in accordance with established communication protocols and issue one report per visit documenting findings. Establish and maintain an issues log for tracking issues identified.
- Direct and witness testing and document results. Issues identified will be documented in the issues log and tracked to resolution. General contractor (GC) will schedule testing activities and ensure that responsible parties needed for verification are present.
- Review O&M information to ensure warranty requirements and preventive maintenance information required are part of the documentation along with a copy of the OPR and Basis of Design information.
- Witness training of O&M staff to help ensure that O&M staff understands the systems and their operation, warranty responsibilities, and preventive maintenance requirements.

2. CONSTRUCTION

The best designs yield the expected energy savings when the construction plans and specifications are correctly designed and executed. This section outlines what actions the project team can perform to assist in meeting the energy goals. (See Table 2-2 to identify the appropriate time in the process to apply specific recommendations from this Guide.)

During construction, the independent CxA conducts submittal reviews and site visits to verify the construction of the building envelope, HVAC system, and lighting system meet the objectives and criteria documented in the OPR. The purposes of these site visits are as follows:

- **Observations for Operability and Maintainability.** Participate in an ongoing review of the building envelope, mechanical systems, and lighting systems. Prepare field notes and deficiency lists and distribute to the owner, designer, and general contractor (GC).
- **Verify Access Requirements.** Review shop drawings and perform construction observations to verify that the required access to systems and equipment has been provided.
- **Random Spot Verification.** Randomly verify installation checklists completed by contractors.

A written report on the site visit that documents issues requiring resolution by the design and/or construction team should be provided. The estimated effort for the CxA's written report is two to four hours during the construction phase for the size of highway lodging buildings covered by this Guide.

3. ACCEPTANCE

At this final stage of construction, the project team and the independent CxA verify that systems are operating as intended, HVAC system airflows are within the design parameters, and daylight harvesting controls are calibrated and operating correctly. When the team is satisfied that all systems are performing as intended, the QA effort of the design and construction team is complete. (See Table 2-3 to identify the appropriate time in the process to apply specific recommendations from this Guide.)

4. OCCUPANCY

During the first year of operation, the building owner needs to review the overall operation and performance of the building. Building systems not performing as expected should be discussed with the design and construction team with issues resolved during the warranty period. The CxA may be brought in to help resolve any Cx/warranty issues. (See Table 2-4 to identify the appropriate time in the process to apply specific recommendations from this Guide.)

5. OPERATION

Energy use and additions of energy-consuming equipment need to be documented and compared against previous data to determine if the building and its systems are operating at peak performance for the life of the building. The CxA needs to provide the ongoing method for monitoring the energy consumption of the building.

Reducing the actual energy use of highway lodging buildings will be enhanced when advisory energy-tracking information is conveyed to the owner or owner's staff as part of the design package. This information should be developed in simple language and format. This will allow the end-user to track and benchmark the facility's utility bills and take corrective action to maintain the intended efficiency of the original design. This ongoing Cx will require some additional cost but will typically save substantially more by preventing efficiency degradation in the facilities' energy systems. Additional information on energy-effective operation and ongoing energy management is available in *ASHRAE Handbook—HVAC Applications*.

ENERGY GOALS AND STRATEGIES

The goals listed in Table 2-5 provide detailed strategies and recommendations to meet the 30% energy use reduction target. The related how-to information in this Guide identifies selected energy-saving measures to meet major energy design goals.

Table 2-2. Energy Goals in the Context of the Bidding and Construction Process

Activities	Responsibilities	Where to Find Information
1. Pre-Bid Conference Discuss importance of energy systems to contractors/subcontractors Define quality control/Cx role	Owner, Designer, CxA, GC	Chapter 5, QA7
2. Progress Meetings Regular updates on energy-efficiency-related measures Scheduling/update QA	Owner, Designer, GC	
3. Envelope/Energy Systems QA QA building envelope construction QA HVAC systems QA lighting systems	CxA	Chapter 5, QA8 and QA9

Table 2-3. Energy Goals in the Context of the Acceptance Phase

Activities	Responsibilities	Where to Find Information
1. Assemble punch list of required items to be completed	GC	
2. Performance testing, as required of GC and subcontractors	GC, Subcontractors	Chapter 5, QA10
3. Building is identified as substantially complete	Owner, Designer, CxA	Chapter 5, QA11
4. Maintenance manual submitted and accepted	Owner, Designer, CxA	Chapter 5, QA12
5. Resolve quality control issues identified throughout the construction phase	Owner, Designer, CxA	Chapter 5, QA13
6. Final acceptance	Owner, Designer	Chapter 5, QA14

Table 2-4. Energy Goals in the Context of the Occupancy Phase

Activities	Responsibilities	Where to Find Information
1. Establish building maintenance program	Owner and staff, CxA	Chapter 5, QA15
2. Create post-occupancy punch list	Owner and staff	
3. Monitor post-occupancy performance	Owner and CxA	Chapter 5, QA16

Table 2-5. Energy Goals and Strategies

Prioritize Goals		General Strategies	Recommendations (see Chapter 3)	How-To Tips (see Chapter 5)
Goal 1. Reduce loads on energy-using systems				
Reduce internal loads	**Equipment and Appliances:** Reduce both cooling loads and energy use	Use more efficient equipment and appliances	Use low-energy computers and monitors; use ENERGY STAR® equipment	PL1–3
		Use controls to minimize usage and waste	Turn off or use “sleep mode” on computers, monitors, copiers, and other equipment	PL3
		Educate building staff	Provide training, brochures, and other material to encourage energy efficiency	EL2–8, 12
	Lighting: Reduce both cooling loads and energy use	Use efficient electric lighting system	Interior lighting	EL8–17
		Use separate controls for lighting in areas near windows	Interior lighting	DL1–11
		Use automatic controls to turn off lights when not in use	Interior lighting	EL8–9
Reduce heat gain/loss through building envelope	**Building Envelope:** Control solar gain to reduce cooling load through windows	Use beneficial building form and orientation		EN21–23
		Minimize windows east and west, maximize north and south	Vertical glazing	EN21–23
		Use glazing with low solar heat gain coefficient (SHGC)	Vertical glazing, skylights	EN16, 21–23,25
		Externally shade glazing to reduce solar heat gain and glare	Vertical glazing	EN19
		Use vegetation on S/E/W to control solar heat gain (and glare)	Vertical glazing	EN24

Table 2-5. Energy Goals and Strategies *(Continued)*

Prioritize Goals		General Strategies	Recommendations (see Chapter 3)	How-To Tips (see Chapter 5)
Reduce heat gain/loss through building envelope *(continued)*	Reduce solar gain through opaque surfaces to reduce cooling load	Increase insulation of opaque surfaces	Roofs, walls, floors, doors	EN2–13
		Increase roof surface reflectance and emittance	Roofs	EN1
		Shade building surfaces with deciduous or coniferous trees as appropriate for surface orientation		
	Reduce conductive heat gain or loss through building envelope	Increase insulation on roof, walls, floor, slabs, and doors and decrease window U-factor	Roofs, walls, floors, doors, vertical glazing	EN2–13, 16
	Reduce air infiltration	Provide continuous air barrier		
	Reduce heat gain or loss from ventilation exhaust air	Use energy recovery to precondition outdoor air	Energy recovery	
Reduce thermal loads	Utilize passive solar designs	Use thermal storage, trombe walls, interior mass		EN25
Reduce HVAC loads	Determine exact ventilation requirements	Set minimum ventilation flow volume exactly based upon space usage, occupancy, floor area, and contaminant generation per ANSI/ASHRAE Standard 62.1 (ASHRAE 2007) or local code, whichever is more stringent	HVAC	HV6–7, HV14
	Reduce heat gain or loss in ductwork	Insulate ductwork	HVAC	HV10
		No ductwork outside the building conditioned space	HVAC	HV9
Refine building to suit local conditions	Consider natural ventilation, highest potential in marine climates, high potential in dry climates	Operable windows with screens so that air conditioning and heating are not necessary during transition periods	Vertical glazing	EN20
		For buildings with operable windows, design building layout for effective cross-ventilation	Vertical glazing	EN20

Table 2-5. Energy Goals and Strategies *(Continued)*

Prioritize Goals		General Strategies	Recommendations (see Chapter 3)	How-To Tips (see Chapter 5)
Goal 2. Size HVAC systems for reduced loads				
Properly size equipment	Calculate load	Calculate building HVAC loads using generally accepted engineering methods that accurately account for the exact building configuration, construction, location, and usage	HVAC	HV3
	Size equipment	Size HVAC equipment to match calculated HVAC loads without excessive safety factors	HVAC	HV1–2, 4
Goal 3. Use more efficient systems				
Use more efficient HVAC systems	Select efficient cooling equipment	Meet or exceed listed equipment efficiencies in Chapter 5	HVAC	HV1–2, 4–5
		Meet or exceed listed part-load performances in Chapter 5	HVAC	HV1–2, 4–5
	Select efficient heating equipment	Meet or exceed listed equipment efficiencies in Chapter 5	HVAC	HV1–2, 5, 17
	Select efficient energy recovery equipment	Meet or exceed listed equipment efficiencies in Chapter 5		HV8
	Maximize heat rejection efficiency	Use controls and maintenance procedures to maximize COP of heat pump	HVAC	HV19–20
Improve outdoor air ventilation	Control outdoor air dampers	Use air economizer		HV7, 14
		Use demand-controlled ventilation (where appropriate)	Ventilation	HV7, 14, 22
		Shut off outdoor air and exhaust air dampers during unoccupied periods	Ventilation	HV7, 8, 14
Improve fan distribution efficiency	Design efficient duct distribution system	Minimize duct and fitting losses	Distribution	HV9
	Reduce duct leakage	Seal all duct joints and seams	Distribution	HV11
	Select efficient motors	Use high-efficiency motors	Distribution	HV12
	Reduce pumping energy	Use shut-off valves and variable speed pumping	Distribution	HV18

Table 2-5. Energy Goals and Strategies *(Continued)*

Prioritize Goals		General Strategies	Recommendations (see Chapter 3)	How-To Tips (see Chapter 5)
Improve HVAC controls	Use control strategies that reduce energy use	Divide building into thermal zones	HVAC	HV13, 21
		Use time-of-day scheduling, temperature setback and setup, and complete preoccupancy purge	HVAC	HV14
Ensure proper air distribution	Test, adjust, and balance the air distribution system	Use industry-accepted procedures	HVAC	HV6, 15
Use more efficient service water heating systems	Select efficient service water heating equipment	Meet or exceed listed equipment efficiencies in Chapter 5	SWH	WH1–4
	Minimize required service water heating	Minimize loads, recover heat from drainwater	SWH	WH5, 8
	Minimize distribution losses	Minimize pipe distribution losses	SWH	WH6
		Insulate piping	SWH	WH7
		Utilize point-of-use water heaters for isolated loads	SWH	WH6
Use more efficient lighting	More efficient interior lighting	Do not use incandescent lighting unless it will be used infrequently; avoid incandescent sources except for specific task requirements		EL7
		Use more efficient electric lighting system	More efficient lamps, ballasts, ceiling fixtures, and task lights	EL4–5, 12–17
	More efficient exterior lighting	Use more efficient electric lighting system	More efficient exterior lighting sources	EL18–21
Goal 4. Refine systems integration				
Integrate building systems	Integrate systems—high-efficiency advanced case			EN17, QA1
	Integrate systems—daylight advanced case		Advanced daylighting option	EN17, QA1

Recommendations by Climate 3

Users should determine the recommendations for their construction project by first locating the correct climate zone. The U.S. Department of Energy (DOE) has identified eight climate zones for the United States, with each defined by county borders, as shown in Figure 3-1. This Guide uses these DOE climate zones in defining energy recommendations that vary by climate. Tables with climate zones identified for a variety of locations in Mexico and Canada are provided in Appendix B.

This chapter contains a unique set of energy-efficient recommendations for each climate zone. The recommendation tables represent *a way*, but *not the only way*, for reaching the 30% energy savings target over ASHRAE/IESNA Standard 90.1–1999. Other approaches may also save energy, but they are not part of the scope of this Guide; assurance of those savings is left to the user. The user should note that the recommendation tables do not include all of the components listed in ASHRAE/IESNA Standard 90.1 since the Guide focuses only on the primary energy systems within a building.

When a recommendation is provided, the recommended value differs from the requirements in ASHRAE/IESNA Standard 90.1–1999. When "No recommendation" is indicated, the user must meet at least the minimum requirements of ASHRAE/IESNA Standard 90.1-1999 or the requirements of local codes whenever they exceed the requirements of ASHRAE/IESNA Standard 90.1-1999.

Each of the climate zone recommendation tables includes a set of common items arranged by building subsystem: envelope, lighting, HVAC, and service water heating (SWH). Recommendations are included for each item, or subsystem, by component within that subsystem. For some subsystems, recommendations depend on the construction type. For example, insulation values are given for mass and steel-framed and

BONUS SAVINGS

Chapter 5 provides additional recommendations and strategies for savings for ventilation control, ground coupled heat pumps, water conservation, plug loads, and daylighting over and above the 30% savings recommendations contained in the following eight climate regions.

wood-framed wall types. For other subsystems, recommendations are given for each subsystem attribute. For example, vertical glazing recommendations are given for thermal transmittance, solar heat gain coefficient (SHGC), and exterior sun control.

The fourth column in each table lists references to how-to tips for implementing the recommended criteria. The tips are found in Chapter 5 under separate sections coded for envelope (EN), electric lighting (EL), HVAC systems and equipment (HV), service water heating systems and equipment (WH) suggestions, and miscellaneous appliances (MA). Besides how-to tips for design and maintenance suggestions that represent good practice, these tips include cautions for what to avoid. Important QA considerations and recommendations are also given for the building design, construction, and post-occupancy phases. Note that each tip is tied to the applicable climate zone in Chapter 5. The final column is provided as a simple checklist to identify the recommendations being used for a specific building design and construction.

The recommendations presented are either minimum, maximum, or specific values (which are both the minimum and maximum values). Minimum values include R-values, mean lumens/watt, SEER, SRI, EER, IPLV, AFUE, E_c, HSPF, COP, E_t, EF, VT, and insulation thicknesses. Maximum values include U-factors, SHGC, area, LPD, and friction rate.

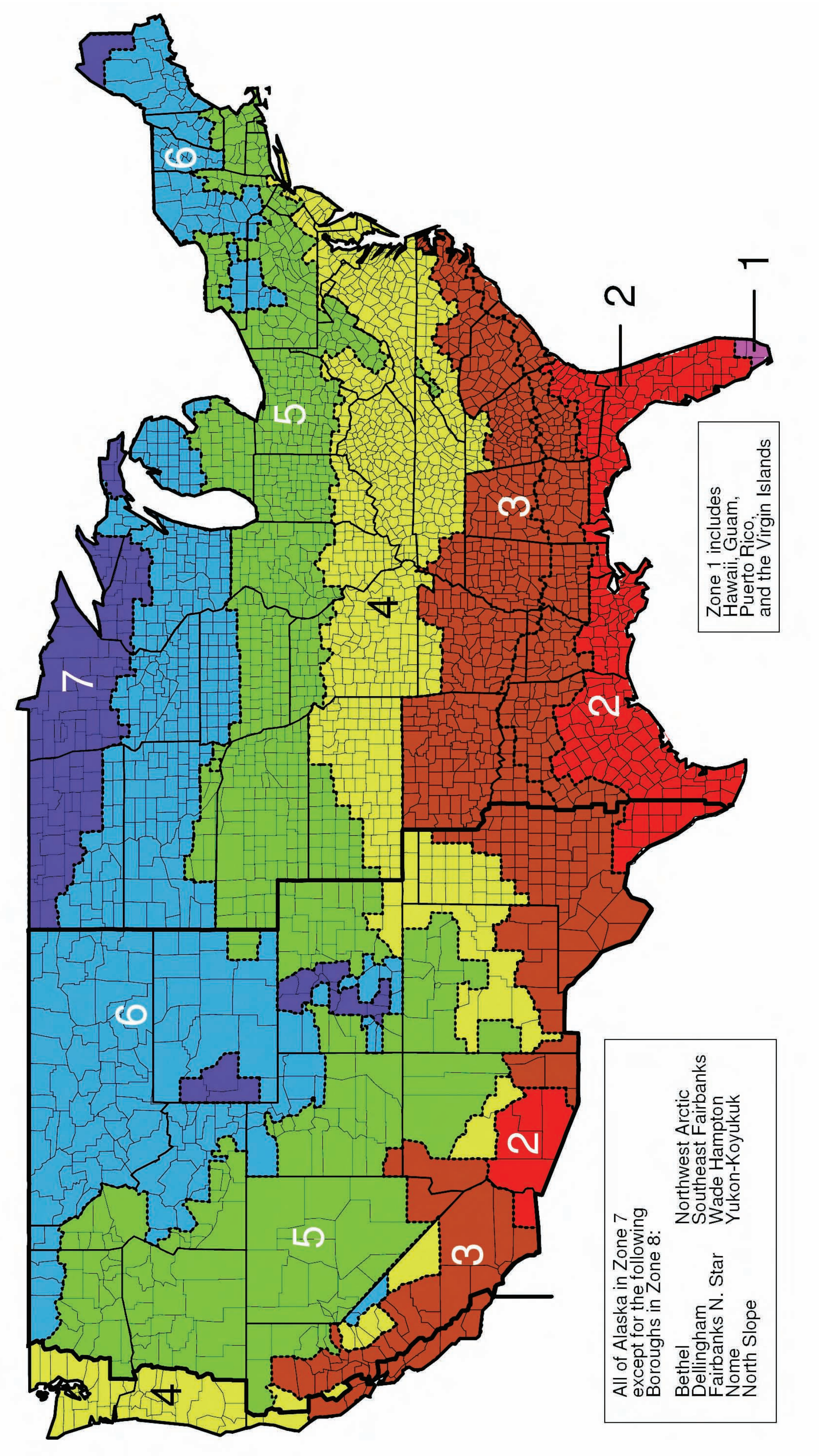


Figure 3-1. DOE climate zone map. A list of counties and their respective climate zones can be found on the following pages and at www.energycodes.gov.

Zone 1

Florida

Broward
Miami-Dade
Monroe

Guam

Hawaii

Puerto Rico

U.S. Virgin Islands

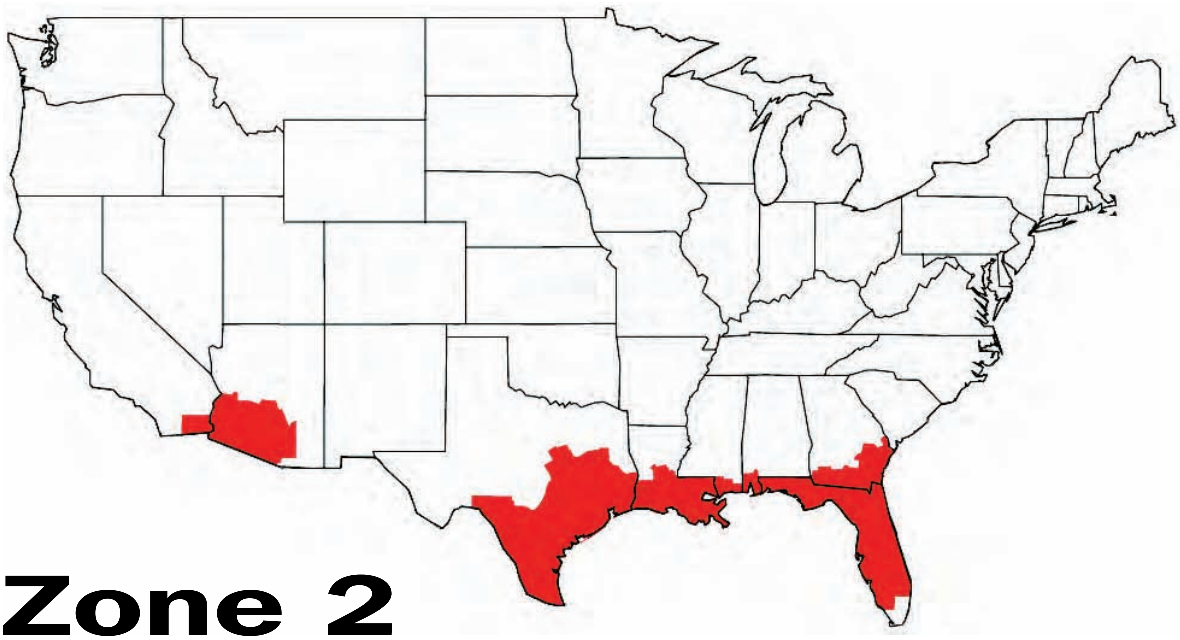
Climate Zone 1 Recommendation Table for Highway Lodging

	Item	Component	Recommendation (Minimum or Maximum)			How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-20.0 c.i.			EN1, 2, 8, 11, 14–15	
		Attic and other	R-38.0			EN3, 11–12, 14–15	
		Single rafter	R-38.0			EN4, 11, 14–15	
		Solar reflectance index (SRI)	78			EN1	
	Walls—Exterior	Mass (HC > 7 Btu/ft^2)	R-5.7 c.i.			EN5, 11, 14–15	
		Steel-framed	R-13.0			EN6, 11, 14–15	
		Wood-framed and other	R-13.0			EN7, 11, 14–15	
	Slabs	Unheated	No recommendation*			EN8, 11, 13–15	
	Doors—Opaque	Swinging	U-0.70			EN9, 14–15	
		Non-swinging	U-1.45			EN10, 14–15	
	Vertical Glazing (Including Doors)	Area (percent of gross wall)	25%			EN17, 21–22, 25	
		Thermal transmittance	U-0.56			EN16	
		Solar heat gain coefficient (SHGC)	N, S, E, W – 0.25			EN16, 21–22, 25	
		Exterior sun control (S, E, W only)	Projection factor > 0.5			EN18–19, 24	
		Vestibule	No recommendation*			EN16	
Lighting	Interior Lighting	Lighting power density (LPD), W/ft^2	Guest rooms = 0.74	Office = 0.9		EL13–17	
			Corridors = 0.5	Lobbies = 1.1			
			Exercise = 0.9	Laundry = 0.6			
			Meeting rooms = 1.1	Stairs = 0.6			
		Fluorescent lamps	Compact fluorescent (CFL) with electronic ballast, T5HO or T8 high-performance with high-performance electronic ballast			EL2–7	
		Occupancy controls	Bi-level in stairs, manual-on/auto-off for all laundry, office, exercise, business center, meeting rooms, and non-public spaces			EL9	
		Guest room controls	Master control and entry and vacancy control in bathroom			EL9–10, HV14	
		Plug load lighting	Compact Fluorescent (CFL) with electronic ballast			EL8	
	Exterior Lighting Power Density (LPD)	Lighting Zone 1 = Developed areas of national parks, state parks, forest land, and rural areas Lighting Zone 2 = Residential mixed-use areas and neighborhood business districts Lighting Zone 3 = All other areas				EL18–21	
			Lighting Zone 1	Lighting Zone 2	Lighting Zone 3		
		Base allowance	500 W	600 W	750 W		
		Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2		
		Walkways less than 10 ft wide	0.7 W/lf	0.7 W/lf	0.8 W/lf		
		Walkways 10 ft wide or greater	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2		
		Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2		
		Façade (use wattage only for façade)	None	0.10 W/ft^2	0.15 W/ft^2		

Climate Zone 1 Recommendation Table for Highway Lodging *(Continued)*

	Item	Component	Recommendation (Minimum or Maximum)	How-To Tips in Chapter 5	✓
HVAC	HVAC	Heating system (guest rooms)	Primary heat source electric heat pump cycle or gas-fired furnace or boiler	HV2	
		Air conditioner (0–65 KBtuh)	13.0 SEER	HV1–5	
		Air conditioner (>65–135 KBtuh)	11.3 EER/11.5 IPLV	HV1–5	
		Air conditioner (>135–240 KBtuh)	11.0 EER/11.5 IPLV	HV1–5	
		Air conditioner (>240 KBtuh)	10.6 EER/11.2 IPLV	HV1–5	
		Gas furnace (0–225 KBtuh—SP)	80% AFUE or E_t	HV1–5	
		Gas furnace (0–225 KBtuh—Split)	80% AFUE or E_t	HV1–5	
		Gas furnace (>225 KBtuh)	80% E_c	HV1–5	
		Packaged terminal heat pump (all capacities)	EER = 13.6 – (0.233 × Cap/1000) COP = 3.8 – (0.053 × Cap/1000)	HV1–5	
		Air source heat pump (0–65 KBtuh)	13.0 SEER/7.7 HSPF	HV1–5	
		Air source heat pump (>65–135 KBtuh)	10.6 EER/11.0 IPLV/3.2 Htg COP	HV1–5	
		Air source heat pump (>135 KBtuh)	10.1 EER/11.5 IPLV/3.1 Htg COP	HV1–5	
		Hydronic heat pump (0–18 KBtuh)	14.6 EER, 4.6 Htg COP	HV1–5	
		Hydronic heat pump (>19 KBtuh)	15.0 EER, 4.8 Htg COP	HV1–5	
		Hydronic heat pump heat source	Use condensing boiler for circulating loop heat source	HV17	
		Pumping for water source heat pumps	Variable speed pumping; water treatment	HV18, HV20	
		Hydronic heat pump heat rejection	Control cooling tower to maximize heat pump EER	HV19	
	Economizer	Air conditioners and heat pumps—SP	No recommendation*	HV6, HV22, HV26	
	Ventilation	Ventilation air supply	Demand Control Ventilation (DCV) for public areas	HV6–7, VC1–2	
		Heat recovery	Ventilation heat recovery with toilet exhaust	HV8	
	Ducts	Friction rate	0.08 in. w.c./100 ft	HV11, 20	
		Sealing	Seal class B	HV13	
		Location	Interior only	HV9	
		Insulation level	R-6	HV10	
SWH	Service Water Heating	Gas water heater efficiency	Storage—90% E_t, Instantaneous—0.81 EF or 81% E_t	WH1–2, 4	
		Electric storage EF (≤12 kW, ≥20 gal)	EF > 0.99 – 0.0012 × Volume	WH1–2, 4	
		Hot water usage reduction	Use 1.75 gpm shower heads, 1.0 gpm faucets and water-conserving clothes washers; utilize laundry heat recovery	WH5, WH8	
		Water heater sizing/location	Avoid oversizing and excessive supply temperatures	WH3, WH6	
		Pipe insulation (d < 1.5 in./ d ≥ 1.5 in.)	1 in./ 1.5 in.	WH7	
Other	Miscellaneous Appliances	Guest room mini-refrigerator	Absorption refrigeration cycle 33W continuously	MA1	
		High-efficiency laundry equipment	0.9 gal water/lb laundry 354G extractor with retained water < 52.5%	MA2	

Note: If the table contains “No recommendation” for a component, the user must meet the more stringent of either ASHRAE/IESNA Standard 90.1 or the local code requirements in order to reach the 30% savings target.



Zone 2

Alabama

Baldwin
Mobile

Arizona

La Paz
Maricopa
Pima
Pinal
Yuma

California

Imperial

Florida

Alachua
Baker
Bay
Bradford
Brevard
Calhoun
Charlotte
Citrus
Clay
Collier
Columbia
DeSoto
Dixie
Duval
Escambia
Flagler
Franklin
Gadsden
Gilchrist
Glades
Gulf
Hamilton
Hardee
Hendry
Hernando
Highlands
Hillsborough
Holmes
Indian River
Jackson
Jefferson
Lafayette
Lake
Lee
Leon
Levy
Liberty
Madison
Manatee
Marion
Martin
Nassau
Okaloosa
Okeechobee
Orange
Osceola
Palm Beach
Pasco
Pinellas
Polk
Putnam
Santa Rosa
Sarasota
Seminole
St. Johns
St. Lucie
Sumter
Suwannee
Taylor
Union
Volusia
Wakulla
Walton
Washington

Georgia

Appling
Atkinson
Bacon
Baker
Berrien
Brantley
Brooks
Bryan
Camden
Charlton
Chatham
Clinch
Colquitt
Cook
Decatur
Echols
Effingham
Evans
Glynn
Grady
Jeff Davis
Lanier
Liberty
Long
Lowndes
McIntosh
Miller
Mitchell
Pierce
Seminole
Tattnall
Thomas
Toombs
Ware
Wayne

Louisiana

Acadia
Allen
Ascension
Assumption
Avoyelles
Beauregard
Calcasieu
Cameron
East Baton
Rouge
East Feliciana
Evangeline
Iberia
Iberville
Jefferson
Jefferson Davis
Lafayette
Lafourche
Livingston
Orleans
Plaquemines
Pointe Coupee
Rapides
St. Bernard
St. Charles
St. Helena
St. James
St. John the Baptist
St. Landry
St. Martin
St. Mary
St. Tammany
Tangipahoa
Terrebonne
Vermilion
Washington
West Baton
Rouge
West Feliciana

Mississippi

Hancock
Harrison
Jackson
Pearl River
Stone

Texas

Anderson
Angelina
Aransas
Atascosa
Austin
Bandera
Bastrop
Bee
Bell
Bexar
Bosque
Brazoria
Brazos
Brooks
Burleson
Caldwell
Calhoun
Cameron
Chambers
Cherokee
Colorado
Comal
Coryell
DeWitt
Dimmit
Duval
Edwards
Falls
Fayette
Fort Bend
Freestone
Frio
Galveston
Goliad
Gonzales
Grimes
Guadalupe
Hardin
Harris
Hays
Hidalgo
Hill
Houston
Jackson
Jasper
Jefferson
Jim Hogg
Jim Wells
Karnes
Kenedy
Kinney
Kleberg
La Salle
Lavaca
Lee
Leon
Liberty
Limestone
Live Oak
Madison
Matagorda
Maverick
McLennan
McMullen
Medina
Milam
Montgomery
Newton
Nueces
Orange
Polk
Real
Refugio
Robertson
San Jacinto
San Patricio
Starr
Travis
Trinity
Tyler
Uvalde
Val Verde
Victoria
Walker
Waller
Washington
Webb
Wharton
Willacy
Williamson
Wilson
Zapata
Zavala

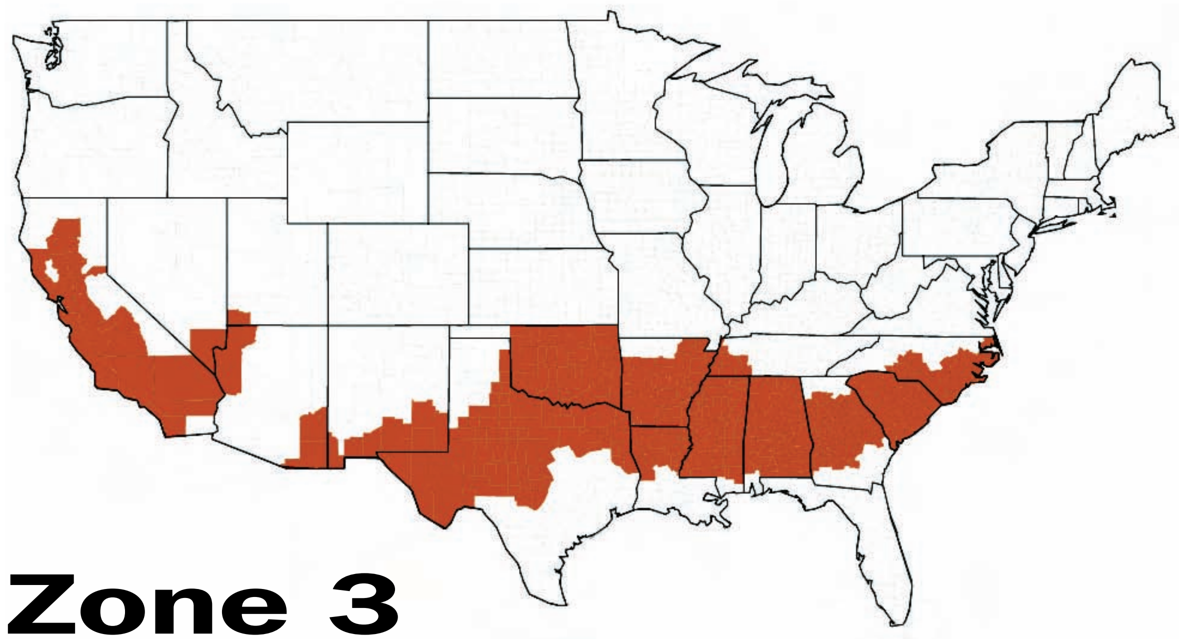
Climate Zone 2 Recommendation Table for Highway Lodging

	Item	Component	Recommendation (Minimum or Maximum)			How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-20.0 c.i.			EN1–2, 11, 14–15	
		Attic and other	R-38.0			EN3, 11–12, 14–15	
		Single rafter	R-38.0			EN4, 11, 14–15	
		Solar reflectance index (SRI)	78			EN1	
	Walls—Exterior	Mass (HC > 7 Btu/ft^2)	R-7.6 c.i.			EN5, 11, 14–15	
		Steel-framed	R-13.0 + R-7.5 c.i.			EN6, 11, 14–15	
		Wood-framed and other	R-13.0			EN7, 11, 14–15	
	Slabs	Unheated	No recommendation*			EN8, 11, 13–15	
	Doors—Opaque	Swinging	U-0.70			EN9, 14–15	
		Non-swinging	U-0.50			EN10,14–15	
	Vertical Glazing (Including Doors)	Area (percent of gross wall)	25%			EN17, 21–22, 25	
		Thermal transmittance	U-0.45			EN16	
		Solar heat gain coefficient (SHGC)	N, S, E, W – 0.25			EN16, 21–22, 25	
		Exterior sun control (S, E, W only)	Projection factor > 0.5			EN18–19, 24	
Lighting	Interior Lighting	Lighting power density (LPD), W/ft^2	Guest rooms = 0.74	Office = 0.9		EL13–17	
			Corridors = 0.5	Lobbies = 1.1			
			Exercise = 0.9	Laundry = 0.6			
			Meeting rooms = 1.1	Stairs = 0.6			
		Fluorescent lamps	Compact fluorescent (CFL) with electronic ballast, T5HO or T8 high-performance with high-performance electronic ballast			EL2–7	
		Occupancy controls	Bi-level in stairs, manual-on/auto-off for all laundry, office, exercise, business center, meeting rooms, and non-public spaces			EL9	
		Guest room controls	Master control and entry and vacancy control in bathroom			EL9–10, HV14	
		Plug-load lighting	Compact fluorescent (CFL) with electronic ballast			EL8	
	Exterior Lighting Power Density (LPD)	Lighting Zone 1 = Developed areas of national parks, state parks, forest land, and rural areas Lighting Zone 2 = Residential mixed-use areas and neighborhood business districts Lighting Zone 3 = All other areas				EL18–21	
			Lighting Zone 1	Lighting Zone 2	Lighting Zone 3		
		Base allowance	500 W	600 W	750 W		
		Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2		
		Walkways less than 10 ft wide	0.7 W/lf	0.7 W/lf	0.8 W/lf		
		Walkways 10 ft wide or greater	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2		
		Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2		
		Façade (use wattage only for façade)	None	0.10 W/ft^2	0.15 W/ft^2		

Climate Zone 2 Recommendation Table for Highway Lodging *(Continued)*

	Item	Component	Recommendation (Minimum or Maximum)	How-To Tips in Chapter 5	✓
HVAC	HVAC	Heating system (guest rooms)	Primary heat source electric heat pump cycle or gas-fired furnace or boiler	HV2	
		Air conditioner (0–65 KBtuh)	13.0 SEER	HV1–5	
		Air conditioner (>65–135 KBtuh)	11.3 EER/11.5 IPLV	HV1–5	
		Air conditioner (>135–240 KBtuh)	11.0 EER/11.5 IPLV	HV1–5	
		Air conditioner (>240 KBtuh)	10.6 EER/11.2 IPLV	HV1–5	
		Gas furnace (0–225 KBtuh—SP)	80% AFUE or E_t	HV1–5	
		Gas furnace (0–225 KBtuh—Split)	80% AFUE or E_t	HV1–5	
		Gas furnace (>225 KBtuh)	80% E_c	HV1–5	
		Packaged terminal heat pump (all capacities)	EER = 13.6 –(0.233 × Cap/1000) COP = 3.8 – (0.053 × Cap/1000)	HV1–5	
		Air source heat pump (0–65 KBtuh)	13.0 SEER/7.7 HSPF	HV1–5	
		Air source heat pump (>65–135 KBtuh)	10.6 EER/11.0 IPLV/3.2 Htg COP	HV1–5	
		Air source heat pump (>135 KBtuh)	10.1 EER/11.5 IPLV/3.1 Htg COP	HV1–5	
		Hydronic heat pump (0–18 KBtuh)	14.6 EER, 4.6 Htg COP	HV1–5	
		Hydronic heat pump (>19 KBtuh)	15.0 EER, 4.8 Htg COP	HV1–5	
		Hydronic heat pump heat source	Use condensing boiler for circulating loop heat source	HV17	
		Pumping for water source heat pumps	Variable speed pumping; water treatment	HV18, HV20	
		Hydronic heat pump heat rejection	Control cooling tower to maximize heat pump EER	HV19	
	Economizer	Air conditioners and heat pumps—SP	No recommendation*	HV6, HV22, HV26	
	Ventilation	Ventilation air supply	Demand control ventilation (DCV) for public areas	HV6–7, VC1–2	
		Heat recovery	Ventilation heat recovery with toilet exhaust	HV8	
	Ducts	Friction rate	0.08 in. w.c./100 ft	HV11, 20	
		Sealing	Seal class B	HV13	
		Location	Interior only	HV9	
		Insulation level	R-6	HV10	
SWH	Service Water Heating	Gas water heater efficiency	Storage—90% E_t, Instantaneous—0.81 EF or 81% E_t	WH1–2, 4	
		Electric storage EF (≤12 kW, ≥20 gal)	EF > 0.99 – 0.0012 × Volume	WH1–2, 4	
		Hot water usage reduction	Use 1.75 gpm shower heads, 1.0 gpm faucets and water-conserving clothes washers; utilize laundry heat recovery	WH5, WH8	
		Water heater sizing/location	Avoid oversizing and excessive supply temperatures	WH3, WH6	
		Pipe insulation (d < 1.5 in./ d ≥ 1.5 in.)	1 in./ 1.5 in.	WH7	
Other	Miscellaneous Appliances	Guest room mini-refrigerator	Absorption refrigeration cycle 33W continuously	MA1	
		High-efficiency laundry equipment	0.9 gal water/lb laundry 354G extractor with retained water < 52.5%	MA2	

Note: If the table contains "No recommendation" for a component, the user must meet the more stringent of either ASHRAE/IESNA Standard 90.1 or the local code requirements in order to reach the 30% savings target.



Zone 3

Alabama

All counties except:
Baldwin
Mobile

Arizona

Cochise
Graham
Greenlee
Mohave
Santa Cruz

Arkansas

All counties except:
Baxter
Benton
Boone
Carroll
Fulton
Izard
Madison
Marion
Newton
Searcy
Stone
Washington

California

All counties except:
Alpine
Amador
Calaveras
Del Norte
El Dorado
Humboldt
Imperial
Inyo
Lake
Lassen
Mariposa
Modoc
Mono
Nevada
Plumas
Sierra
Siskiyou
Trinity
Tuolumne

Georgia

All counties except:
Appling
Atkinson
Bacon
Baker
Banks
Berrien
Brantley
Brooks
Bryan
Catoosa
Camden
Charlton
Chatham
Chattooga
Clinch
Colquitt
Cook
Dade
Dawson
Decatur
Echols
Effingham
Evans
Fannin
Floyd
Franklin
Gilmer
Glynn
Gordon
Grady
Habersham
Hall
Jeff Davis
Lanier
Liberty
Long
Lowndes
Lumpkin
McIntosh
Miller
Mitchell
Murray
Pickens
Pierce
Rabun
Seminole
Stephens
Tattnall
Thomas
Toombs
Towns
Union
Walker
Ware
Wayne
White
Whitfield

Louisiana

Bienville
Bossier
Caddo
Caldwell
Catahoula
Claiborne
Concordia
De Soto
East Carroll
Franklin
Grant
Jackson
La Salle
Lincoln
Madison
Morehouse
Natchitoches
Ouachita
Red River
Richland
Sabine
Tensas
Union
Vernon
Webster
West Carroll
Winn

Mississippi

All counties except:
Hancock
Harrison
Jackson
Pearl River
Stone

New Mexico

Chaves
Dona Ana
Eddy
Hidalgo
Lea
Luna
Otero

Nevada

Clark

Texas

Andrews
Archer
Baylor
Blanco
Borden
Bowie
Brewster
Brown
Burnet
Callahan
Camp
Cass
Childress
Clay
Coke
Coleman
Collingsworth
Collin
Comanche
Concho
Cottle
Cooke
Crane
Crockett
Crosby
Culberson
Dallas
Dawson
Delta
Denton
Dickens
Eastland
Ector
El Paso
Ellis
Erath
Fannin
Fisher
Foard
Franklin
Gaines
Garza
Gillespie
Glasscock
Grayson
Gregg
Hall
Hamilton
Hardeman
Harrison
Haskell
Hemphill
Henderson
Hood
Hopkins
Howard
Hudspeth
Hunt
Irion
Jack
Jeff Davis
Johnson
Jones
Kaufman
Kendall
Kent
Kerr
Kimble
King
Knox
Lamar
Lampasas
Llano
Loving
Lubbock
Lynn
Marion
Martin
Mason
McCulloch
Menard
Midland
Mills
Mitchell
Montague
Morris
Motley
Nacogdoches
Navarro
Nolan
Palo Pinto
Panola
Parker
Pecos
Presidio
Rains
Reagan
Reeves
Red River
Rockwall
Runnels
Rusk
Sabine
San Augustine
San Saba
Schleicher
Scurry
Shackelford
Shelby
Smith
Somervell
Stephens
Sterling
Stonewall
Sutton
Tarrant
Taylor
Terrell
Terry
Throckmorton
Titus
Tom Green
Upshur
Upton
Van Zandt
Ward
Wheeler
Wichita
Wilbarger
Winkler
Wise
Wood
Young

Utah

Washington

North Carolina

Anson
Beaufort
Bladen
Brunswick
Cabarrus
Camden
Carteret
Chowan
Columbus
Craven
Cumberland
Currituck
Dare
Davidson
Duplin
Edgecombe
Gaston
Greene
Hoke
Hyde
Johnston
Jones
Lenoir
Martin
Mecklenburg
Montgomery
Moore
New Hanover
Onslow
Pamlico
Pasquotank
Pender
Perquimans
Pitt
Randolph
Richmond
Robeson
Rowan
Sampson
Scotland
Stanly
Tyrrell
Union
Washington
Wayne
Wilson

Oklahoma

All counties except:
Beaver
Cimarron
Texas

South Carolina

All counties

Tennessee

Chester
Crockett
Dyer
Fayette
Hardeman
Hardin
Haywood
Henderson
Lake
Lauderdale
Madison
McNairy
Shelby
Tipton

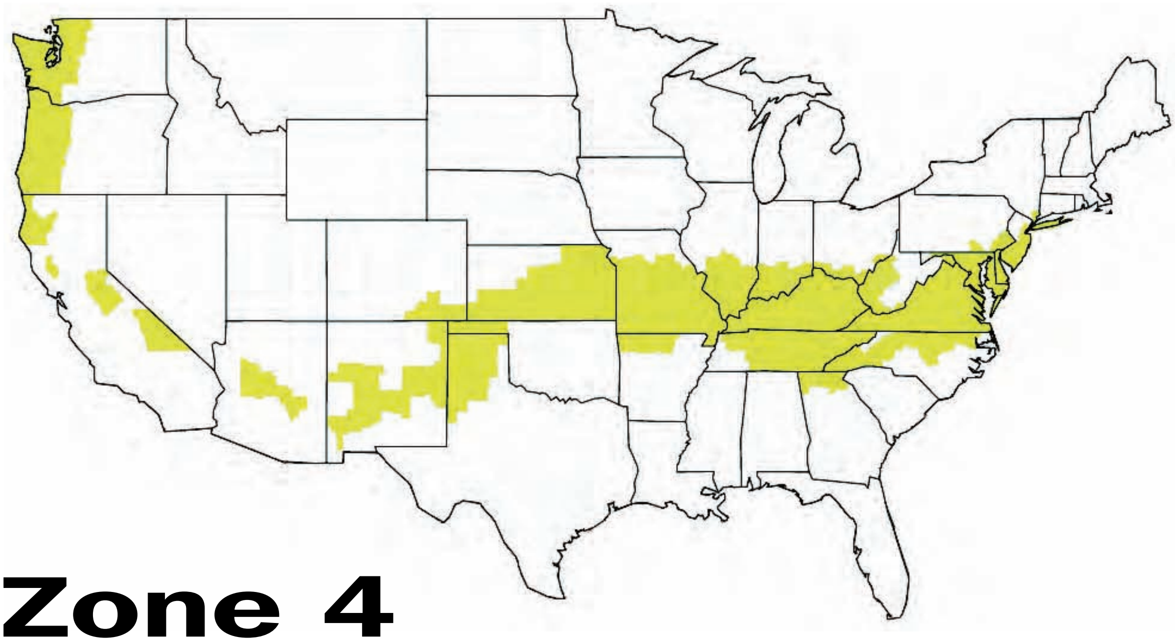
Climate Zone 3 Recommendation Table for Highway Lodging

	Item	Component	Recommendation (Minimum or Maximum)			How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-20.0 c.i.			EN1–2, 11, 14–15	
		Attic and other	R-38.0			EN3, 11–12, 14–15	
		Single rafter	R-38.0 + R-5.0 c.i.			EN4, 11, 14–15	
		Solar reflectance index (SRI)	78			EN1	
	Walls—Exterior	Mass (HC > 7 Btu/ft^2)	R-11.4 c.i.			EN5, 11, 14–15	
		Steel-framed	R-13.0 + R-7.5 c.i.			EN6, 11, 14–15	
		Wood-framed and other	R-13.0			EN7, 11, 14–15	
	Slabs	Unheated	No recommendation*			EN8, 11, 13–15	
	Doors—Opaque	Swinging	U-0.70			EN9, 14–15	
		Non-swinging	U-5.0			EN10, 14–15	
	Vertical Glazing (Including Doors)	Area (percent of gross wall)	25%			EN17, 21–22, 25	
		Thermal transmittance	U-0.41			EN16	
		Solar heat gain coefficient (SHGC)	N, S, E, W – 0.25			EN16, 21–22, 25	
		Exterior sun control (S, E, W only)	Projection factor > 0.5			EN18–19, 24	
		Vestibule	No recommendation*			EN16	
Lighting	Interior Lighting	Lighting power density (LPD), W/ft2	Guest rooms = 0.74	Office = 0.9		EL13–17	
			Corridors = 0.5	Lobbies = 1.1			
			Exercise = 0.9	Laundry = 0.6			
			Meeting rooms = 1.1	Stairs = 0.6			
		Fluorescent lamps	Compact fluorescent (CFL) with electronic ballast, T5HO or T8 high-performance with high-performance electronic ballast			EL2–7	
		Occupancy controls	Bi-level in stairs, manual-on/auto-off for all laundry, office, exercise, business center, meeting rooms, and non-public spaces			EL9	
		Guest room controls	Master control and entry and vacancy control in bathroom			EL9–10, HV14	
		Plug load lighting	Compact fluorescent (CFL) with electric ballast			EL8	
	Exterior Lighting Power Density (LPD)	Lighting Zone 1 = Developed areas of national parks, state parks, forest land, and rural areas Lighting Zone 2 = Residential mixed-use areas and neighborhood business districts Lighting Zone 3 = All other areas				EL18–21	
			Lighting Zone 1	Lighting Zone 2	Lighting Zone 3		
		Base allowance	500 W	600 W	750 W		
		Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2		
		Walkways less than 10 ft wide	0.7 W/lf	0.7 W/lf	0.8 W/lf		
		Walkways 10 ft wide or greater	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2		
		Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2		
		Façade (use wattage only for façade)	None	0.10 W/ft^2	0.15 W/ft^2		

Climate Zone 3 Recommendation Table for Highway Lodging *(Continued)*

	Item	Component	Recommendation (Minimum or Maximum)	How-To Tips in Chapter 5	✓
HVAC	HVAC	Heating system (guest rooms)	Primary heat source electric heat pump cycle or gas-fired furnace or boiler	HV2	
		Air conditioner (0–65 KBtuh)	13.0 SEER	HV1–5	
		Air conditioner (>65–135 KBtuh)	11.3 EER/11.5 IPLV	HV1–5	
		Air conditioner (>135–240 KBtuh)	11.0 EER/11.5 IPLV	HV1–5	
		Air conditioner (>240 KBtuh)	10.6 EER/11.2 IPLV	HV1–5	
		Gas furnace (0–225 KBtuh—SP)	80% AFUE or E_t	HV1–5	
		Gas furnace (0–225 KBtuh—Split)	80% AFUE or E_t	HV1–5	
		Gas furnace (>225 KBtuh)	80% E_c	HV1–5	
		Packaged terminal heat pump (all capacities)	EER = 13.6 – (0.233 × Cap/1000) COP = 3.8 – (0.053 × Cap/1000)	HV1–5	
		Air source heat pump (0–65 KBtuh)	13.0 SEER/7.7 HSPF	HV1–5	
		Air source heat pump (>65–135 KBtuh)	10.6 EER/11.0 IPLV/3.2 Htg COP	HV1–5	
		Air source heat pump (>135 KBtuh)	10.1 EER/11.5 IPLV/3.1 Htg COP	HV1–5	
		Hydronic heat pump (0–18 KBtuh)	14.6 EER, 4.6 Htg COP	HV1–5	
		Hydronic heat pump (>19 KBtuh)	15.0 EER, 4.8 Htg COP	HV1–5	
		Hydronic heat pump heat source	Use condensing boiler for circulating loop heat source	HV17	
		Pumping for water source heat pumps	Variable speed pumping; water treatment	HV18, HV20	
		Hydronic heat pump heat rejection	Control cooling tower to maximize heat pump EER	HV19	
	Economizer	Air conditioners and heat pumps—SP	Cooling capacity > 54 KBtuh	HV6, HV22, HV26	
	Ventilation	Ventilation air supply	Demand control ventilation (DCV) for public areas	HV6–7, VC1–2	
		Heat recovery	Ventilation heat recovery with toilet exhaust	HV8	
	Ducts	Friction rate	0.08 in. w.c./100 ft	HV11, 20	
		Sealing	Seal class B	HV13	
		Location	Interior only	HV9	
		Insulation level	R-6	HV10	
SWH	Service Water Heating	Gas water heater efficiency	Storage—90% E_t, Instantaneous—0.81 EF or 81% E_t	WH1–2, 4	
		Electric storage EF (≤12 kW, ≥20 gal)	EF > 0.99 – 0.0012 × Volume	WH1–2, 4	
		Hot water usage reduction	Use 1.75 gpm shower heads, 1.0 gpm faucets and water conserving clothes washers/ Utilize leaundry heat recovery	WH5, WH8	
		Water heater sizing/location	Avoid oversizing and excessive supply temperatures	WH3, WH6	
		Pipe insulation (d < 1½ in./ d ≥ 1½ in.)	1 in./1.5 in.	WH7	
Other	Miscellaneous Appliances	Guest room mini-refrigerator	Absorption refrigeration cycle 33W continuously	MA1	
		High-efficiency laundry equipment	0.9 gal water/lb laundry 354G extractor with retained water < 52.5%	MA2	

Note: If the table contains “No recommendation” for a component, the user must meet the more stringent of either ASHRAE/IESNA Standard 90.1 or the local code requirements in order to reach the 30% savings target.



Zone 4

Arizona
Gila
Yavapai

Arkansas
Baxter
Benton
Boone
Carroll
Fulton
Izard
Madison
Marion
Newton
Searcy
Stone
Washington

California
Amador
Calaveras
Del Norte
El Dorado
Humboldt
Inyo
Lake
Mariposa
Trinity
Tuolumne

Colorado
Baca
Las Animas
Otero

Delaware
All counties

District of Columbia

Georgia
Banks
Catoosa
Chattooga
Dade
Dawson
Fannin
Floyd
Franklin
Gilmer
Gordon
Habersham
Hall
Lumpkin
Murray
Pickens
Rabun
Stephens
Towns
Union
Walker
White
Whitfield

Illinois
Alexander
Bond
Brown
Christian
Clay
Clinton
Crawford
Edwards
Effingham
Fayette
Franklin
Gallatin
Hamilton
Hardin
Jackson
Jasper
Jefferson
Johnson
Lawrence
Macoupin
Madison
Marion
Massac
Monroe
Montgomery
Perry
Pope
Pulaski
Randolph
Richland
Saline
Shelby
St. Clair
Union
Wabash
Washington
Wayne
White
Williamson

Indiana
Clark
Crawford
Daviess
Dearborn
Dubois
Floyd
Gibson
Greene
Harrison
Jackson
Jefferson
Jennings
Knox
Lawrence
Martin
Monroe
Ohio
Orange
Perry
Pike
Posey
Ripley
Scott
Spencer
Sullivan
Switzerland
Vanderburgh
Warrick
Washington

Kansas
All counties except:
Cheyenne
Cloud
Decatur
Ellis
Gove
Graham
Greeley
Hamilton
Jewell
Lane
Logan
Mitchell
Ness
Norton
Osborne
Phillips
Rawlins
Republic
Rooks
Scott
Sheridan
Sherman
Smith
Thomas
Trego
Wallace
Wichita

Kentucky
All counties

Maryland
All counties except:
Garrett

Missouri
All counties except:
Adair
Andrew
Atchison
Buchanan
Caldwell
Chariton
Clark
Clinton
Daviess
DeKalb
Gentry
Grundy
Harrison
Holt
Knox
Lewis
Linn
Livingston
Macon
Marion
Mercer
Nodaway
Pike
Putnam
Ralls
Schuyler
Scotland
Shelby
Sullivan
Worth

New Jersey
All counties except:
Bergen
Hunterdon
Mercer
Morris
Passaic
Somerset
Sussex
Warren

New Mexico
Bernalillo
Cibola
Curry
DeBaca
Grant
Guadalupe
Lincoln
Quay
Roosevelt
Sierra
Socorro
Union
Valencia

New York
Bronx
Kings
Nassau
New York
Queens
Richmond
Suffolk
Westchester

North Carolina
Alamance
Alexander
Bertie
Buncombe
Burke
Caldwell
Caswell
Catawba
Chatham
Cherokee
Clay
Cleveland
Davie
Durham
Forsyth
Franklin
Gates
Graham
Granville
Guilford
Halifax
Harnett
Haywood
Henderson
Hertford
Iredell
Jackson
Lee
Lincoln
Macon
Madison
McDowell
Nash
Northampton
Orange
Person
Polk
Rockingham
Rutherford
Stokes
Surry
Swain
Transylvania
Vance
Wake
Warren
Wilkes
Yadkin

Ohio
Adams
Brown
Clermont
Gallia
Hamilton
Lawrence
Pike
Scioto
Washington

Oklahoma
Beaver
Cimarron
Texas

Oregon
Benton
Clackamas
Clatsop
Columbia
Coos
Curry
Douglas
Jackson
Josephine
Lane
Lincoln
Linn
Marion
Multnomah
Polk
Tillamook
Washington
Yamhill

Pennsylvania
Bucks
Chester
Delaware
Montgomery
Philadelphia
York

Tennessee
All counties except:
Chester
Crockett
Dyer
Fayette
Hardeman
Hardin
Haywood
Henderson
Lake
Lauderdale
Madison
McNairy
Shelby
Tipton

Texas
Armstrong
Bailey
Briscoe
Carson
Castro
Cochran
Dallam
Deaf Smith
Donley
Floyd
Gray
Hale
Hansford
Hartley
Hockley
Hutchinson
Lamb
Lipscomb
Moore
Ochiltree
Oldham
Parmer
Potter
Randall
Roberts
Sherman
Swisher
Yoakum

Virginia
All counties

Washington
Clallam
Clark
Cowlitz
Grays Harbor
Island
Jefferson
King
Kitsap
Lewis
Mason
Pacific
Pierce
San Juan
Skagit
Snohomish
Thurston
Wahkiakum
Whatcom

West Virginia
Berkeley
Boone
Braxton
Cabell
Calhoun
Clay
Gilmer
Jackson
Jefferson
Kanawha
Lincoln
Logan
Mason
McDowell
Mercer
Mingo
Monroe
Morgan
Pleasants
Putnam
Ritchie
Roane
Tyler
Wayne
Wirt
Wood
Wyoming

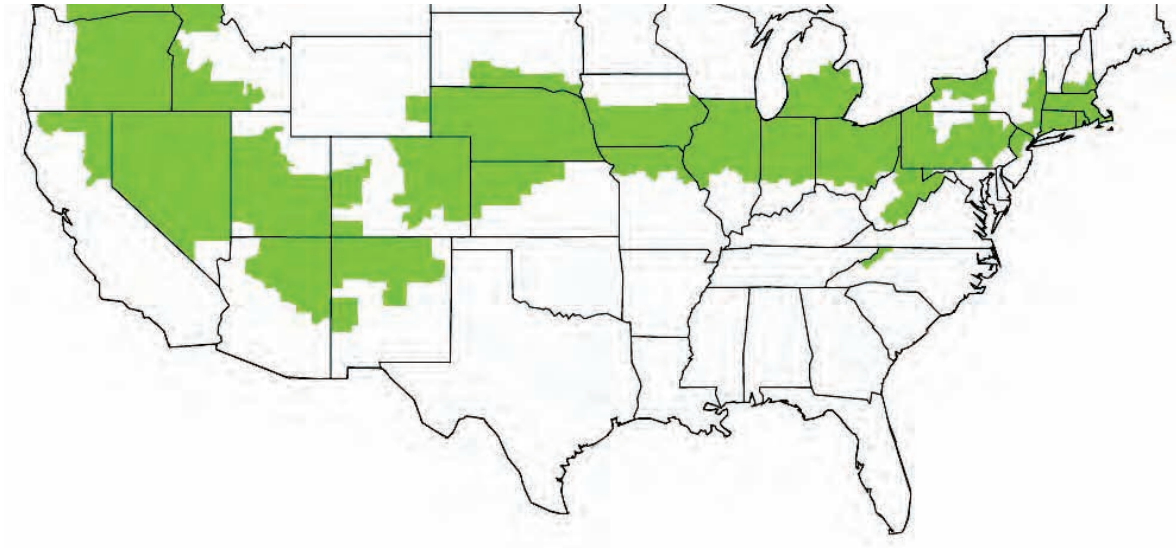
Climate Zone 4 Recommendation Table for Highway Lodging

	Item	Component	Recommendation (Minimum or Maximum)			How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-20.0 c.i.			EN1–2, 11 ,14–15	
		Attic and other	R-38.0			EN3, 11–12, 14–15	
		Single rafter	R-38.0 + R-5.0 c.i.			EN4, 11, 14–15	
		Solar reflectance index (SRI)	No recommendation*			EN1	
	Walls—Exterior	Mass (HC > 7 Btu/ft^2)	R-13.3 c.i.			EN5, 11, 14–15	
		Steel-framed	R-13.0 + R-7.5 c.i.			EN6, 11, 14–15	
		Wood-framed and other	R-13.0 + R-3.8 c.i.			EN7, 11, 14–15	
	Slabs	Unheated	R-10.0 for 24 in.			EN8, 11, 13–15	
	Doors—Opaque	Swinging	U-0.50			EN9, 14–15	
		Non-swinging	U-0.50			EN10, 14–15	
	Vertical Glazing (Including Doors)	Area	25%			EN17, 21–22, 25	
		Thermal transmittance	U-0.38			EN16	
		Solar heat gain coefficient (SHGC)	N, S, E, W – 0.40			EN16, 21, 23, 25	
		Exterior sun control (S, E, W only)	Projection factor > 0.5			EN18–19, 24	
		Vestibule	Required			EN16	
Lighting	Interior Lighting	Lighting power density (LPD), W/ft^2	Guest rooms = 0.74	Office = 0.9		EL13–17	
			Corridors = 0.5	Lobbies = 1.1			
			Exercise = 0.9	Laundry = 0.6			
			Meeting rooms = 1.1	Stairs = 0.6			
		Fluorescent lamps	Compact fluorescent (CFL) with electronic ballast, T5HO or T8 high-performance with high-performance electronic ballast			EL2–7	
		Occupancy controls	Bi-level in stairs, manual-on/auto-off for all laundry, office, exercise, business center, meeting rooms, and non-public spaces			EL9	
		Guest room control	Master control and entry and vacancy control in bathroom			EL9–10, HV14	
		Plug load lighting	Compact fluorescent (CFL) with electronic ballast			EL8	
	Exterior Lighting Power Density (LPD)	Lighting Zone 1 = Developed areas of national parks, state parks, forest land, and rural areas Lighting Zone 2 = Residential mixed-use areas and neighborhood business districts Lighting Zone 3 = All other areas				EL18–21	
			Lighting Zone 1	Lighting Zone 2	Lighting Zone 3		
		Base allowance	500 W	600 W	750 W		
		Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2		
		Walkways less than 10 ft wide	0.7 W/lf	0.7 W/lf	0.8 W/lf		
		Walkways 10 ft wide or greater	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2		
		Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2		
		Façade (use wattage only for façade)	None	0.10 W/ft^2	0.15 W/ft^2		

Climate Zone 4 Recommendation Table for Highway Lodging *(Continued)*

	Item	Component	Recommendation (Minimum or Maximum)	How-To Tips in Chapter 5	✓
HVAC	HVAC	Heating system (guest rooms)	Primary heat source electric heat pump cycle or gas-fired furnace or boiler	HV2	
		Air conditioner (0–65 KBtuh)	13.0 SEER	HV1–5	
		Air conditioner (>65–135 KBtuh)	11.3 EER/11.5 IPLV	HV1–5	
		Air conditioner (>135–240 KBtuh)	11.0 EER/11.5 IPLV	HV1–5	
		Air conditioner (>240 KBtuh)	10.6 EER/11.2 IPLV	HV1–5	
		Gas furnace (0–225 KBtuh—SP)	80% AFUE or E_t	HV1–5	
		Gas furnace (0–225 KBtuh—Split)	80% AFUE or E_t	HV1–5	
		Gas furnace (>225 KBtuh)	80% E_c	HV1–5	
		Packaged terminal heat pump (all capacities)	EER = 13.6 – (0.233 × Cap/1000) COP = 3.8 – (0.053 × Cap/1000)	HV1–5	
		Air source heat pump (0–65 KBtuh)	13.0 SEER/7.7 HSPF	HV1–5	
		Air source heat pump (>65–135 KBtuh)	10.6 EER/11.0 IPLV/3.2 Htg COP	HV1–5	
		Air source heat pump (>135 KBtuh)	10.1 EER/11.5 IPLV/3.1 Htg COP	HV1–5	
		Hydronic heat pump (0–18 KBtuh)	14.6 EER, 4.6 Htg COP	HV1–5	
		Hydronic heat pump (>19 KBtuh)	15.0 EER, 4.8 Htg COP	HV1–5	
		Hydronic heat pump heat source	Use condensing boiler for circulating loop heat source	HV17	
		Pumping for water source heat pumps	Variable speed pumping; water treatment	HV18, HV20	
		Hydronic heat pump heat rejection	Control cooling tower to maximize heat pump EER	HV19	
	Economizer	Air conditioners and heat pumps—SP	Cooling capacity > 54 KBtuh	HV6, HV22, HV26	
	Ventilation	Ventilation air supply	Demand control ventilation (DCV) for public areas	HV6–7, VC1–2	
		Heat recovery	Ventilation heat recovery with toilet exhaust	HV8	
	Ducts	Friction rate	0.08 in. w.c./100 ft	HV11, 20	
		Sealing	Seal class B	HV13	
		Location	Interior only	HV9	
		Insulation level	R-6	HV10	
SWH	Service Water Heating	Gas water heater efficiency	Storage—90% E_t, Instantaneous—0.81 EF or 81% E_t	WH1–2, 4	
		Electric storage EF (≤12 kW, ≥20 gal)	EF > 0.99 – 0.0012 × Volume	WH1–2, 4	
		Hot water usage reduction	Use 1.75 gpm shower heads, 1.0 gpm faucets and water-conserving clothes washers; utilize laundry heat recovery	WH5, WH8	
		Water heater sizing/location	Avoid oversizing and excessive supply temperatures	WH3, WH6	
		Pipe insulation (d < 1½ in./ d ≥ 1½ in.)	1 in./ 1.5 in.	WH7	
Other	Miscellaneous Appliances	Guest room mini-refrigerator	Absorption refrigeration cycle 33W continuously	MA1	
		High-efficiency laundry equipment	0.9 gal water/lb laundry 354G extractor with retained water < 52.5%	MA1	

Note: If the table contains "No recommendation" for a component, the user must meet the more stringent of either ASHRAE/IESNA Standard 90.1 or the local code requirements in order to reach the 30% savings target.



Zone 5

Arizona
Apache
Coconino
Navajo

California
Lassen
Modoc
Nevada
Plumas
Sierra
Siskiyou

Colorado
Adams
Arapahoe
Bent
Boulder
Cheyenne
Crowley
Delta
Denver
Douglas
Elbert
El Paso
Fremont
Garfield
Gilpin
Huerfano
Jefferson
Kiowa
Kit Carson
La Plata
Larimer
Lincoln
Logan
Mesa
Montezuma
Montrose
Morgan
Phillips
Prowers
Pueblo
Sedgwick
Teller
Washington
Weld
Yuma

Connecticut
All counties

Idaho
Ada
Benewah
Canyon
Cassia
Clearwater
Elmore
Gem
Gooding
Idaho
Jerome
Kootenai
Latah
Lewis
Lincoln
Minidoka
Nez Perce
Owyhee
Payette
Power
Shoshone
Twin Falls
Washington

Illinois
All counties except:
Alexander
Bond
Christian
Clay
Clinton
Crawford
Edwards
Effingham
Fayette
Franklin
Gallatin
Hamilton
Hardin
Jackson
Jasper
Jefferson
Johnson
Lawrence
Macoupin
Madison
Marion
Massac
Monroe
Montgomery
Perry
Pope
Pulaski
Randolph
Richland
Saline
Shelby
St. Clair
Union
Wabash
Washington
Wayne
White
Williamson
Brown

Indiana
All counties except:
Clark
Crawford
Daviess
Dearborn
Dubois
Floyd
Gibson
Greene
Harrison
Jackson
Jefferson
Jennings
Knox
Lawrence
Martin
Monroe
Ohio
Orange
Perry
Pike
Posey
Ripley
Scott
Spencer
Sullivan
Switzerland
Vanderburgh
Warrick
Washington

Iowa
All counties except:
Allamakee
Black Hawk
Bremer
Buchanan
Buena Vista
Butler
Calhoun
Cerro Gordo
Cherokee
Chickasaw
Clay
Clayton
Delaware
Dickinson
Emmet
Fayette
Floyd
Franklin
Grundy
Hamilton
Hancock
Hardin
Howard
Humboldt
Ida
Kossuth
Lyon
Mitchell
O'Brien
Osceola
Palo Alto
Plymouth
Pocahontas
Sac
Sioux
Webster
Winnebago
Winneshiek
Worth
Wright

Kansas
Cheyenne
Cloud
Decatur
Ellis
Gove
Graham
Greeley
Hamilton
Jewell
Lane
Logan
Mitchell
Ness
Norton
Osborne
Phillips
Rawlins
Republic
Rooks
Scott
Sheridan
Sherman
Smith
Thomas
Trego
Wallace
Wichita

Maryland
Garrett

Massachusetts
All counties

Michigan
Allegan
Barry
Bay
Berrien
Branch
Calhoun
Cass
Clinton
Eaton
Genesee
Gratiot
Hillsdale
Ingham
Ionia
Jackson
Kalamazoo
Kent
Lapeer
Lenawee
Livingston
Macomb
Midland
Monroe
Montcalm
Muskegon
Oakland
Ottawa
Saginaw
Shiawassee
St. Clair
St. Joseph
Tuscola
Van Buren
Washtenaw
Wayne

Missouri
Adair
Andrew
Atchison
Buchanan
Caldwell
Chariton
Clark
Clinton
Daviess
DeKalb
Gentry
Grundy
Harrison
Holt
Knox
Lewis
Linn
Livingston
Macon
Marion
Mercer
Nodaway
Pike
Putnam
Ralls
Schuyler
Scotland
Shelby
Sullivan
Worth

Nebraska
All counties

Nevada
All counties except:
Clark

New Hampshire
Cheshire
Hillsborough
Rockingham
Strafford

New Jersey
Bergen
Hunterdon
Mercer
Morris
Passaic
Somerset
Sussex
Warren

New Mexico
Catron
Colfax
Harding
Los Alamos
McKinley
Mora
Rio Arriba
Sandoval
San Juan
San Miguel
Santa Fe
Taos
Torrance

New York
Albany
Cayuga
Chautauqua
Chemung
Columbia
Cortland
Dutchess
Erie
Genesee
Greene
Livingston
Monroe
Niagara
Onondaga
Ontario
Orange
Orleans
Oswego
Putnam
Rensselaer
Rockland
Saratoga
Schenectady
Seneca
Tioga
Washington
Wayne
Yates

North Carolina
Alleghany
Ashe
Avery
Mitchell
Watauga
Yancey

Ohio
All counties except:
Adams
Brown
Clermont
Gallia
Hamilton
Lawrence
Pike
Scioto
Washington

Oregon
Baker
Crook
Deschutes
Gilliam
Grant
Harney
Hood River
Jefferson
Klamath
Lake
Malheur
Morrow
Sherman
Umatilla
Union
Wallowa
Wasco
Wheeler

Pennsylvania
All counties except:
Bucks
Cameron
Chester
Clearfield
Delaware
Elk
McKean
Montgomery
Philadelphia
Potter
Susquehanna
Tioga
Wayne
York

Rhode Island
All counties

South Dakota
Bennett
Bon Homme
Charles Mix
Clay
Douglas
Gregory
Hutchinson
Jackson
Mellette
Todd
Tripp
Union
Yankton

Utah
All counties except:
Box Elder
Cache
Carbon
Daggett
Duchesne
Morgan
Rich
Summit
Uintah
Wasatch
Washington

Washington
Adams
Asotin
Benton
Chelan
Columbia
Douglas
Franklin
Garfield
Grant
Kittitas
Klickitat
Lincoln
Skamania
Spokane
Walla Walla
Whitman
Yakima

Wyoming
Goshen
Platte

West Virginia
Barbour
Brooke
Doddridge
Fayette
Grant
Greenbrier
Hampshire
Hancock
Hardy
Harrison
Lewis
Marion
Marshall
Mineral
Monongalia
Nicholas
Ohio
Pendleton
Pocahontas
Preston
Raleigh
Randolph
Summers
Taylor
Tucker
Upshur
Webster
Wetzel

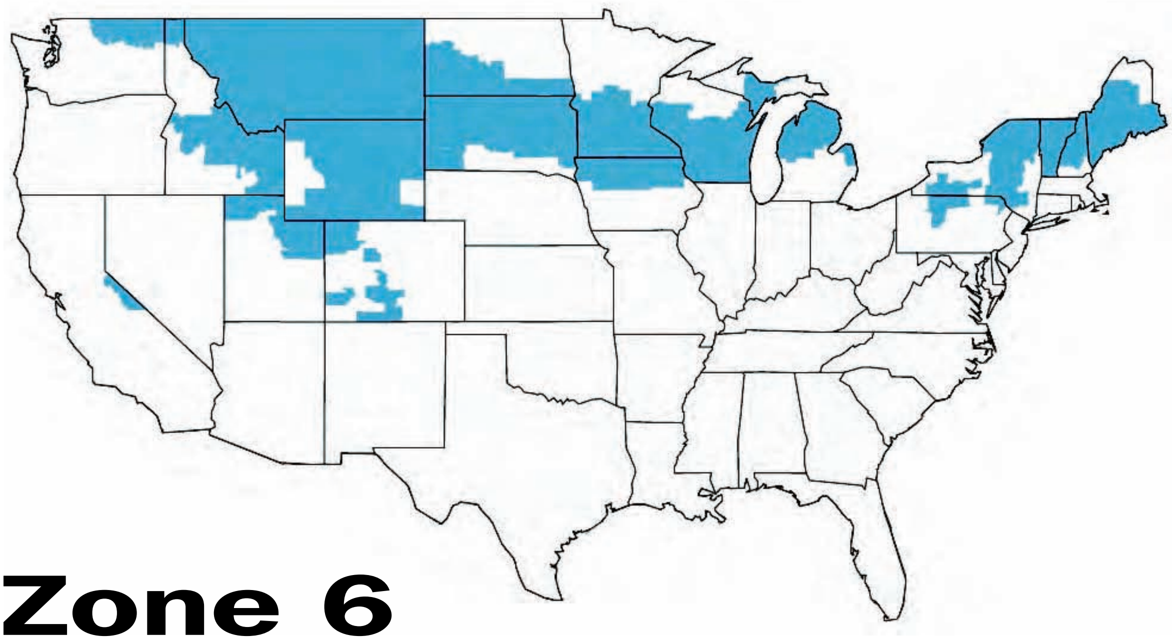
Climate Zone 5 Recommendation Table for Highway Lodging

	Item	Component	Recommendation (Minimum or Maximum)			How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-20.0 c.i.			EN1–2, 11, 14–15	
		Attic and other	R-38.0			EN3, 11–12, 14–15	
		Single rafter	R-38.0 + R-5.0 c.i.			EN4, 11, 14–15	
		Solar reflectance index (SRI)	No recommendation*			EN1	
	Walls—Exterior	Mass (HC > 7 Btu/ft^2)	R-13.3 c.i.			EN5, 11, 14–15	
		Steel-framed	R-13.3 + R-7.5 c.i.			EN6, 11, 14–15	
		Wood-framed and other	R-13.0 + R-7.5 c.i.			EN7, 11, 14–15	
	Slabs	Unheated	R-10.0 for 24 in.			EN8, 11, 13–15	
	Doors—Opaque	Swinging	U-0.50			EN9, 14–15	
		Non-swinging	U-0.50			EN10, 14–15	
	Vertical Glazing (Including Doors)	Area (percent of gross wall)	25%			EN17, 21–22, 25	
		Thermal transmittance	U-0.35			EN16	
		Solar heat gain coefficient (SHGC)	N, S, E, W-0.40			EN16, 21, 23, 25	
		Exterior sun control (S, E, W only)	Projection factor > 0.5			EN18–19, 24	
		Vestibule	Required			EN16	
Lighting	Interior Lighting	LIghting power density (LPD), W/ft^2	Guest rooms = 0.74	Office = 0.9		EN13–17	
			Corridors = 0.5	Lobbies = 1.1			
			Exercise = 0.9	Laundry = 0.6			
			Meeting rooms = 1.1	Stairs = 0.6			
		Fluorescent lamps	Compact fluorescent (CFL) with electronic ballast, T5HO or T8 high-performance with high-performance electronic ballast			EL2–7	
		Occupancy controls	Bi-level in stairs, manual-on/auto-off for all laundry, office, exercise, business center, meeting rooms, and non-public spaces			EL9	
		Guest room controls	Master control and entry and vacancy control in bathroom			EL9–10, HV14	
		Plug load lighting	Compact fluorescent (CFL) with electronic ballast			EL8	
	Exterior Lighting Power Density (LPD)	Lighting Zone 1 = Developed areas of national parks, state parks, forest land, and rural areas Lighting Zone 2 = Residential mixed-use areas and neighborhood business districts Lighting Zone 3 = All other areas				EL18–21	
			Lighting Zone 1	Lighting Zone 2	Lighting Zone 3		
		Base allowance	500 W	600 W	750 W		
		Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2		
		Walkways less than 10 ft wide	0.7 W/lf	0.7 W/lf	0.8 W/lf		
		Walkways 10 ft wide or greater	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2		
		Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2		
		Façade (use wattage only for façade)	None	0.10 W/ft^2	0.15 W/ft^2		

Climate Zone 5 Recommendation Table for Highway Lodging *(Continued)*

	Item	Component	Recommendation (Minimum or Maximum)	How-To Tips in Chapter 5	✓
HVAC	HVAC	Heating system (guest rooms)	Primary heat source electric heat pump cycle or gas-fired furnace or boiler	HV2	
		Air conditioner (0–65 KBtuh)	13.0 SEER	HV1–5	
		Air conditioner (>65–135 KBtuh)	11.3 EER/11.5 IPLV	HV1–5	
		Air conditioner (>135–240 KBtuh)	11.0 EER/11.5 IPLV	HV1–5	
		Air conditioner (>240 KBtuh)	10.6 EER/11.2 IPLV	HV1–5	
		Gas furnace (0–225 KBtuh—SP)	80% AFUE or E_t	HV1–5	
		Gas furnace (0–225 KBtuh—Split)	80% AFUE or E_t	HV1–5	
		Gas furnace (>225 KBtuh)	80% E_c	HV1–5	
		Packaged terminal heat pump (all capacities)	EER = 13.6 – (0.233 × Cap/1000) COP = 3.8 – (0.053 × Cap/1000)	HV1–5	
		Air source heat pump (0–65 KBtuh)	13.0 SEER/7.7 HSPF	HV1–5	
		Air source heat pump (>65–135 KBtuh)	10.6 EER/11.0 IPLV/3.2 Htg COP	HV1–5	
		Air source heat pump (>135 KBtuh)	10.1 EER/11.5 IPLV/3.1 Htg COP	HV1–5	
		Hydronic heat pump (0–18 KBtuh)	14.6 EER, 4.6 Htg COP	HV1–5	
		Hydronic heat pump (>19 KBtuh)	15.0 EER, 4.8 Htg COP	HV1–5	
		Hydronic heat pump heat source	Use condensing boiler for circulating loop heat source	HV17	
		Pumping for water source heat pumps	Variable speed pumping; water treatment	HV18, HV20	
		Hydronic heat pump heat rejection	Control cooling tower to maximize heat pump EER	HV19	
	Economizer	Air conditioners and heat pumps—SP	Cooling capacity > 54 KBtuh	HV6, HV22, HV26	
	Ventilation	Ventilation air supply	Demand control ventilation (DCV) for public areas	HV6–7, VC1–2	
		Heat recovery	Ventilation heat recovery with toilet exhaust	HV8	
	Ducts	Friction rate	0.08 in. w.c./100 ft	HV11, 20	
		Sealing	Seal class B	HV13	
		Location	Interior only	HV9	
		Insulation level	R-6	HV10	
SWH	Service Water Heating	Gas water heater efficiency	Storage—90% E_t, Instantaneous—0.81 EF or 81% E_t	WH1–2, 4	
		Electric storage EF (≤12 kW, ≥20 gal)	EF > 0.99 – 0.0012 × Volume	WH1–2, 4	
		Hot water usage reduction	Use 1.75 gpm shower heads, 1.0 gpm faucets and water-conserving clothes washers; utilize laundry heat recovery	WH5, WH8	
		Water heater sizing/location	Avoid oversizing and excessive supply temperatures	WH3, WH6	
		Pipe insulation (d < 1½ in./ d ≥ 1½ in.)	1 in./ 1.5 in.	WH7	
Other	Miscellaneous Appliances	Guest room mini-refrigerator	Absorption refrigeration cycle 33W continuously	MA1	
		High-efficiency laundry equipment	0.9 gal water/lb laundry 354G extractor and retained water < 52.5%	MA2	

Note: If the table contains “No recommendation” for a component, the user must meet the more stringent of either ASHRAE/IESNA Standard 90.1 or the local code requirements in order to reach the 30% savings target.



Zone 6

California

Alpine
Mono

Colorado

Alamosa
Archuleta
Chaffee
Conejos
Costilla
Custer
Dolores
Eagle
Moffat
Ouray
Rio Blanco
Saguache
San Miguel

Idaho

Adams
Bannock
Bear Lake
Bingham
Blaine
Boise
Bonner
Bonneville
Boundary
Butte
Camas
Caribou
Clark
Custer
Franklin
Fremont
Jefferson
Lemhi
Madison
Oneida
Teton
Valley

Iowa

Allamakee
Black Hawk
Bremer
Buchanan
Buena Vista
Butler
Calhoun
Cerro Gordo
Cherokee
Chickasaw
Clay
Clayton
Delaware
Dickinson
Emmet
Fayette
Floyd
Franklin
Grundy
Hamilton
Hancock
Hardin
Howard
Humboldt
Ida
Kossuth
Lyon
Mitchell
O'Brien
Osceola
Palo Alto
Plymouth
Pocahontas
Sac
Sioux
Webster
Winnebago
Winneshiek
Worth
Wright

Maine

All counties except:
Aroostook

Michigan

Alcona
Alger
Alpena
Antrim
Arenac
Benzie
Charlevoix
Cheboygan
Clare
Crawford
Delta
Dickinson
Emmet
Gladwin
Grand Traverse
Huron
Iosco
Isabella
Kalkaska
Lake
Leelanau
Manistee
Marquette
Mason
Mecosta
Menominee
Missaukee
Montmorency
Newaygo
Oceana
Ogemaw
Osceola
Oscoda
Otsego
Presque Isle
Roscommon
Sanilac
Wexford

Minnesota

Anoka
Benton
Big Stone
Blue Earth
Brown
Carver
Chippewa
Chisago
Cottonwood
Dakota
Dodge
Douglas
Faribault
Fillmore
Freeborn
Goodhue
Hennepin
Houston
Isanti
Jackson
Kandiyohi
Lac qui Parle
Le Sueur
Lincoln
Lyon
Martin
McLeod
Meeker
Morrison
Mower
Murray
Nicollet
Nobles
Olmsted
Pipestone
Pope
Ramsey
Redwood
Renville
Rice
Rock
Scott
Sherburne
Sibley
Stearns
Steele
Stevens
Swift
Todd
Traverse
Wabasha
Waseca
Washington
Watonwan
Winona
Wright
Yellow Medicine

Montana

All counties

New Hampshire

Belknap
Carroll
Coos
Grafton
Merrimack
Sullivan

New York

Allegany
Broome
Cattaraugus
Chenango
Clinton
Delaware
Essex
Franklin
Fulton
Hamilton
Herkimer
Jefferson
Lewis
Madison
Montgomery
Oneida
Otsego
Schoharie
Schuyler
Steuben
St. Lawrence
Sullivan
Tompkins
Ulster
Warren
Wyoming

North Dakota

Adams
Billings
Bowman
Burleigh
Dickey
Dunn
Emmons
Golden Valley
Grant
Hettinger
LaMoure
Logan
McIntosh
McKenzie
Mercer
Morton
Oliver
Ransom
Richland
Sargent
Sioux
Slope
Stark

Pennsylvania

Cameron
Clearfield
Elk
McKean
Potter
Susquehanna
Tioga
Wayne

South Dakota

All counties except:
Bennett
Bon Homme
Charles Mix
Clay
Douglas
Gregory
Hutchinson
Jackson
Mellette
Todd
Tripp
Union
Yankton

Utah

Box Elder
Cache
Carbon
Daggett
Duchesne
Morgan
Rich
Summit
Uintah
Wasatch

Vermont

All counties

Washington

Ferry
Okanogan
Pend Oreille
Stevens

Wisconsin

All counties except:
Ashland
Bayfield
Burnett
Douglas
Florence
Forest
Iron
Langlade
Lincoln
Oneida
Price
Sawyer
Taylor
Vilas
Washburn

Wyoming

All counties except:
Goshen
Platte
Lincoln
Sublette
Teton

Climate Zone 6 Recommendation Table for Highway Lodging

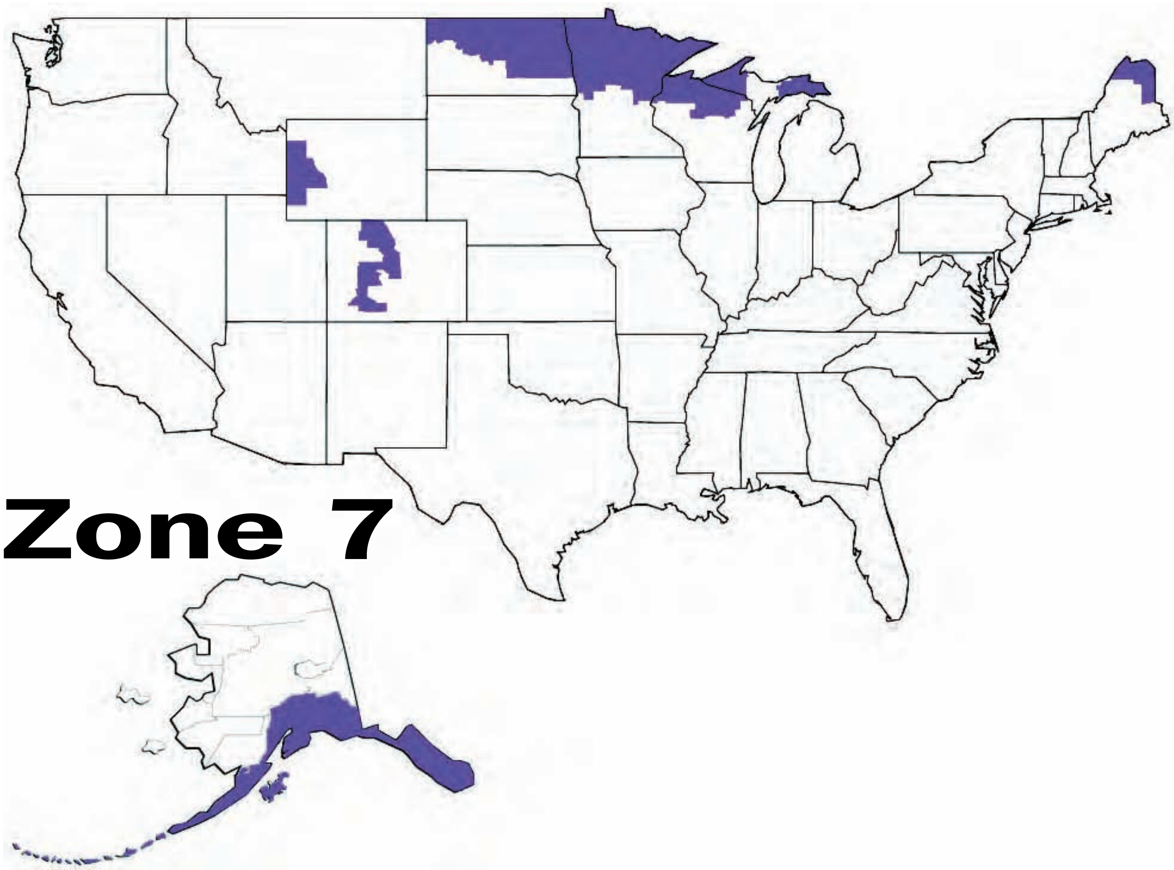
	Item	Component	Recommendation (Miniumum or Maximum)			How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-20.0 c.i.			EN1–2, 11, 14–15	
		Attic and other	R-38.0			EN3, 11–12, 14–15	
		Single rafter	R-38.0 + R-5.0 c.i.			EN4, 11, 14–15	
		Solar reflectance index (SRI)	No recommendation*			EN1	
	Walls—Exterior	Mass (HC > 7 Btu/ft^2)	R-13.3 c.i.			EN5, 11, 14–15	
		Steel-framed	R-13.3 + R-7.5 c.i.			EN6, 11, 14–15	
		Wood-framed and other	R-13.0 + R-7.5 c.i.			EN7, 11, 14–15	
	Slabs	Unheated	R-15.0 for 24 in.			EN8, 11, 13–15	
	Doors—Opaque	Swinging	U-0.50			EN9, 14–15	
		Non-swinging	U-0.50			EN10, 14–15	
	Vertical Glazing (Including Doors)	Area (percent of gross wall)	25%			EN17, 21–22, 25	
		Thermal transmittance	U-0.35			EN16	
		Solar heat gain coefficient (SHGC)	N, S, E, W-0.40			EN16, 21, 23, 25	
		Exterior sun control (S, E, W only)	Projection factor > 0.5			EN18–19, 24	
		Vestibule	Required			EN16	
Lighting	Interior Lighting	LIghting power density (LPD), W/ft^2	Guest rooms = 0.74	Office = 0.9		EN13–17	
			Corridors = 0.5	Lobbies = 1.1			
			Exercise = 0.9	Laundry = 0.6			
			Meeting rooms = 1.1	Stairs = 0.6			
		Fluorescent lamps	Compact fluorescent (CFL) with electronic ballast, T5HO or T8 high-performance with high-performance electronic ballast			EL2–7	
		Occupancy controls	Bi-level in stairs, manual-on/auto-off for all laundry, office, exercise, business center, meeting rooms, and non-public spaces			EL9	
		Guest room controls	Master control and entry and vacancy control in bathroom			EL9–10, HV14	
		Plug load lighting	Compact fluorescent (CFL) with electronic ballast			EL8	
	Exterior Lighting Power Density (LPD)	Lighting Zone 1 = Developed areas of national parks, state parks, forest land, and rural areas Lighting Zone 2 = Residential mixed-use areas and neighborhood business districts Lighting Zone 3 = All other areas				EL18–21	
			Lighting Zone 1	Lighting Zone 2	Lighting Zone 3		
		Base allowance	500 W	600 W	750 W		
		Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2		
		Walkways less than 10 ft wide	0.7 W/lf	0.7 W/lf	0.8 W/lf		
		Walkways 10 ft wide or greater	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2		
		Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2		
		Façade (use wattage only for façade)	None	0.10 W/ft^2	0.15 W/ft^2		

Climate Zone 6 Recommendation Table for Highway Lodging *(Continued)*

	Item	Component	Recommendation (Miniumum or Maximum)	How-To Tips in Chapter 5	✓
HVAC	HVAC	Heating system (guest rooms)	Primary heat source electric heat pump cycle or gas-fired furnace or boiler	HV2	
		Air conditioner (0–65 KBtuh)	13.0 SEER	HV1–5	
		Air conditioner (>65–135 KBtuh)	11.3 EER/11.5 IPLV	HV1–5	
		Air conditioner (>135–240 KBtuh)	11.0 EER/11.5 IPLV	HV1–5	
		Air conditioner (>240 KBtuh)	10.6 EER/11.2 IPLV	HV1–5	
		Gas furnace (0–225 KBtuh—SP)	80% AFUE or E_t	HV1–5	
		Gas furnace (0–225 KBtuh—Split)	80% AFUE or E_t	HV1–5	
		Gas furnace (>225 KBtuh)	80% E_c	HV1–5	
		Packaged terminal heat pump (all capacities)	EER = 13.6 – (0.233 × Cap/1000) COP = 3.8 – (0.053 × Cap/1000)	HV1–5	
		Air source heat pump (0–65 KBtuh)	13.0 SEER/7.7 HSPF	HV1–5	
		Air source heat pump (>65–135 KBtuh)	10.6 EER/11.0 IPLV/3.2 Htg COP	HV1–5	
		Air source heat pump (>135 KBtuh)	10.1 EER/11.5 IPLV/3.1 Htg COP	HV1–5	
		Hydronic heat pump (0–18 KBtuh)	14.6 EER, 4.6 Htg COP	HV1–5	
		Hydronic heat pump (>19 KBtuh)	15.0 EER, 4.8 Htg COP	HV1–5	
		Hydronic heat pump heat source	Use condensing boiler for circulating loop heat source	HV17	
		Pumping for water source heat pumps	Variable speed pumping; water treatment	HV18, HV20	
		Hydronic heat pump heat rejection	Control cooling tower to maximize heat pump EER	HV19	
	Economizer	Air conditioners and heat pumps—SP	Cooling capacity > 54 KBtuh	HV6, HV22, HV26	
	Ventilation	Ventilation air supply	Demand control ventilation (DCV) for public areas	HV6–7, VC1–2	
		Heat recovery	Ventilation heat recovery with toilet exhaust	HV8	
	Ducts	Friction rate	0.08 in. w.c./100 ft	HV11, 20	
		Sealing	Seal class B	HV13	
		Location	Interior only	HV9	
		Insulation level	R-8	HV10	
SWH	Service Water Heating	Gas water heater efficiency	Storage—90% E_t, Instantaneous—0.81 EF or 81% E_t	WH1–2, 4	
		Electric storage EF (≤12 kW, ≥20 gal)	EF > 0.99 – 0.0012 × Volume	WH1–2, 4	
		Hot water usage reduction	Use 1.75 gpm shower heads, 1.0 gpm faucets and water-conserving clothes washers; utilize laundry heat recovery	WH5, WH8	
		Water heater sizing/location	Avoid oversizing and excessive supply temperatures	WH3, WH6	
		Pipe insulation (d < 1½ in./ d ≥ 1½ in.)	1 in./ 1.5 in.	WH7	
Other	Miscellaneous Appliances	Guest room mini-refrigerator	Absorption refrigeration cycle 33W continuously	MA1	
		High-efficiency laundry equipment	0.9 gal water/lb laundry 354G extractor and retained water < 52.5%	MA2	

Note: If the table contains "No recommendation" for a component, the user must meet the more stringent of either ASHRAE/IESNA Standard 90.1 or the local code requirements in order to reach the 30% savings target.

Zone 7



Alaska

Aleutians East
Aleutians West (CA)
Anchorage
Angoon (CA)
Bristol Bay
Denali
Haines
Juneau
Kenai Peninsula
Ketchikan (CA)
Ketchikan Gateway
Kodiak Island
Lake and Peninsula
Matanuska-Susitna
Prince of Wales-Outer
Sitka
Skagway-Hoonah-
Valdez-Cordova (CA)
Wrangell-Petersburg (CA)
Yakutat

Colorado

Clear Creek
Grand
Gunnison
Hinsdale
Jackson
Lake
Mineral
Park
Pitkin
Rio Grande
Routt
San Juan
Summit

Maine

Aroostook

Michigan

Baraga
Chippewa
Gogebic
Houghton
Iron
Keweenaw
Luce
Mackinac
Ontonagon
Schoolcraft

Minnesota

Aitkin
Becker
Beltrami
Carlton
Cass
Clay
Clearwater
Cook
Crow Wing
Grant
Hubbard
Itasca
Kanabec
Kittson
Koochiching
Lake
Lake of the Woods
Mahnomen
Marshall
Mille Lacs
Norman
Otter Tail
Pennington
Pine
Polk
Red Lake
Roseau
St. Louis
Wadena
Wilkin

North Dakota

Barnes
Benson
Bottineau
Burke
Cass
Cavalier
Divide
Eddy
Foster
Grand Forks
Griggs
Kidder
McHenry
McLean
Mountrail
Nelson
Pembina
Pierce
Ramsey
Renville
Rolette
Sheridan
Steele
Stutsman
Towner
Traill
Walsh
Ward
Wells
Williams

Wisconsin

Ashland
Bayfield
Burnett
Douglas
Florence
Forest
Iron
Langlade
Lincoln
Oneida
Price
Sawyer
Taylor
Vilas
Washburn

Wyoming

Lincoln
Sublette
Teton

Climate Zone 7 Recommendation Table for Highway Lodging

	Item	Component	Recommendation (Minimum or Maximum)			How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-25.0 c.i.			EN1–2, 11, 14–15	
		Metal building	R-60 c.i.			EN3, 11–12, 14–15	
		Single rafter	R-38.0 + R-10.0 c.i.			EN4, 11, 14–15	
		Solar reflectance index (SRI)	No recommendation*			EN1	
	Walls—Exterior	Mass (HC > 7 Btu/ft^2)	R-15.2 c.i.			EN5, 11, 14–15	
		Steel-framed	R-13.0 + R-15.6 c.i.			EN6, 11, 14–15	
		Wood-framed and other	R-13.0 + R-10.0 c.i.			EN7, 11, 14–15	
	Slabs	Unheated	R-15.0 for 24 in.			EN8, 11, 13–15	
	Doors—Opaque	Swinging	U-0.50			EN9, 14–15	
		Non-swinging	U-0.50			EN10, 14–15	
	Vertical Glazing (Including Doors)	Area (percent of gross roof)	25%			EN17, 21–22, 25	
		Thermal transmittance	U-0.33			EN16	
		Solar heat gain coefficient (SHGC)	N, S, E, W-0.41			EN16, 21, 23, 25	
		Exterior sun control (S, E, W only)	Projection factor > 0.5			EN18–19, 24	
		Vestibule	Required			EN16	
Lighting	Interior Lighting	Lighting power density (LPD) W/ft^2	Guest rooms = 0.74	Office = 0.9		EL13–17	
			Corridors = 0.5	Lobbies = 1.1			
			Exercise = 0.9	Laundry = 0.6			
			Meeting rooms = 1.1	Stairs = 0.6			
		Fluorescent lamps	Compact fluorescent (CFL) with electronic ballast, T5HO or T8 high-performance with high-performance electronic ballast			EL2–7	
		Occupancy controls	Bi-level in stairs, manual-on/auto-off for all laundry, office, exercise, business center, meeting rooms, and non-public spaces			EL9	
		Guest room controls	Master control and entry and vacancy control in bathroom			EL9–10, HV14	
		Plug load lighting	Compact fluorescent (CFL) with electronic ballast			EL8	
	Exterior Lighting Power Density (LPD)	Lighting Zone 1 = Developed areas of national parks, state parks, forest land, and rural areas Lighting Zone 2 = Residential mixed-use areas and neighborhood business districts Lighting Zone 3 = All other areas				EL18–21	
			Lighting Zone 1	Lighting Zone 2	Lighting Zone 3		
		Base allowance	500 W	600 W	750 W		
		Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2		
		Walkways less than 10 ft wide	0.7 W/lf	0.7 W/lf	0.8 W/lf		
		Walkways 10 ft wide or greater	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2		
		Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2		
		Façade (use wattage only for façade)	None	0.10 W/ft^2	0.15 W/ft^2		

Climate Zone 7 Recommendation Table for Highway Lodging *(Continued)*

	Item	Component	Recommendation (Minimum or Maximum)	How-To Tips in Chapter 5	✓
HVAC	HVAC	Heating system (guest rooms)	Primary heat source extended range electric heat pump cycle or gas-fired furnace or boiler	HV2	
		Air conditioner (0–65 KBtuh)	13.0 SEER with gas/oil-fired supplemental heat	HV1–5	
		Air conditioner (>65–135 KBtuh)	11.3 EER/11.5 IPLV with gas/oil-fired supplemental heat	HV1–5	
		Air conditioner (>135–240 KBtuh)	11.0 EER/11.5 IPLV with gas/oil-fired supplemental heat	HV1–5	
		Air conditioner (>240 KBtuh)	10.6 EER/11.2 IPLV with gas/oil-fired supplemental heat	HV1–5	
		Gas furnace (0–225 KBtuh—SP)	80% AFUE or E_t	HV1–5	
		Gas furnace (0–225 KBtuh—Split)	80% AFUE or E_t	HV1–5	
		Gas furnace (>225 KBtuh)	80% E_c	HV1–5	
		Packaged terminal heat pump (all capacities)	EER = 13.6 – (0.233 x Cap/1000) (Not typically used) COP = 3.8 – (0.053 x Cap/1000)	HV1–5	
		Air source heat pump (0–65 KBtuh)	13.0 SEER/7.7 HSPF; Extended Htg range	HV1–5	
		Air source heat pump (>65–135 KBtuh)	10.6 EER/11.0 IPLV/ 3.2 Htg COP; Extended Htg range	HV1–5	
		Air source heat pump (>135 KBtuh)	10.1 EER/11.5 IPLV/ 3.1 Htg COP; Extended Htg range	HV1–5	
		Hydronic heat pump (0–18 KBtuh)	14.6 EER, 4.6 Heating COP	HV1–5	
		Hydronic heat pump (>19 KBtuh)	15.0 EER, 4.8 Heating COP	HV1–5	
		Hydronic heat pump heat source	Use condensing boiler for circulating loop heat source	HV17	
		Pumping for water source heat pumps	Variable speed pumping; water treatment	HV18, HV20	
		Hydronic heat pump heat rejection	Control cooling tower to maximize heat pump EER	HV19	
	Economizer	Air conditioners and heat pumps—SP	Cooling capacity > 54 KBtuh	HV6, HV22, HV26	
	Ventilation	Ventilation air supply	Demand control ventilation (DCV) for public areas	HV6–7, VC1–2	
		Heat recovery	Ventilation heat recovery with toilet exhaust	HV8	
	Ducts	Friction rate	0.08 in. w.c./100 ft	HV11, 20	
		Sealing	Seal class B	HV13	
		Location	Interior only	HV9	
		Insulation level	R-8	HV10	
SWH	Service Water Heating	Gas water heater efficiency	Storage—90% E_t, Instantaneous—0.81 EF or 81% E_t	WH1–2, 4	
		Electric storage EF (≤12 kW, ≥20 gal)	EF > 0.99 – 0.0012 × Volume	WH1–2, 4	
		Hot water usage reduction	Use 1.75 gpm shower heads, 1.0 gpm faucets and water conserving clothes waters; utilize laundry heat recovery	WH5, WH8	
		Water heater sizing/location	Avoid oversizing and excessive supply temperatures	WH3, WH6	
		Pipe insulation (d < 1.5 in./ d ≥ 1.5in.)	1 in./ 1.5 in.	WH7	
Other	Miscellaneous Appliances	Guest room mini-refrigerator	Absorption refrigeration cycle 33W continuously	MA1	
		High-efficiency laundry equipment	0.9 gal water/lb laundry 354G extractor with retained water < 52.5%	MA2	

Note: If the table contains “No recommendation” for a component, the user must meet the more stringent of either ASHRAE/IESNA Standard 90.1 or the local code requirements in order to reach the 30% savings target.

Alaska

Bethel (CA)
Dillingham (CA)
Fairbanks North Star
Nome (CA)
North Slope
Northwest Arctic
Southeast Fairbanks (CA)
Wade Hampton (CA)
Yukon-Koyukuk (CA)

Climate Zone 8 Recommendation Table for Highway Lodging

	Item	Component	Recommendation (Maximum or Minimum)			How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-30.0 c.i.			EN1–2, 11, 14–15	
		Attic and other	R-60.0 c.i.			EN3, 11–12, 14–15	
		Single rafter	R-38.0 + R-10.0 c.i.			EN4, 11, 14–15	
		Solar reflectance index (SRI)	No recommendation*			EN1	
	Walls—Exterior	Mass (HC > 7 Btu/ft^2)	R-25.0 c.i.			EN5, 11, 14–15	
		Steel-framed	R-13.0 + R-21.6 c.i.			EN6, 11, 14–15	
		Wood-framed and other	R-13.0 + R-15.6 c.i.			EN7, 11, 14–15	
	Slabs	Unheated	R-20.0 for 24 in.			EN8, 11, 13–15	
	Doors—Opaque	Swinging	U-0.50			EN9, 14–15	
		Non-swinging	U-0.50			EN10, 14–15	
	Vertical Glazing (Including Doors)	Area (percent of gross wall)	25%			EN17, 21–22, 25	
		Thermal transmittance	U-0.25			EN16	
		Solar heat gain coefficient (SHGC)	N, S, E, W-0.38			EN16, 21–22, 25	
		Exterior sun control (S, E, W only)	Projection factor > 0.5			EN18, 19, 24	
		Vestibule	Required			EN16	
Lighting	Interior Lighting	Light power density (LPD), W/ft^2	Guest rooms = 0.74	Office = 0.9		EL13–17	
			Corridors = 0.5	Lobbies = 1.1			
			Exercise = 0.9	Laundry = 0.6			
			Meeting rooms = 1.1	Stairs = 0.6			
		Fluorescent lamps	Compact fluorescent (CFL) with electronic ballast, T5HO or T8 high-performance with high-performance electronic ballast			EL2–7	
		Occupancy controls	Bi-level in stairs, manual-on/auto-off for all laundry, office, exercise, business center, meeting rooms, and non-public spaces			EL9	
		Guest room controls	Master control and entry and vacancy control in bathroom			EL9–10, HV14	
		Plug load lighting	Compact fluorescent (CFL) with electronic ballast			EL8	
	Exterior Lighting Power Density (LPD)	Lighting Zone 1 = Developed areas of national parks, state parks, forest land, and rural areas Lighting Zone 2 = Residential mixed-use areas and neighborhood business districts Lighting Zone 3 = All other areas				EL18–21	
			Lighting Zone 1	Lighting Zone 2	Lighting Zone 3		
		Base allowance	500 W	600 W	750 W		
		Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2		
		Walkways less than 10 ft wide	0.7 W/lf	0.7 W/lf	0.8 W/lf		
		Walkways 10 ft wide or greater	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2		
		Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2		
		Façade (use wattage only for façade)	None	0.10 W/ft^2	0.15 W/ft^2		

Climate Zone 8 Recommendation Table for Highway Lodging *(Continued)*

	Item	Component	Recommendation (Maximum or Minimum)	How-To Tips in Chapter 5	✓
HVAC	HVAC	Heating system (guest rooms)	Primary heat source extended range electric heat pump cycle or gas-fired furnace or boiler	HV2	
		Air conditioner (0–65 KBtuh)	13.0 SEER with gas/oil-fired supplemental heat	HV1–5	
		Air conditioner (>65–135 KBtuh)	11.3 EER/11.5 IPLV with gas/oil-fired supplemental heat	HV1–5	
		Air conditioner (>135–240 KBtuh)	11.0 EER/11.5 IPLV with gas/oil-fired supplemental heat	HV1–5	
		Air conditioner (>240 KBtuh)	10.6 EER/11.2 IPLV with gas/oil-fired supplemental heat	HV1–5	
		Gas furnace (0–225 KBtuh—SP)	80% AFUE or E_t	HV1–5	
		Gas furnace (0–225 KBtuh—Split)	80% AFUE or E_t	HV1–5	
		Gas furnace (>225 KBtuh)	80% E_c	HV1–5	
		Packaged terminal heat pump (all capacities)	EER = 13.6 – (0.233 x Cap/1000) (Not typically used) COP = 3.8 – (0.053 x Cap/1000)	HV1–5	
		Air source heat pump (0–65 KBtuh)	13.0 SEER/7.7 HSPF; Extended Htg range	HV1–5	
		Air source heat pump (>65–135 KBtuh)	10.6 EER/11.0 IPLV/ 3.2 Htg COP; Extended Htg range	HV1–5	
		Air source heat pump (>135 KBtuh)	10.1 EER/11.5 IPLV/ 3.1 Htg COP; Extended Htg range	HV1–5	
		Hydronic heat pump (0–18 KBtuh)	14.6 EER, 4.6 Heating COP	HV1–5	
		Hydronic heat pump (>19 KBtuh)	15.0 EER, 4.8 Heating COP	HV1–5	
		Hydronic heat pump heat source	Use condensing boiler for circulating loop heat source	HV17	
		Pumping for water source heat pumps	Variable speed pumping; water treatment	HV18, HV20	
		Hydronic heat pump heat rejection	Control cooling tower to maximize heat pump EER	HV19	
	Economizer	Air conditioners and heat pumps—SP	Cooling capacity > 54 KBtuh	HV6, HV22, HV26	
	Ventilation	Ventilation air supply	Demand control ventilation (DCV) for public areas	HV6–7, VC1–2	
		Heat recovery	Ventilation heat recovery with toilet exhaust	HV8	
	Ducts	Friction rate	0.08 in. w.c./100 ft	HV11, 20	
		Sealing	Seal class B	HV13	
		Location	Interior only	HV9	
		Insulation level	R-8	HV10	
SWH	Service Water Heating	Gas water heater efficiency	Storage—90% E_t, Instantaneous—0.81 EF or 81% E_t	WH1–2, 4	
		Electric storage EF (≤12 kW, ≥20 gal)	EF > 0.99 – 0.0012 × Volume	WH1–2, 4	
		Hot water usage reduction	Use 1.75 gpm shower heads, 1.0 gpm faucets and water conserving clothes waters; utilize laundry heat recovery	WH5, WH8	
		Water heater sizing/location	Avoid oversizing and excessive supply temperatures	WH3, WH6	
		Pipe insulation (d < 1.5 in./ d ≥ 1.5in.)	1 in./ 1.5 in.	WH7	
Other	Miscellaneous Appliances	Guest room mini-refrigerator	Absorption refrigeration cycle 33W continuously	MA1	
		High-efficiency laundry equipment	0.9 gal water/lb laundry 354G extractor with retained water < 52.5%	MA2	

Note: If the table contains "No recommendation" for a component, the user must meet the more stringent of either ASHRAE/IESNA Standard 90.1 or the local code requirements in order to reach the 30% savings target.

Technology Examples and Case Studies 4

Chapter 4 presents technology examples and case studies of buildings that have incorporated energy-efficient elements into their design. In many cases, the measures described are consistent with the recommendations presented in this Guide. The technology examples represent a specific portion of the building that would contribute to meeting the energy target—such as lighting, equipment efficiencies, or envelop measures. While several of the facilities presented as case studies are urban hotels that are larger than facilities targeted by this guide, the measures implemented provide valuable insight for any lodging facility.

CLIMATE ZONE 2—SPRINGHILL SUITES PENSACOLA BEACH

PENSACOLA BEACH, FLORIDA

This hotel on a barrier island on the Florida's Gulf Coast is a five-story, 117-room resort-style hotel that features a large public area and meeting space, a dining area with limited breakfast service, and a health club. Opened in July 2002, the hotel uses a hybrid geothermal system. In general, conditioned areas around the hotel are maintained from 72°F to 74°F dry bulb with 45% to 50% relative humidity in cooling and 68°F to 70°F dry bulb with 30% to 50% relative humidity in heating. Occupants have been pleased with the indoor air quality.

The system features a 150-ton closed-loop evaporative fluid cooler. The loop field is set up parallel to the 150-ton fluid cooler, which offers considerable heat rejection control and redundancy. Three 5 hp water-to-water geothermal heat pumps provide domestic hot water. All pool and spa heating is provided by geothermal heat pumps. In addition, more than 300 tons of room unitary ducted geothermal heat pumps are used in guest suites and to serve all other conditioned areas of the hotel. The hotel's five ice machines are water-cooled units tied to the geothermal loop.

Two modified geothermal rooftop packaged heat pumps provide 7,630 cfm of zone-neutral outdoor air directly into guest rooms and other areas throughout the hotel. Sensors are placed in a downstream supply duct location on these 100% outdoor air heat pumps. The heat pump system discharges air to the zones and tracks the required performance to maintain the zone's neutral supply air conditions.

Outdoor pool and spa heating is managed by two 390 kBtu/h water-to-water geothermal heat pumps. The pool heating temperature is held at 85°F, while the spa is maintained at 102°F. Estimated efficiency for these units in the pool and spa heating mode was 6.5 COP, resulting in an 86% heating cost reduction from standard pool heating equipment.

Several advantages were achieved by the water-cooled ice machines connected to the main hybrid geothermal loop. First, offensive heat rejection into the conditioned corridor vending area was avoided and sensible heat load for the building from the ice-making process was eliminated to reduce zone cooling tonnage. Second, this measure reduced hotel interior common area noise adjacent to guest rooms. Finally, water-cooled ice-making equipment has a 1.9 kWh (23%) energy advantage per 100 lbs of ice production over an air-cooled equivalent machine.

The domestic water heating configuration is three 64 kBtu/h geothermal, water-to-water heat pumps that provide primary 130°F water heating into two parallel-piped storage tanks. This stored hot water is passed to two parallel-piped 80 gallon supplemental 36 kW electric water heaters as backup final finish and redundant water heating. Hot water is sent to the blending valve and building hot water circulation loop at 120°F. Supplemental water heating has not been necessary to maintain primary water heating.

Additional energy-efficient items used include compact fluorescent lighting and an ozone laundry process washing system.

Energy use, water consumption, loop temperatures, and indoor space conditions were monitored during a one-year period from May 2003 through April 2004. Data collected during this period shows an overall annual energy intensity of 79 kBtu/ft^2, which is 37% below the 1995 Commercial Building Energy Consumption Survey (CBECS) intensity for the lodging segment national average of 135 kBtu/ft^2.

SPRINGHILL SUITES PENSACOLA BEACH	
Energy Savings Measures	**Description of Element**
HVAC	The system features a 150-ton closed-loop evaporative fluid cooler. The loop field is set up in parallel with the 150-ton fluid cooler. Main geothermal loop pumping is provided by a 40 hp constant speed loop pump with a standby pump. Two modified geothermal rooftop, packaged heat pumps provide 7,630 cfm of zone neutral outdoor air directly into guest rooms and other areas throughout the hotel.
Service Water Heating	Three 64 kBtu/h geothermal water-to-water heat pumps provide primary 130°F water heating into two parallel-piped storage tanks.
System Controls	Sensors are placed in a downstream supply duct location on these 100% outdoor air heat pumps. The heat pump system discharges air to the zones and tracks the required performance to maintain the zone neutral supply air conditions.
Other Savings	
Lighting	Compact fluorescent lighting
Ice Makers	Water-cooled ice machines connected to the main hybrid geothermal loop.
Laundry	Ozone laundry process washing system.

Data provided by SpringHill Suites

Figure 4-1. Beach-side loop field surface.

Figure 4-2. Geothermal loop field headers.

Photographs courtesy of Ron Nall, Gulf Power

Figure 4-3. Room HVAC unit.

CLIMATE ZONE 3—MARRIOTT COURTYARD OAKLAND EMERYVILLE

EMERYVILLE, CALIFORNIA

Centrally located in the Bay area, the Marriott Courtyard Oakland Emeryville is an 11-story, 295-room in-town facility. It features meeting space, a dining area with breakfast and dinner service, an exercise room, and an indoor pool. Aimed not only at reducing energy use and costs but also at improving occupant comfort and system operability, a number of measures were incorporated into the hotel in 2005, resulting in an ENERGY STAR® label from the U.S. Environmental Protection Agency. The measures were estimated to save more than $20,000 per year in energy costs and expected to provide a simple payback in fewer than two years.

The implemented changes were confined to the HVAC and the domestic hot water systems. Although this facility is larger than those targeted by this Guide, the measures implemented provide some valuable insight for any lodging facility.

On the 270-ton air-cooled chiller, a central plant direct digital control (DDC) system was installed that allowed the chilled-water temperature to be reset based on the outdoor air temperature. Similarly, for the boilers in the heating hot water system, a central plant DDC control system was implemented that allows the hot water temperature to be reset based on the outdoor air temperature. For both systems, the flow through the pump is controlled with a variable-frequency drive (VFD) via the temperature sensors located on the chilled or hot water return pipe. The chiller, boilers, and pumps can be locked out when the outdoor air temperature is lower than 60°F (chiller) or higher than 80°F (boilers), eliminating the possibility of operation if a guest sets the thermostat at an unusually low or high temperature. The chiller, boilers, and pumps are staged ON and OFF automatically. In both systems, the pumps run an equal amount of time based on a lead-lag rotation to reduce excessive operation of a single pump. The control system senses if a pump fails and starts the other pump as needed to ensure proper system operation.The setpoint temperature of the domestic hot water system was decreased from 140°F to 130°F. During periods of very high demand at 100% occupancy, the domestic hot water temperature does not reach the requested temperature of 120°F at the highest floors, so the system was designed to be reset to 140°F when hotel occupancy rises above 95%.

COURTYARD MARRIOTT OAKLAND EMERYVILLE	
Energy Savings Measures	**Description of Element**
HVAC	
Chilled-Water System Controls	Central plant direct digital control (DDC) system resets chilled-water temperature based on outdoor temperature. Variable-frequency drives (VFDs) are controlled by the temperature sensors located on the chilled water return pipe. Lead lag rotation of pumps to reduce excessive operation on one pump.
Heating Hot Water System Controls	Central plant DDC system resets hot water temperature based on outdoor temperature.VFDs are controlled by the temperature sensors located on the hot water return pipe. Lead lag rotation of pumps to reduce excessive operation on one pump.
Service Water Heating	
Supply Temperature Setting	System setpoint of 120°F for standard operation with reset to 140°F when occupancy exceeds 95%.

Data provided by Marriott International

Figure 4-4. Exterior view of the Marriott Courtyard Oakland Emeryville.

Figure 4-5. Guest room.

Photographs copyright Marriott International

Figure 4-6. Hotel lobby.

CLIMATE ZONE 3—MARRIOTT COURTYARD SAN FRANCISCO DOWNTOWN

SAN FRANCISCO, CALIFORNIA

Centrally located in the Bay area, this hotel is an 18-floor, 401-room downtown urban facility that features a parking garage, meeting space, restaurants, a fitness facility, and an indoor pool. The HVAC systems were retrofit with various energy-saving measures in 2006. The changes resulted in an ENERGY STAR® label from the U.S. Environmental Protection Agency. The measures were estimated to save more than $70,000 per year in energy costs and are expected to provide a simple payback of just a little over a year.

The implemented changes were confined to the HVAC and domestic water systems, and while this facility is an urban hotel that is larger than those targeted by this guide, the implementations and their effects provide valuable insight for any lodging facility.

Two air handlers serve the corridors with heating, cooling, and ventilation. The supply duct for the air handler serving the corridors in the top half of the hotel was straightened to remove four 90° elbows and turning vanes were added in the remaining 90° elbows, which lowered the pressure drop of the system from 2.3 to 1.92 in. w.c., resulting in fan energy savings. On both air-handling units, the economizer settings were changed to enthalpy controllers and set to keep the outdoor air dampers open until the outdoor air reaches the return air enthalpy.

All 57 fan-coil units that serve non-guest-room areas (meeting rooms, lobby, offices, etc.) were rezoned into similar occupancy areas and given occupied and unoccupied setpoints. The fans run continuously when the space is occupied and only cycle on when unoccupied to maintain the unoccupied setpoint.

For the boilers in the heating hot water system, the building automation system (BAS) was programmed to reset the hot water temperature setpoint based on an outdoor air temperature reset schedule. The boiler system is designed to limit short cycling and is enabled to run on a lead lag rotation when outdoor air temperature drops below a specified temperature.

The control settings on the domestic hot water heaters were set to minimize boiler cycling to keep individual boilers operating for longer periods of time. The control settings were also designed to keep the supply water temperature within the Marriott specified temperature range of 120°F to 128°F. Variable-frequency drives (VFDs) were installed for the domestic cold water booster pumps to control the domestic water pressure at a setpoint of 116 psi.

Lastly, contaminant control ventilation was implemented in the parking garage. Carbon monoxide (CO) sensors were installed and a VFD was installed to modulate the exhaust fans in order to keep exhaust levels below the maximum CO level.

COURTYARD SAN FRANCISCO DOWNTOWN	
Energy Savings Measures	**Description of Element**
HVAC	
Equipment—Air Handlers	Ductwork modified to replace four 90° elbows with straight duct. Economizer settings set to close the outdoor air damper open when outdoor air reaches return air enthalpy. Non-guest room area fan-coil operating hours and temperature setpoints tied to occupancy schedules.
Boilers	Optimized main boilers' control sequence. Reset supply hot water temperature via the BAS.
Service Water Heating	Optimized domestic hot water heaters' control sequence. Installed VFD for domestic cold water booster pumps to control domestic water pressure.
Additional Features	
Garage Exhaust Fan	Installed CO sensor in garage and modulated exhaust fan with a VFD to maintain below the maximum CO level.

Data provided by Marriott International

Figure 4-7. Exterior view of the Marriott Courtyard San Francisco Downtown.

Figure 4-8. Guest room.

Photographs copyright Marriott International

Figure 4-9. Lobby sitting area.

CLIMATE ZONE 5—COMFORT INN & SUITES BOSTON LOGAN AIRPORT

REVERE, MASSACHUSETTS

This airport hotel located just minutes from downtown Boston is an eight-story, 208-room facility that features meeting space, a restaurant, a fitness room, and an indoor pool. Designed by Harry Wheeler of Group One Partners and completed in September 2000, the hotel was designed with high performance, energy efficiency, and environmental leadership as goals. The various design features coupled with ongoing staff training have ensured successful implementation and operation of these goal-achieving measures. The design and continued efforts toward energy efficiency earned it an ENERGY STAR® label in 2003 and 2007 with ratings of 93 and 96, respectively.

The building construction is concrete masonry unit with an exterior insulation and finish system (EIFS) and 1.5 in. rigid insulation. The total R-value of the exterior walls ranges from 15.75 to 18.40. The roof is a rubber membrane on top of 3 in. structural metal decking over a tube steel frame with rigid insulation tapered to the edges. The facility uses prefinished aluminum double-frame low-e windows with 1 in. insulated glass.

Energy efficient lighting is used throughout the building, including 9, 13, and 23 W compact fluorescent lamps in the guest rooms; 13 and 14 W compact fluorescent lamps in the lobby; T8 32 W fluorescent lamps in the stairwells, service areas, and corridors; 32 W U-shaped fluorescent lamps in the offices and meeting spaces; and LED exit signs throughout the building. The back-of-house areas also employ motion sensors and light timers to turn off the lights when the areas are unoccupied. Daylighting was also incorporated into the high-performance design via clerestories for the lobby of the building and portions of the second floor. The hotel management adjust the interior lighting manually based on the amount of natural light available.

Packaged terminal air-conditioning (PTAC) units are used in the guest rooms with the remainder of the hotel HVAC needs handled with a high-efficiency boiler. An energy management system (EMS) controls the thermostat in the guest rooms via occupancy sensors.

In other efforts, the hotel uses ENERGY STAR rated equipment wherever possible, including the televisions in the guest rooms. The vending machines employ a motion sensor to power down the lights and refrigeration when there is no foot traffic. Other controls power up the refrigeration system periodically to maintain product temperature and prevent the machine from being powered down when the compressor is operating. An ozone laundry process washing system is used for hotel linens to reduce hot water requirements. A daylight sensor turns off the flagpole illumination during daylight hours and light-emitting diode (LED) exit signs are used throughout the building.

Photograph copyright Choice Hotels International

Figure 4-10. Hotel breakfast area.

COMFORT INN & SUITES BOSTON LOGAN AIRPORT	
Energy Savings Measures	**Description of Element**
Envelope	
Opaque Components—Walls	Concrete masonry construction with an EIFS and 1.5 in. rigid insulation. R-value range of 15.75 to 18.40 on exterior walls.
Opaque Components—Roof	Rubber membrane on top of structural metal decking over tube steel frame with rigid insulation tapered to edges.
Vertical Glazing	Prefinished aluminum double frame low-e windows with 1-inch insulated glass.
Lighting	
Lamps	Guest rooms—9, 13, and 23 W compact fluorescent lamps; lobby—13 and 14 W compact fluorescent lamps; stairwells, service areas, and corridors—T8, 32 W fluorescent lamps; offices and meeting spaces—32 W U-shaped fluorescent lamps; LED exit signs throughout the building.
Controls	Occupancy sensors or light timers in the back-of-house areas and restrooms.
Day Lighting	Clerestories for lobby and portions of the second floor.
HVAC	
Equipment	Packaged terminal air-conditioning (PTAC) units in guest rooms.
Controls	Occupancy-sensor-based energy management system (EMS) to control HVAC in guest rooms.
Other Savings	
Plug Loads	ENERGY STAR rated televisions in guest rooms and ENERGY STAR rated office equipment such as photocopiers, printers, computers and monitors. Motion sensors and controls on vending machines.
Laundry Operation	Ozone laundry process washing system to reduce hot water requirements.
Exterior Lighting	Daylight sensor for flagpole lighting.

Data provided by Choice Hotels International

Figure 4-11. Guest room.

Photographs copyright Choice Hotels International

Figure 4-12. Indoor swimming pool.

How to Implement Recommendations 5

Recommendations are contained in the individual tables in Chapter 3, "Recommendations by Climate." The following how-to tips are intended to provide guidance on good practices for implementing the recommendations as well as cautions to avoid known problems in energy-efficient construction.

QUALITY ASSURANCE

Quality and performance are never an accident. They are always the result of high intention, sincere effort, intelligent direction, and skilled execution. A high-quality building that functions in accordance with its design intent, and thus meets the performance goals established for it, requires that quality assurance (QA) be an integral part of the design and construction process as well as the continued operation of the facility. This process is typically referred to as *commissioning*.

To reduce project risk, commissioning (Cx) requires a dedicated person (one with no other project responsibilities) who can execute a systematic process that verifies that the systems and assemblies perform as required. An independent party, whether it is a third-party Cx professional or a capable member of the organization of the installing contractor, architect, or engineer of record, is needed to ensure that the strategy sets and recommendations contained in this Guide meet the owner's stated requirements. This person is the commissioning authority, or CxA.

The Cx process defined by *ASHRAE Guideline 0, The Commissioning Process*, and *ASHRAE Guideline 1.1, HVAC&R Technical Requirements for The Commissioning Process*, is applicable to all buildings. Owners, occupants, and the delivery team benefit equally from the QA process. Large and complex buildings require a correspondingly greater level of effort than that required for small, simpler buildings. Hotel buildings covered by this Guide have relatively simple systems and generally do not require the level of Cx effort required for more complex buildings. The following Cx practice recommendations meet this objective.

Activity	Complete
Owner selects CxA/QA provider and commitment to QA to designers and, through the contract documents, to contractors. The owner's responsibility includes directing the team to resolve issues identified through the QA process.	
CxA/QA provider reviews the OPR and the designers' Basis of Design documentation for completeness and clarity and identifies areas requiring further clarification.	
CxA/QA provider conducts focused review of 100% construction documents that verifies the design meets the defined objectives and criteria established by OPR and documents concerns to owner and designers.	
CxA/QA provider reviews comments from design review with designers and owner and adjudicates issues.	
CxA/QA provider develops Cx specifications that define team roles and responsibilities and pass/fail criteria for performance verification.	
CxA/QA provider assists design team by providing overview of process to prospective bidders and answers questions at pre-bid meeting.	
CxA/QA provider prepares pre-functional checklists and Cx plan and conducts meeting with project team and establishes tentative schedule for Cx activities.	
CxA/QA provider reviews submittal information for systems being commissioned and develops functional test procedures contractors will use to demonstrate commissioned system performance.	
CxA/QA provider conducts two site visits during construction to verify that concerns identified during 100% construction document review were corrected and to identify issues that would affect performance.	
CxA/QA provider schedules testing through GC and directs, witnesses, and documents the functional testing that demonstrates performance.	
CxA/QA provider reviews O&M information and verifies that owner is trained in warranty and preventive maintenance requirements and has operational and maintenance information needed to meet the requirements.	

Note that the following how-to tips address the recommendations in Chapter 3, as they are generally applicable to many specific construction projects.

Good Design Practice

QA1 *Select Team*

Selection of the correct team members is critical to the success of a project. Owners who understand the connection between a building's performance and its impact on the environment, the psychological and physiological perceptions of occupants, and the total cost of ownership also understand the importance of team dynamics in selecting the team members responsible for delivering their project. Owners should evaluate qualifications of candidates, their past performance, the cost of their services, and their availability when making a selection. Once the team is selected, a pre-design meeting should be held to define team members' roles and responsibilities. This includes defining deliverables at each phase of the process and the Cx process.

QA2 *Selection of Quality Assurance Provider*

Quality assurance is a systematic process of verifying the Owner's Project Requirements, operational needs, and Basis of Design and ensuring that the building performs in accordance with these defined needs. The selection of a QA provider should include the same evaluation process the owner would use to select other team members. Qualifications in providing QA services, past performance of projects, cost of services, and availability of the candidate are some of the parameters an owner should investigate and consider when making a selection. Owners may select a member of the design or construction team as the QA provider. While there are exceptions, in general most designers are not comfortable operating and testing assemblies and equipment and most contractors do not have the technical background necessary to evaluate performance. Commissioning requires in-depth technical knowledge of the building envelope and the mechanical, electrical, and plumbing systems and operational and construction experience. This function is best performed by a third party responsible to the owner because political issues often inhibit a member of the design or construction organizations from fulfilling this responsibility.

QA3 Owner's Project Requirements

The Owner's Project Requirements (OPR) details the functional requirements of a project and the expectations of how the facility will be used and operated. This includes strategies and recommendations selected from this Guide (see Table 2-1 and Chapters 3 and 4) that will be incorporated into the project, anticipated hours of operation provided by the owner, and Basis of Design assumptions. The OPR forms the foundation of the team's tasks by defining project and design goals, measurable performance criteria, owner directives, budgets, schedules, and supporting information in a single, concise document. The QA process depends on a clear, concise, and comprehensive OPR.

Development of the OPR requires input from all key facility users and operators. The OPR evolves through each project phase and contains documented decisions made during the design, construction, occupancy, and operation phases. This becomes the primary document for recording success and quality at all phases of the project delivery and throughout the life of the facility. Included in the OPR are the designers' assumptions, which form the Basis of Design. The Basis of Design records the concepts, calculations, decisions, and product selections used to meet the OPR and to satisfy applicable regulatory requirements, standards, and guidelines.

Note: The OPR remains relatively fixed from its initial development until directed otherwise by the owner.

QA4 Budgets Contained in the OPR

The OPR is used to define the team's scope in both broad and specific terms. It also defines the QA scope and budgets. The effort and cost associated with designing and constructing an energy-efficient building can be and often are lost because the performance of systems is not verified.

QA5 Design and Construction Schedule

The inclusion of QA activities in the construction schedule fulfills a critical part of delivering a successful project. Identify the activities and time required for design review and performance verification to minimize time and effort needed to accomplish activities and correct deficiencies.

QA6 Design Review

A second pair of eyes provided by the CxA/QA provider gives a fresh perspective that allows identification of issues and opportunities to improve the quality of the construction documents with verification that the OPR is being met. Issues identified can be more easily corrected early in the project, providing potential savings in construction costs and reducing risk to the team. (See "Suggested Quality Assurance Scope" in Chapter 2 for more detail.)

QA7 Defining Quality Assurance at Pre-Bid

The building industry has traditionally delivered buildings without using a verification process. Changes in traditional design and construction procedures and practices require education of the construction team that explains how the QA process change will affect the various trades bidding the project. It is extremely important that the QA process be reviewed with the bidding contractors to facilitate understanding of and to help minimize fear associated with new practices. Teams who have participated in the Cx process typically appreciate the process because they are able to resolve problems while their manpower and materials are still on the project, significantly reducing delays, callbacks, and associated costs while enhancing their delivery capacity. These requirements can be reviewed by the Architect and Engineer of Record at the pre-bid meeting, as defined in the specifications.

QA8 Verifying Building Envelope Construction

The building envelope is a key element of an energy-efficient design. Compromises in assembly performance are common and are caused by a variety of factors that can easily be avoided. Improper placement of insulation, improper sealing or lack of sealing around air barriers, wrong or poorly performing glazing and fenestration systems, incorrect placement of shading devices, misplacement of daylighting shelves, and misinterpretation of assembly details can significantly compromise the energy performance of the building (see “Cautions” sections throughout this chapter). The perceived value of the Cx process is that it is an extension of the quality control processes of the designer and contractor as the team works together to produce quality energy-efficient projects.

QA9 Verifying Lighting Construction

In hotel buildings, lighting plays a significant role in the energy consumption of the building. Lighting for the public, back-of-house, and office areas will many times have light sources operating 24 hours a day, unless control measures are incorporated to minimize use. Guest room lighting will normally be under the control of the guest when occupied and set to minimal levels by housekeeping staff when the room is not occupied.

QA10 Verifying Electrical and HVAC Systems Construction

Performance of electrical and HVAC systems are key elements of this Guide. How systems are installed affects how efficiently they can be serviced and how well they will perform. Design reviews and construction observations identify problems when they are easy to correct.

QA11 Testing

Testing of systems is essential to ensuring that a project following this Guide will actually attain the energy savings that can be expected from the strategies and recommendations contained in this Guide (see “Suggested Commissioning Scope” in Chapter 2 for the CxA/QA provider responsibilities). If the contractors utilize the checklists as intended, testing of systems will occur quickly and only minor but important issues will need to be resolved to ensure that the building will perform as intended. Owners with operational and maintenance personnel can use the testing process as a training tool to educate their staff on how the systems operate as well as for system orientation. All system controls, such as lighting and HVAC controls, must be thoroughly tested to verify that the systems function as intended.

QA12 Substantial Completion

Substantial completion generally means the completion and acceptance of the life safety systems and the facility is ready to be occupied. All of the systems should be operating as intended. Expected performance can only be accomplished when all systems operate interactively to provide the desired results. As contractors finish their work, they will identify and resolve many performance problems. The CxA/QA provider verifies that the contractor maintained a quality control process by directing and witnessing testing and then helps to resolve remaining issues.

QA13 Maintenance Manual Submitted and Accepted

The Cx/QA process includes communication of activities that the owner will be responsible for completing in order to maintain the manufacturers' warranties (see "Suggested Commissioning Scope" in Chapter 2 for QA provider responsibilities). A copy of the OPR should be provided to the operation and maintenance (O&M) staff as a reference of the design intent along with an O&M manual that notes system modifications and/or operation for an understanding of how the building is intended to operate.

QA14 Resolve Quality Control Issues Identified Throughout the Construction Phase

Issues identified during the construction process are documented in an "issues log" and presented to the team for collaborative resolution. Issues are tracked and reviewed at progress meetings until they are resolved. Typically the CxA develops and maintains the issues log. Completion and acceptance of the systems and assemblies by the owner will be contingent upon what issues are still outstanding at the end of the project. Minor issues may be tracked by the owner's O&M staff, while other issues will require resolution before acceptance of the work. The Cx/QA process finishes with verification that the issues identified have been resolved. The owner provides direction to the team to resolve issues identified.

QA15 Final Acceptance

Final acceptance generally occurs after the Cx/QA issues in the issues log have been resolved, except for minor issues the owner is comfortable with resolving during the warranty period.

QA16 Establish Building Maintenance Program

Continued performance and control of O&M costs require a maintenance program. The O&M manuals provide information that the O&M staff uses to develop this program. Detailed O&M system manual and training requirements are defined in the OPR and executed by the project team to ensure the O&M staff has the tools and skills necessary. The level of expertise typically associated with O&M staff for buildings covered by this Guide is generally much lower than that of a degreed or accredited engineer, and they typically need assistance with development of a preventive maintenance program. The CxA/QA provider can help bridge the knowledge gaps of the O&M staff and assist the owner with developing a program that would help ensure continued performance. The benefits associated with energy-efficient buildings are realized when systems perform as intended through proper design, construction, operation, and maintenance.

QA17 Monitor Post-Occupancy Performance

Establishing measurement and verification procedures with a performance baseline from actual building performance after it has been commissioned can identify when corrective action and/or repair is required to maintain energy performance. Utility consumption and factors affecting utility consumption should be monitored and recorded to establish building performance during the first year of operation.

Variations in utility usage can be justified based on changes in conditions typically affecting energy use, such as weather, occupancy, operational schedule, maintenance procedures, and equipment operations required by these conditions. While most buildings covered in this Guide will not use a formal measurement and verification process, tracking the specific parameters listed above does allow the owner to quickly review utility bills and changes in conditions. Poor performance is generally obvious to the reviewer when comparing the various parameters. CxA/QA providers can typically help owners understand when operational tolerances are exceeded and can provide assistance in defining what actions may be required to return the building to peak performance.

References

ASHRAE. 2005. *ASHRAE Guideline 0-2005, The Commissioning Process*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ASHRAE. 2007. *ASHRAE Guideline 1.1-2007, HVAC&R Technical Requirements for The Commissioning Process*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ENVELOPE

Opaque Envelope Components

Good Design Practice

EN1 *Cool Roofs* (Climate Zones: ❶ ❷ ❸)

Cool roofs are recommended for roofs with insulation entirely above deck. In order to be considered a cool roof, a solar reflectance index (SRI) of 78 or higher is recommended. A high reflectance keeps much of the sun's energy from being absorbed, while a high thermal emittance radiates away any solar energy that is absorbed, allowing the roof to cool more rapidly. Cool roofs are typically white and have a smooth surface. Commercial roof products that qualify as cool roofs fall into three categories: single-ply, liquid-applied, and metal panels. Examples are presented in Table 5-1.

The solar reflectance and thermal emmittance property values represent initial conditions as determined by a laboratory accredited by the Cool Roof Rating Council.

An SRI can be determined by the following equations:

$$SRI = 123.97 - 141.35(\chi) + 9.655(\chi^2)$$

where

$$\chi = \frac{20.797 \times \alpha - 0.603 \times \varepsilon}{9.5205 \times \varepsilon + 12.0},$$

where α is the solar absorptance (= 1 – solar reflectance) and ε is the thermal emissivity, which were derived from ASTM E1980 assuming a medium wind speed.

Table 5-1. Examples of Cool Roofs

Category	Product	Reflectance	Emissivity	SRI
Single-ply	White polyvinyl chloride (PVC)	0.86	0.86	107
Single-ply	White chlorinated polyethylene (CPE)	0.86	0.88	108
Single-ply	White chlorosulfonated polyethylene (CPSE), e.g., Hypalon	0.85	0.87	106
Single-ply	White thermoplastic polyolefin (TSO)	0.77	0.87	95
Liquid-applied	White elastomeric, polyurethane, acrylic coating	0.71	0.86	86
Liquid-applied	White paint (on metal or concrete)	0.71	0.85	86
Metal panels	Factory-coated white finish	0.70	0.87	85

EN2 *Roofs, Insulation Entirely above Deck* (Climate Zones: all)

The insulation entirely above deck (see Figure 5-1) should be continuous insulation (c.i.) rigid boards because there are no framing members present that would introduce thermal bridges or short circuits to bypass the insulation.

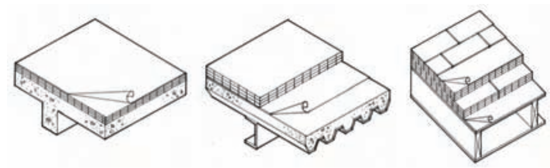


Figure 5-1. (EN2) Insulation entirely above deck—insulation is installed above (a) concrete, (b) metal, or (c) wood deck in a continuous manner.

When two layers of c.i. are used in this construction, the board edges should be staggered to reduce the potential for convection losses or thermal bridging. If an inverted or protected membrane roof system is used, at least one layer of insulation is placed above the membrane while a maximum of one layer is placed beneath the membrane.

EN3 *Roofs, Attics and Other Roofs* (Climate Zones: all)

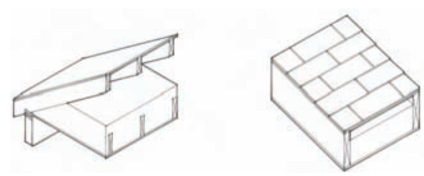


Figure 5-2. (EN3) Attics and other roofs.

Attics and other roofs include roofs with insulation entirely below (within) the roof structure (i.e., attics and cathedral ceilings) and roofs with insulation both above and below the roof structure (see Figure 5-2). Ventilated attic spaces need to have the insulation installed at the ceiling line (see Figure 5-2a). Unventilated attic spaces may have the insulation installed at the roof line. When suspended ceilings with removable ceiling tiles are used, have the insulation installed at the roof line (see Figure 5-2b). For buildings with attic spaces, ventilation should be provided equal to 1 ft^2 of open area per 100 ft^2 of attic space. This will provide adequate ventilation as long as openings are split between the bottom and top of the attic space.

EN4 *Roofs, Single Rafter* (Climate Zones: all)

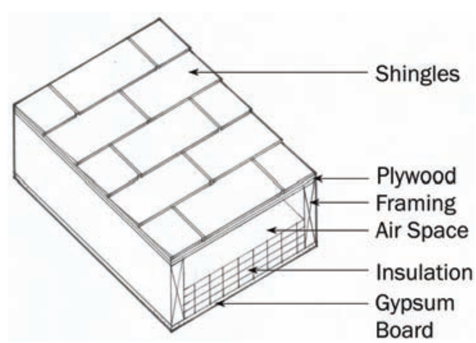


Figure 5-3. (EN4) Wood joists, single rafter.

Single-rafter roofs have the roof above and ceiling below both attached to the same wood rafter, and the cavity insulation is located between the wood rafters (see Figure 5-3). Continuous insulation (c.i.), when recommended, is installed to the bottom of the rafters and above the ceiling material. Single rafters can be constructed using solid wood framing members or truss type framing members. The cavity insulation should be installed between the wood rafters and in intimate contact with the ceiling to avoid the potential thermal short-circuiting associated with open or exposed air spaces.

EN5 *Walls, Mass* (Climate Zones: all)

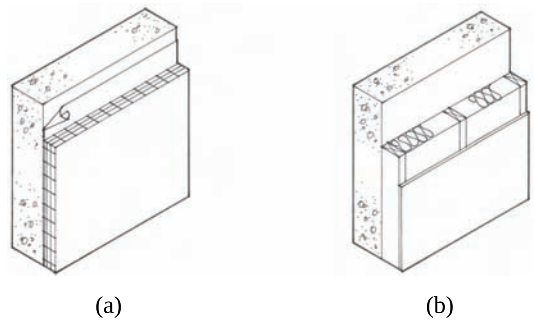


Figure 5-4. (EN5) Walls, mass—any concrete or mass wall with a heat capacity exceeding 7 Btu/ft^2·°F.

Mass walls are defined as those with a heat capacity exceeding 7 Btu/ft^2·°F. Insulation may be placed on either the inside or the outside of the mass wall (see Figure 5-4). When insulation is placed on the exterior of the wall (Figure 5-4a), rigid c.i. is recommended; when insulation is placed on the interior of the wall (Figure 5-4b), a furring or framing system may be used, provided the total wall assembly has a U-factor that is less than or equal to the appropriate climate zone construction listed in Appendix A.

The greatest advantages of mass can be obtained when insulation is placed on the exterior of the mass. In this case, the mass absorbs internal heat gains that are later released in the evenings when the buildings are not occupied.

EN6 *Walls, Steel Framed* (Climate Zones: all)

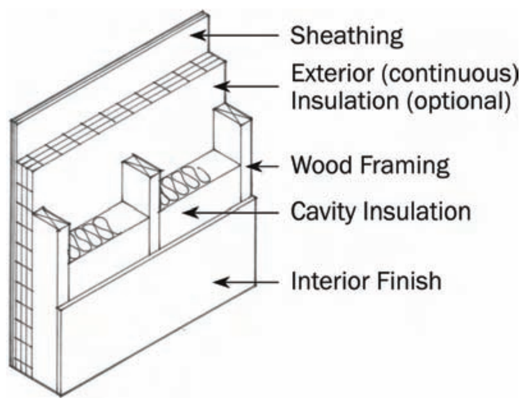


Figure 5-5. (EN6) Walls, steel framed—a common construction type in highway lodging.

Cold-formed steel framing members are thermal bridges to the cavity insulation (see Figure 5-5). The preferred method to improve the thermal performance of the wall is to add exterior foam sheathing as c.i. because it isolates the thermal bridging of the wall assembly.

Alternative combinations of cavity insulation and sheathing in thicker steel-framed walls can be used provided the proposed total wall assembly has a U-factor less than or equal to the U-factor for the appropriate climate zone construction listed in Appendix A.

EN7 *Walls, Wood Frame and Other* (Climate Zones: all)

Cavity insulation is used within the wood-frame wall, while rigid c.i. is placed on the exterior side of the framing (see Figure 5-6). Care must be taken to have a vapor retarder on the warm side of the wall and to utilize a vapor-retarder-faced batt insulation product to avoid insulation sagging away from the vapor barrier.

Alternative combinations of cavity insulations and sheathings in thicker walls can be used provided the total wall assembly has a U-factor that is less than or equal to the appropriate climate zone construction listed in Appendix A.

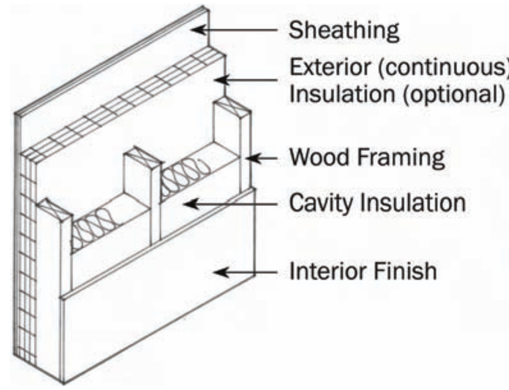
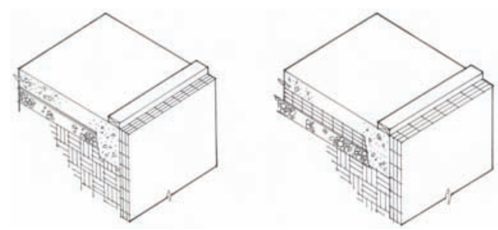


Figure 5-6. (EN7) Walls, wood frame and other.

EN8 *Slab-on-Grade Floors, Unheated* (Climate Zones: 4 5 6 7 8)

As shown in Figure 5-7, (a) rigid c.i. should be used around the perimeter of the slab and should reach the depth listed in the recommendation or to the bottom of the footing, whichever is less; (b) additionally, in climate zones 5–8 and in cases where the frost line is deeper than the footing, c.i. should be placed beneath the slab as well.



(a) (b)

Figure 5-7. (EN8) Slab-on-grade floors, unheated—no heating elements either within or below the slab.

EN9 *Doors, Opaque and Swinging* (Climate Zones: all)

A U-factor of 0.37 corresponds to an insulated double-panel metal door. A U-factor of 0.61 corresponds to a double-panel metal door. If at all possible, single swinging doors should be used. Double swinging doors are difficult to seal at the center of the doors (see Figure 5-8) unless there is a center post. Double swinging doors without a center post should be minimized and limited to areas where width is important. Vestibules can be added to further improve the energy efficiency.

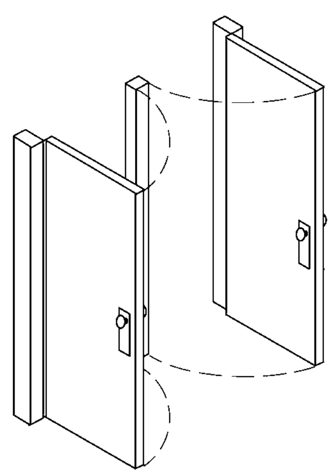


Figure 5-8. (EN9) Doors, swinging—opaque doors.

EN10 *Doors, Opaque and Roll-Up or Sliding* (Climate Zones: all)

Roll-up or sliding doors are recommended to have R-4.75 rigid insulation or meet the recommended U-factor. When meeting the recommended U-factor, the thermal bridging at the door and section edges is to be included in the analysis. Roll-up doors that have solar exposure should be painted with a reflective paint (or high emmissivity) and/or should be shaded. The issue with metal doors is that they typically have poor emmissivity and collect heat, which is transmitted through even the best insulated door, causing cooling loads and thermal comfort issues in the space.

If at all possible, use insulated panel doors over roll-up doors, as the insulation values can approach R-10 and provide a tighter seal to minimize infiltration.

Options

EN11 *Alternative Constructions* (Climate Zones: all)

The climate zone recommendations provide only one solution for upgrading the thermal performance of the envelope; while other constructions can be equally effective, they are not discussed in this Guide. Any alternative construction that is less than or equal to the U-factor or F-factor for the appropriate climate zone construction is equally acceptable. A table of U-factors and F-factors that corresponds to all of the recommendations is presented in Appendix A.

Procedures to calculate U-factors are presented in the *ASHRAE Handbook—Fundamentals*, and expanded U-factor and F-factor tables can be found in ASHRAE/IESNA Standard 90.1, Appendix A.

Cautions

The design of building envelopes for durability, indoor environmental quality, and energy conservation should not create conditions of accelerated deterioration, reduced thermal performance, or problems associated with moisture and air infiltration. The following cautions should be incorporated into the design and construction of the building.

EN12 *Heel Heights* (Climate Zones: all)

When insulation levels are increased in attic spaces, the heel height should be raised to avoid or at least minimize the eave compression.

EN13 *Slab-Edge Insulation* (Climate Zones: all)

Use of slab-edge insulation improves thermal performance, but problems can occur in regions of the country that have termites.

EN14 *Moisture Control* (Climate Zones: all)

Building envelope assemblies (see Figures 5-9a and 5-9b) should be designed to prevent wetting, high moisture content, liquid water intrusion, and condensation caused by diffusion of water vapor (see *ASHRAE Handbook—Fundamentals*).

EN15 *Air Infiltration Control* (Climate Zones: all)

The building envelope should be designed and constructed with a continuous air barrier system to control air leakage into or out of the conditioned space. An air barrier system should also be provided for interior separations between conditioned space and space designed to maintain temperature or humidity levels that differ from those in the conditioned space by more than 50% of the difference between the conditioned space and design ambient conditions. The air barrier system should have the following characteristics:

- It should be continuous, with all joints made airtight.
- Air barrier materials used in frame walls should have an air permeability not to exceed 0.004 cfm/ft^2 under a pressure differential of 0.3 in. water (1.57 lb/ft^2) when tested in accordance with ASTM E 2178.

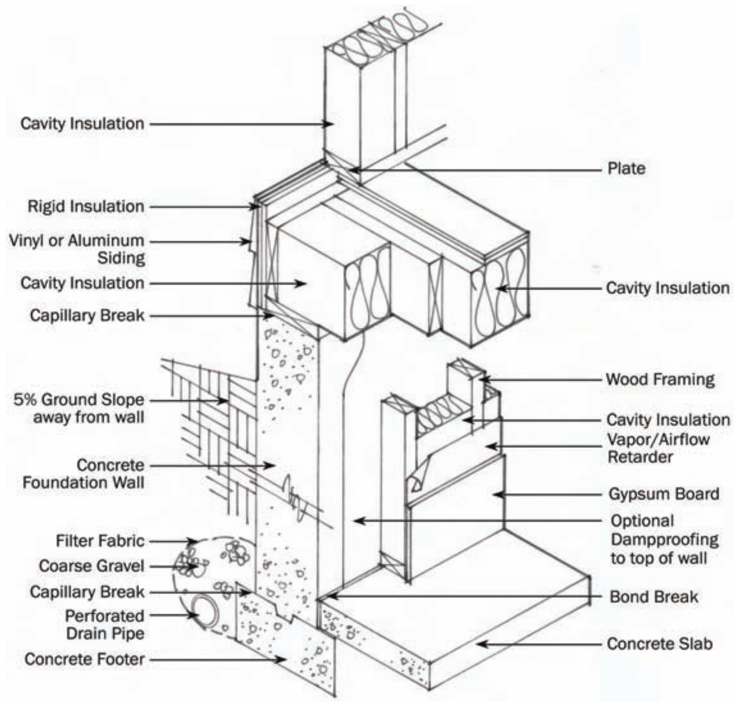


Figure 5-9a. (EN14) Moisture control for mixed climates.

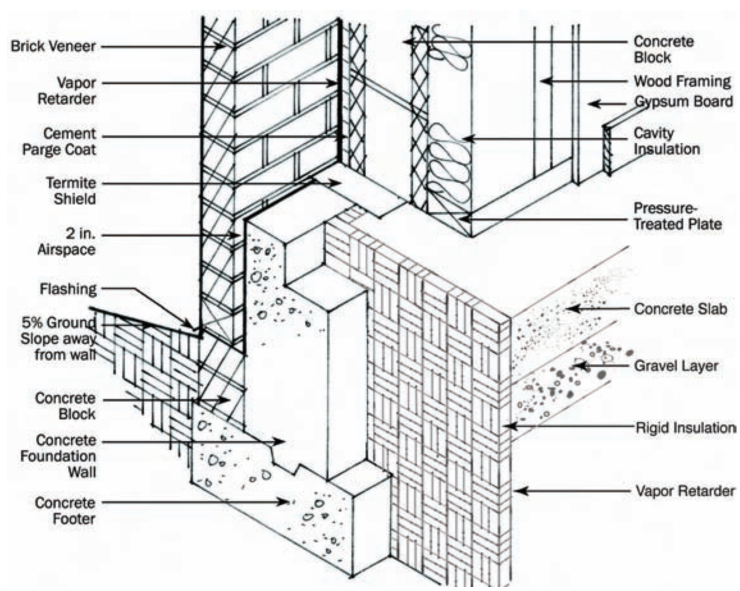


Figure 5-9b. (EN14) Moisture control for warm, humid climates.

- The system is capable of withstanding positive and negative combined design wind, fan, and stack pressures on the envelope without damage or displacement and should transfer the load to the structure. It should not displace adjacent materials under full load.
- It is durable or maintainable.
- The air barrier material of an envelope assembly should be joined in an airtight and flexible manner to the air barrier material of adjacent assemblies, allowing for the relative movement of these assemblies and components due to thermal and moisture variations, creep, and structural deflection.
- Connections should be made between:
    a. Foundation and walls
    b. Walls and windows or doors
    c. Different wall systems
    d. Wall and roof
    e. Wall and roof over unconditioned space
    f. Walls, floors, and roof across construction, control, and expansion joints
    g. Walls, floors, and roof to utility, pipe, and duct penetrations
- All penetrations of the air barrier system and paths of air infiltration/exfiltration should be made airtight.

Fenestration: Vertical Glazing and Skylights (Envelope)

Good Design Practice

EN16 *Vertical Glazing* (Climate Zones: all)

The recommendations for fenestration (e.g., windows and glazed doors) are listed in Chapter 3 by climate zone. Vertical fenestration is defined as a slope greater than 60^o from the horizontal (see Figure 5-10). While vestibules are required in climate zones 4–8, they can be added to climate zones 1–3 to further improve the energy efficiency.

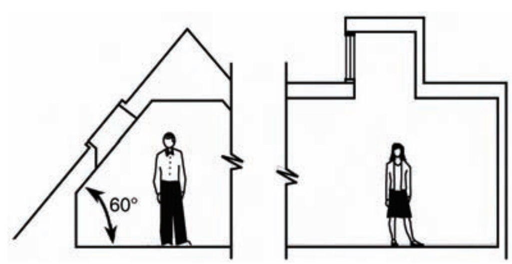


Figure 5-10. (EN16) Vertical fenestration—defined as slope greater than 60° from the horizontal.

Table 5-2 lists the type of vertical glazing construction that generally corresponds to the U-factors and solar heat gain coefficient (SHGC) values in the Chapter 3 Recommendation Tables.

To be useful and consistent, the U-factors should be measured over the entire fenestration assembly, not just the center of glass. Look for a National Fenestration Rating Council (NFRC) label (or NFRC Label Certificate for site-built fenestration) that denotes the fenestration product is rated, certified, and labeled in accordance with NFRC procedures. The selection of high-performance window products should be considered separately for each orientation of the building and for daylighting and viewing functions.

When considering fenestration choice, structural performance and life safety criteria must be considered in conjunction with thermal performance. Taller buildings, especially those categorized as high-rise buildings, may require fenestration products that meet specific structural, ballistic, leakage, and other testing requirements.

Table 5-2. Vertical Fenestration Descriptions

U-Factor	SHGC	VT	Class or Coating	Spacer	Frame
0.56	0.25	0.30	Double reflective or tinted with selective low-e coating		Metal, vinyl, wood
0.45	0.25	0.30	Double reflective or tinted with selective low-e coating		Metal with thermal break, vinyl, wood; pultruded fiberglass.
0.41	0.25	0.60	Tinted with selective low-e coating	Insulated	Metal with improved thermal break, vinyl, wood; pultruded fiberglass.
0.38	0.40	0.60	Double clear with selective low-e coating	Insulated	Metal with isolation bar, vinyl, wood; pultruded fiberglass.
0.35	0.40	0.60	Double clear with selective low-e coating, argon fill	Insulated	Metal with isolation bar, vinyl, wood; pultruded fiberglass.
0.25	0.38	0.50	Triple clear with low-e coating; argon fill	Insulated	Metal with improved isolation bar, vinyl, wood; pultruded fiberglass.

EN17 *Vertical Glazing Area as a Percent of Gross Wall Area* (Climate Zones: all)

The vertical glazing area is the percentage resulting from dividing the total fenestration—including glazed doors—by the gross exterior wall area. For any area less than 25%, the recommended values for U-factor and SHGC contribute toward the 30% savings target of the entire building. A reduction in the overall fenestration area will also save energy, especially if glazing is significantly reduced on the east and west façades.

EN18 *Fenestration Design Guidelines for Thermal Conditions* (Climate Zones: all)

Uncontrolled solar heat gain is a major cause of energy consumption for cooling in warmer climates and thermal discomfort for occupants. Appropriate configuration of vertical glazing and skylights according to the orientation of the wall on which they are placed can significantly reduce these problems.

EN19 *Solar Heat Gain is Most Effectively Controlled on the Outside of the Building* (Climate Zones: all)

Significantly greater energy savings are realized when sun penetration is blocked before entering the windows. Horizontal overhangs located at the top of the windows are most effective for south-facing façades and must continue beyond the width of the windows to adequately shade them. In predominantly sunny climates the overhang should be totally opaque, while in predominantly cloudy climates the overhang should be translucent. The vertical extension of the overhang depends on the height of the overhang from the bottom of the window sill (see Figure 5-11). *Note:* Overhangs located directly above the window head need the least projection.

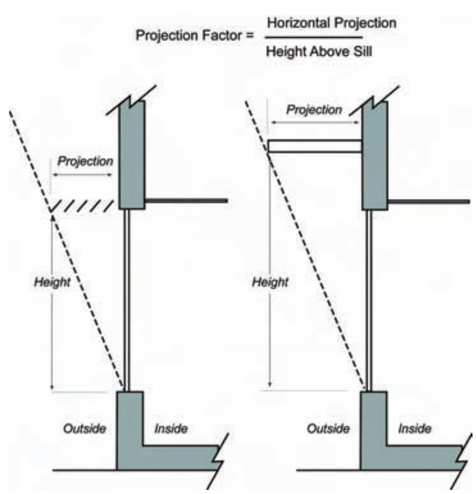


Figure 5-11. (EN19) Windows with overhang.

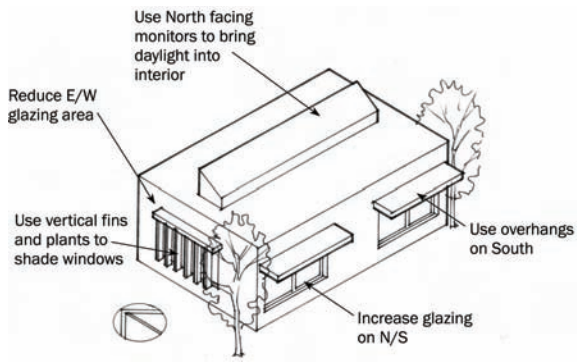


Figure 5-12. (EN19) Exterior sun control.

Vertical fins oriented slightly north are most effective for east- and west-facing façades (see Figure 5-12). Consider louvered or perforated sun control devices, especially in primarily overcast and colder climates, to prevent a totally dark appearance in those environments.

EN20 *Operable versus Fixed Windows* (Climate Zones: all)

Operable windows offer the advantage of personal comfort control and beneficial connections to the environment. However, individual operation of the windows not in coordination with the HVAC system settings and requirements can have impacts on the energy use of a building's system. Advanced energy buildings with operable windows should strive for a high level of integration between envelope and HVAC system design. First, the envelope should be designed to take advantage of natural ventilation with well-placed operable openings. Second, the mechanical system should employ interlocks on operable windows to ensure that the HVAC system responds by shutting down in the affected zone if the window is opened. It is important to design the window interlock zones to correspond as closely as possible to the HVAC zone affected by the open window.

EN21 *Building Form and Window Orientation* (Climate Zones: all)

In all climates, north- and south-facing glass can be more easily shielded and can result in less solar heat gain and less glare than can east- and west-facing glass. During site selection, preference should be given to sites that permit locating office areas along south or north sides of the building (see Figure 5-13).

A good design strategy avoids glass that does not contribute to the daylighting of the space. If possible, configure the building to maximize north-facing walls and glass by elongating the floor plan. Since sun-control devices are less effective on the east and west façades, the solar penetration through the east- and west-facing glazing can cause a problem with glare and is usually shaded. This can be done by reducing the area of glazing, reducing the SHGC, or preferably both. Thus, the area of glazing on the east and west façades, multiplied by their respective SHGCs, should be less than the area of glazing on the north and south façades multiplied by their respective

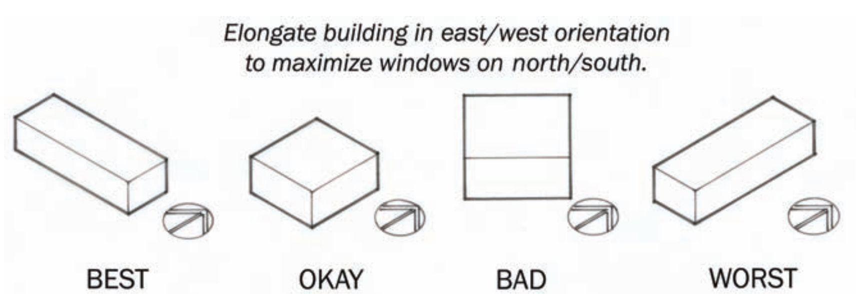


Figure 5-13. (EN21) Building and window orientation.

SHGCs. If each façade has a different area or SHGC, the formula becomes: ((W window area × W SHGC) + (E window area × E SHGC)) < ((N window area × N SHGC) + (S window area × S SHGC)). For buildings where a predominantly east-west exposure is unavoidable, or if the application of this equation would result in SHGCs of less than 0.25, then more aggressive energy conservation measures may be required in other building components to achieve an overall 30% energy savings.

Warm Climates

EN22 *Glazing* (Climate Zones: ❶ ❷ ❸)

For north- and south-facing windows, select windows with a low SHGC and an appropriate visible transmittance (VT). Certain window coatings, called *selective low-e*, transmit the visible portions of the solar spectrum selectively, rejecting the nonvisible infrared sections. These glass and coating selections provide superior view and daylighting while minimizing solar heat gain. Window manufacturers market special "solar low-e" windows for warm climates. All values are for the entire fenestration assembly, in compliance with NFRC procedures, and are not simply center-of-glass values. For warm climates, a low SHGC is much more important for low building energy consumption than the window assembly U-factor. Windows with low SHGC values will tend to have a low center-of-glass U-factor, however, because they are designed to reduce the conduction of the solar heat gain absorbed on the outer light of glass through to the inside of the window.

EN23 *Glazing* (Climate Zones: ❹ ❺ ❻ ❼ ❽)

For more northerly locations, only the south-facing glass receives much sunlight during the cold winter months. If possible, maximize south-facing windows by elongating the floor plan in the east-west direction and relocate windows to the south face. Be careful to install blinds or other sun-control devices for south-facing glass to allow for passive effects when desired but prevent unwanted glare and solar overheating. Glass facing east and west should be significantly limited. Areas of glazing facing north should be cautiously sized for daylighting and view. (See DL3 for additional information.) Although higher SHGCs are allowed in colder climate zones, continuous horizontal overhangs are still useful for blocking summer sun. Window manufacturers market low-e glazing with higher SHGCs for cold climates.

EN24 *Obstructions and Planting* (Climate Zones: all)

Adjacent taller buildings and trees, shrubs, or other plantings are effective for shading glass on south, east, and west facades. For south-facing windows, remember that the sun is higher in the sky during the summer, so shading plants should be located high above the windows to effectively shade the glass. The glazing of fully shaded windows can be selected with higher SHGC ratings without increasing energy consumption. The solar reflections from adjacent buildings with reflective surfaces (metal, windows, or especially reflective curtain walls) should be considered in the design. Such reflections may modify shading strategies, especially on the north façade.

EN25 *Passive Solar* (Climate Zones: all)

Passive solar energy-saving strategies should be limited to lobbies and circulation areas. Consider heat-absorbing blinds in cold climates or reflective blinds in warm climates. In spaces where glare is not an issue, the usefulness of the solar heat gain collected by windows can be increased by using massive thermally conductive floor surfaces, such as tile or concrete, in locations where the transmitted sunlight will fall. These floor surfaces absorb the transmitted solar heat gain and release it slowly over time to provide a more gradual heating of the structure. Consider low-e glazing with exterior overhangs.

References

ASHRAE. 2009. *2009 ASHRAE Handbook—Fundamentals*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ASTM. 2001. *ASTM E 1980, Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces*. West Conshokocken, PA: ASTM International.

ASTM. 2003. *ASTM E 2178, Standard Test Method for Air Permeance of Building Materials*. West Conshokocken, PA: ASTM International.

LIGHTING

The goals for the lighting section are to optimize electric lighting in the guest rooms, interior corridors, laundry, and main lobby area of lodging facilities. Often the lighting in the guest rooms is used on a sporadic basis and, if not planned well, will result in a darker space. In the interior corridors, lighting often runs 24 hours a day. This is an area for possible daylight savings from top lighting (skylights) or occupancy sensors that reduce lighting when the space is unoccupied.

Electric Lighting Design

Interior Electric Lighting

Good Design Practice

For this Guide, the lodging is divided into "guest rooms" comprising 63% of the total floor area, "corridors" at 13% of the floor area, and "lobby/lounge" and "stairs" at 4% each. Storage, office/reception, meeting rooms, laundry room, and exercise room make up the remainder of the floor area.

In all spaces the goal is to maximize energy efficiency while maintaining the good aesthetics/functional qualities of the lighting system. Use compact fluorescent in downlights, wall sconces, and table lamps. Use incandescent sparingly, such as in accent lighting of artwork or highlighting of special architectural features in the lobby. Use translucent wall sconces and table lamps to better light the space and patrons' faces. When using compact fluorescent downlights, use downlights with a regressed lens (the lens is recessed at least 1 in. into the downlight trim) to soften the compact fluorescent lamp.

EL1 *Reflectance* (Climate Zones: all)

High (80+) surface reflectance on ceilings in all areas will reduce contrast between skylights, luminaires, and ceiling. Reflectance values are available from paint manufacturers. Reflectance should be verified by the quality assurance provider.

Guest Rooms. Energy savings outlined in this Guide were based on a reflectance of 80-50-20 (ceiling-wall-floor). If the reflectance is lower, then additional attention to the ambient lighting energy requirements may be necessary. Wherever possible, do not reduce the ceiling reflectance.

Corridor and Lobby. Energy savings outlined in this Guide were based on a reflectance of 80-50-20 (ceiling-wall-floor). If the reflectance is lower, then additional attention to the placement of luminaires to the tasks will be necessary to meet the light level recommendations while maintaining the energy requirements.

EL2 *Color Rendering Index* (Climate Zones: all)

The color rendering index (CRI) is a scale measurement identifying a lamp's ability to adequately reveal color characteristics of objects and people. The scale maximizes at 100, with 100 indicating the best color rendering capability. While color rendering may not seem important, the higher the CRI, the more accurately colors will be perceived. The fluorescent lamps recommended in EL5 for energy saving should have a minimum CRI of 80 to provide good color properties. Look on the product label or in the manufacturers catalog for the CRI rating.

EL3 *Color Temperature* (Climate Zones: all)

Color temperature is a scale to identify a lamp's relative warmth or coolness. Color temperature ratings in the 3000 to 4100 K are generally referred to as "white," where the 3000 K lamp can be described as having a warmish color and the 4100 K a coolish color. To achieve an incandescent look, use either 2700 or 3000 K fluorescent lamps. 3500 K lamps can be used in the corridors and lobby to provide a cooler-looking space, but specifying a single color temperature simplifies maintenance.

EL4 *Linear Fluorescent Lamps and Ballasts* (Climate Zones: ❶ ❷ ❸ ❹ ❺ ❻ ❼)

To achieve the lighting power density (LPD) recommendations in Chapter 3, high-performance T-8 lamps and high-performance electronic ballasts are used for the general lighting in the laundry room (linear fluorescent lamps may also be used in corridors and lobbies). The use of standard T-8 and energy-saving T-8 lamps may also be considered in ceiling heights below 10 ft but will result in lower ambient light levels or an increased number of luminaires and lamps to achieve recommended light levels.

High-performance T-8 lamps are defined, for the purpose of this Guide, as having a lamp efficacy of 90+ lumens per watt, based on mean lumens divided by the cataloged lamp input watts. Mean lumens are published in the lamp catalogs as the reduced lumen output that occurs at 40% of the lamp's rated life. High-performance T-8s also are defined as having a CRI of 81 or higher and 94% lumen maintenance. The higher performance is achieved by increasing the output (3100 lumens) while keeping the same 32-watt input as standard T-8s. Energy-saving T-8 lamps achieve higher performance by reducing the wattage while keeping the light output similar to standard T-8s (e.g., 2750 lumens for 28 W or 2850 lumens for 30 W).

High-performance electronic ballasts are defined, for the purpose of this Guide, as a 2-lamp ballast using 55 W or less with a ballast factor (BF) of 0.87 or greater. 1-lamp, 3-lamp, and 4-lamp ballasts may be used but should have the same, or better, efficiency as the 2-lamp ballast. Dimming ballasts do not need to meet this requirement. The high-performance T-8 lamps are visibly brighter than standard T-8s, and using ballasts with a BF of 0.77 may provide more comfortable lamp brightness in office areas and in mounting heights below 10 ft.

- *Program start ballasts* are recommended on frequently switched lamps (switched on and off more than five times a day) because they greatly extend lamp life over frequently switched instant start ballasts. (Also see EL9.)
- *Instant start T-8 ballasts* typically provide greater energy savings and are the least costly option, plus the parallel operation allows one lamp to operate even if the other burns out. However, instant start ballasts may reduce lamp life, especially when controlled by occupancy sensors or daylight switching systems.
- T-5HO ballasts should always be program start.

T-5HO lamps may be an alternative solution to T-8 lamps. They have initial lumens per watt that are slightly lower than the high-performance T-8s, but they produce approximately twice the lumen output of T-8 lamps, allowing the luminaire to use fewer lamps. In addition to energy, T-5HOs use fewer natural resources (glass, metal, phosphors) than a comparable lumen output T-8 system. The T-5HO also is smaller in diameter, allowing the luminaire reflector to be designed to more effectively get light out of the luminaire and down to the floor in high-mounting applications. T-5s have higher surface brightness and caution should be used in open-bottom fixtures to minimize direct glare from T-5 lamps.

EL5 *Compact Fluorescent Lamps* (Climate Zones: all)

To achieve the LPD recommendations in Chapter 3, compact fluorescent lamps (CFLs) with electronic ballasts are used for the general lighting in the guest rooms, corridors, and lobby.

When using CFLs in exterior corridors, be sure to use amalgam CFLs and specify cold starting ballasts in enclosed luminaires in cold climates.

EL6 *Ceramic Metal Halide (CMH) and Metal Halide* (Climate Zones: all)

To achieve the LPD recommendations in Chapter 3, metal halide luminaires may be part of the solution for interior accent lighting, using low-wattage ceramic metal halide (CMH) lamps and exterior environments. (See EL19 for more information on exterior lighting sources.)

CMH lamps can be up to 250% more efficient and have three to five times greater lamp life than halogen sources and are recommended over halogen infrared (IR) lamps. However, there likely will be instances where the use of CMH lamps will not be practical as a result of cost considerations or because the size or ambient condition of the space will not support the intensity of CMH lamps.

When using metal halide, use pulse-start lamps, which have better lumen maintenance than probe start lamps (approximately 75% for pulse-start and 64% for probe start). Newer electronic high-intensity discharge (HID) ballasts also improve lumen maintenance to approximately 86% for the pulse-start lamps and can extend lamp life up to 50%.

Unlike fluorescent lamps, metal halide lamps are not temperature sensitive and may be a better choice in hot or cold interior environments.

EL7 *Halogen IR* (Climate Zones: all)

To achieve the LPD recommendations in Chapter 3, halogen IR lamps may be used for accent lighting. *Halogen IR lamps* are defined, for the purpose of this Guide, as having a lamp efficacy of 17+ lumens per watt and using thin films to help redirect thermal energy to the filament, increasing light output.

If halogen IR lamps are used, then it is recommended that the lamp envelopes be limited to MR16 bulb sizes. In all cases, the lamp wattage would be comparable to the lower wattage CMH lamps; wattage is limited by the lamp size. PAR30IR and PAR38IR lamps could be used but are not recommended because of the breadth of lamp wattages and types available with which a fixture could be re-lamped at a future time. Standard incandescent and halogen sources are not recommended.

EL8 *Plug-In Lighting* (Climate Zones: all)

Use compact fluorescent fixtures with electronic ballasts in all plug-in table and floor lamps in guest rooms, lobbies, and common areas.

EL9 *Occupancy Sensors* (Climate Zones: all)

Use occupancy sensor controls on all luminaires in corridors, stairs, offices, and laundry/storage rooms. In every application it should not be possible for the occupant to override the automatic OFF setting, even if set for manual ON. Unless otherwise recommended, factory-set occupancy sensors should be set for medium to high sensitivity and a 15 min time delay (the optimum time to achieve energy savings without excessive loss of lamp life). Review manufacturer data for proper placement, coverage, and commissioning requirements.

Vacancy Sensors. Another type of occupancy sensor is often called a *vacancy sensor* and should be used in all guest room bathrooms. The vacancy sensor shall be capable of automatically turning off the bathroom lighting, except for night lighting not exceeding 5 W, after the guest leaves the space. Vacancy sensor time delay should be capable of being set up to 60 min for guest comfort and safety while bathing. For safety reasons, a minimum setting of 30 min is recommended.

The two primary types of occupancy sensors are *infrared* and *ultrasonic*. Infrared sensors see heat that moves and will not see around corners; ultrasonic sensors send out an active signal and look for a change in the reflection to detect motion and may be disrupted by air movement near the sensor.

- If sensors false trigger OFF (turn lights off when someone is present), adjust the time setting up by 2 min on infrared sensors and/or adjust the sensitivity up by 20% on ultrasonic sensors.
- If the lights false trigger ON with ultrasonic sensors, first check for high airflow near the sensor (ultrasonic sensors should not be located near HVAC equipment, including ceiling fans). If the sensor is not in a high airflow area, adjust the sensitivity down by 20%.

EL10 *Lighting Circuits and Automatic Control* (Climate Zones: all)

In guest rooms, install a control device at the entry door that collectively controls all permanently installed luminaires and switched receptacles. (See HV14 for more information; see EL19 vacancy sensor section for bathroom controls).

EL11 *Luminaire Distribution* (Climate Zones: all)

In lobby, corridors, and guest rooms where sconces, floor lamps, and table lamps are used, the shade or diffuser should be translucent, not opaque, to reduce contrast between the luminaire and the surroundings. Translucent shades and diffusers also light guests' faces better than opaque materials.

EL12 *Glare Control* (Climate Zones: all)

Specify luminaires with lenses/louvers or proper depth so that the bare lamp is not visible at normal viewing angles. Direct view of the lamp can create disability glare for guests, which can be dangerous around stairs and other uneven surfaces.

Sample Design Layouts for Lodging Facilities

The recommendations for lighting power (shown below and in each Recommendation Table in Chapter 3) of 0.74 W/ft^2 for guest rooms, 0.9 W/ft^2 for offices, 0.5 W/ft^2 for corridors, 0.6 W/ft^2 for laundry areas, 1.1 W/ft^2 for lobbies, 0.9 W/ft^2 for exercise rooms, 1.1 W/ft^2 for meeting rooms, and 0.6 W/ft^2 for stairs represent average LPDs for these individual spaces, not the entire building. Individual spaces within each space type may have higher power densities if they are offset by lower power densities in other areas within the same space type (breakfast room and elevator lobby would be considered part of the lobby and may be lighted to lower/higher light levels and therefore lower/higher W/ft^2 allowing higher/lower footcandles and W/ft^2 in the main lobby and registration area). The example designs described below are *a way*, but *not the only way*, that these W/ft^2 limits can be met.

Individual Space Average Lighting Power Densities (W/ft^2) from Recommendation Tables in Chapter 3	
Guest Rooms = 0.74	Offices = 0.9
Corridors = 0.5	Lobbies = 1.1
Exercise Rooms = 0.9	Laundry Room = 0.6
Meeting Rooms = 1.1	Stairs = 0.6

EL13 *General Lighting in Guest Rooms* (Climate Zones: all)

The target LPD of 0.74 W/ft^2 in guest rooms assumes a typical room of 350 ft^2 and the lighting providing approximately 35 average maintained footcandles at the desk area and bedside table. The typical layout in Figure 5-14 uses a two-lamp 26 W CFL ceiling-mounted fixture at the entry, two 26 watt CFL wall sconces at the bedside table plus one 26 watt CFL wall sconce near the dresser/TV, and one 26 watt CFL table lamp on the desk. An additional 26 watt CFL floor lamp is added for supplemental lighting, but this lamp is not included in the 0.74 W/ft^2. (See HV14 for additional control recommendations.)

Bathroom lighting is provided by a two-lamp CFL surface decorative fixture for general area lighting and a two-lamp 4 ft T-8 fluorescent valance over the mirror. (See EL9 for information on vacancy sensors in bathrooms.)

EL14 *General Lighting in Corridors* (Climate Zones: all)

The target lighting in the corridors is 5 average maintained footcandles. To achieve the desired light levels, the luminaires in the corridor are a combination of 26 watt CFL ceiling mounted decorative luminaires and/or 26 watt CFL downlights for general lighting. Use 26 watt CFL wall sconces at the guest room door for task lighting and facial recognition. (See Figure 5-15.)

Circuit the wall sconces near the guest room doors and the decorative ceiling fixtures in the elevator lobby separate from the general lighting provided by downlights and/or ceiling decorative fixtures in the corridor. Use an ultrasonic ceiling-mounted occupancy sensor connected to the general lighting fixtures and set the time delay at the maximum allowed by the sensor.

EL15 *General Lighting in Laundry Area* (Climate Zones: all)

The target lighting in the laundry area is 30 average maintained footcandles. To achieve the desired light levels, use surface or recessed fluorescent luminaires with T-8 high-performance lamps and high-performance electronic ballasts. Use ceiling-mounted dual-technology occupancy sensors mounted in the center of the laundry area. Set sensitivity of occupancy sensors to high settings to avoid lights turning off when the space is occupied. (See Figure 15-16.)

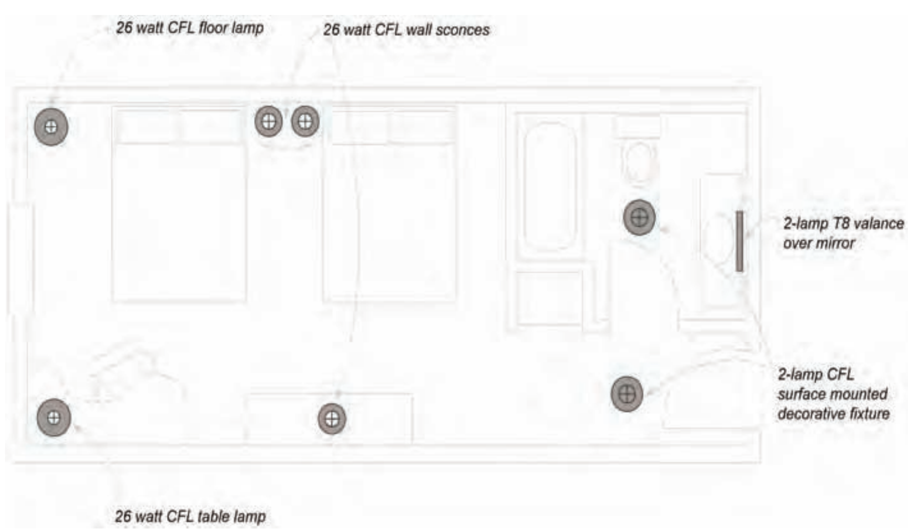


Figure 5-14. (EL13) Layout for guest rooms.

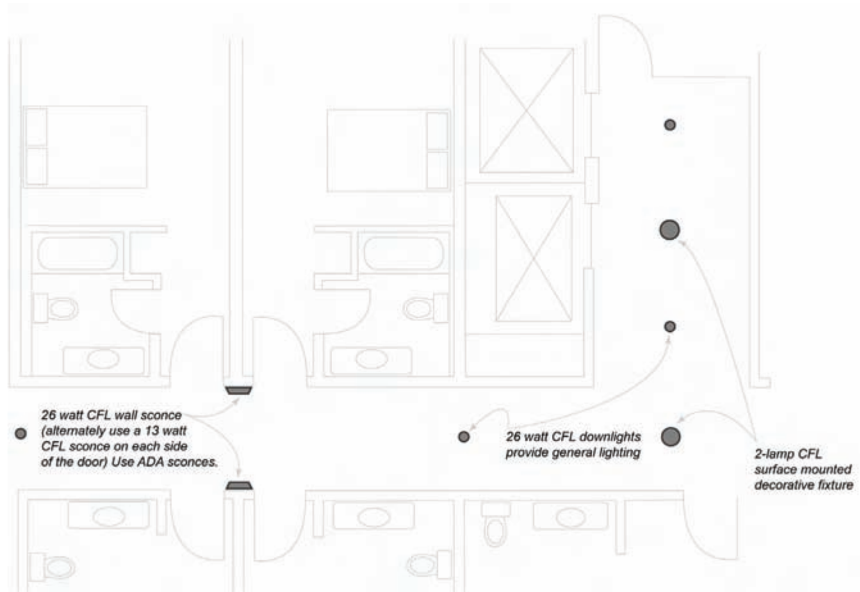


Figure 5-15. (EL14) Layout for corridors.

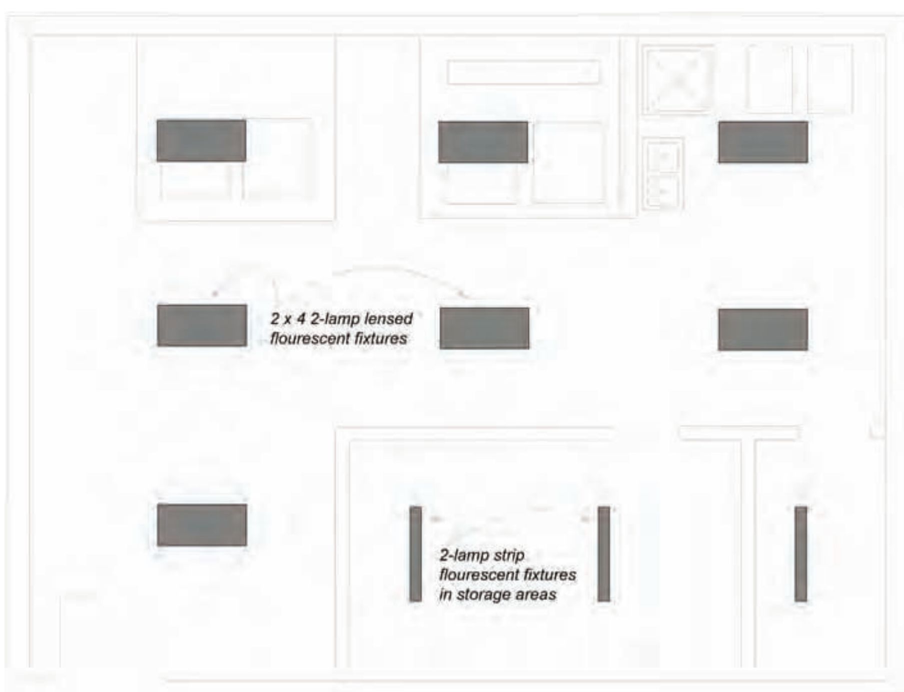


Figure 5-16. (EL15) Layout for laundry area.

EL16 *General Lighting in Lobby* (Climate Zones: all)

The target lighting in the lobby is 15 average maintained footcandles for ambient lighting with a total of at least 30 footcandles provided on and behind the reception counter by a combination of the ambient and supplemental task lighting. In Figure 5-17, 26 watt CFL downlights over the reception desk provide the general lighting and 26 watt CFL wall washers highlight the wall behind the desk. General lighting in the lobby area is provided by 26 watt CFL downlights and two-lamp 26 watt decorative surface or pendant fixtures to provide a decorative feel. The reception/dining area is lighted with 26 watt CFL downlights to provide an even, general light level while 26 watt CFL wall sconces and matching two-lamp 26 watt CFL decorative pendant fixtures define the architecture and soften the space. Use 26 watt CFL plug-in floor or table lamps in the reception area to provide a more residential feel.

EL17 *General Lighting in Other Spaces* (Climate Zones: all)

For the following applications use two-lamp T-8 high-performance lamps and high-performance ballasts (see EL4 for more information) in a recommended layout.

For office lighting use lensed or recessed basket or high-performance lensed fixtures. Use one fixture for every 64 ft^2 to achieve 0.9 W/ft^2. Rotate the fixture so the length of the lamps is perpendicular to the desk location if possible. In private offices, use a wall-switch mounted, manual ON, infrared occupancy sensor with a time delay of approximately 15 minutes. In larger, multi-person offices, use ceiling-mounted dual-technology occupancy sensors.

For exercise rooms, use lensed or recessed basket or high-performance lensed fixtures. Use one fixture for every 64 ft^2 to achieve 0.9 W/ft^2. Locate exercise equipment between (not under) light fixtures for user comfort. Use a ceiling-mounted dual-technology occupancy sensor to control all lights in the room.

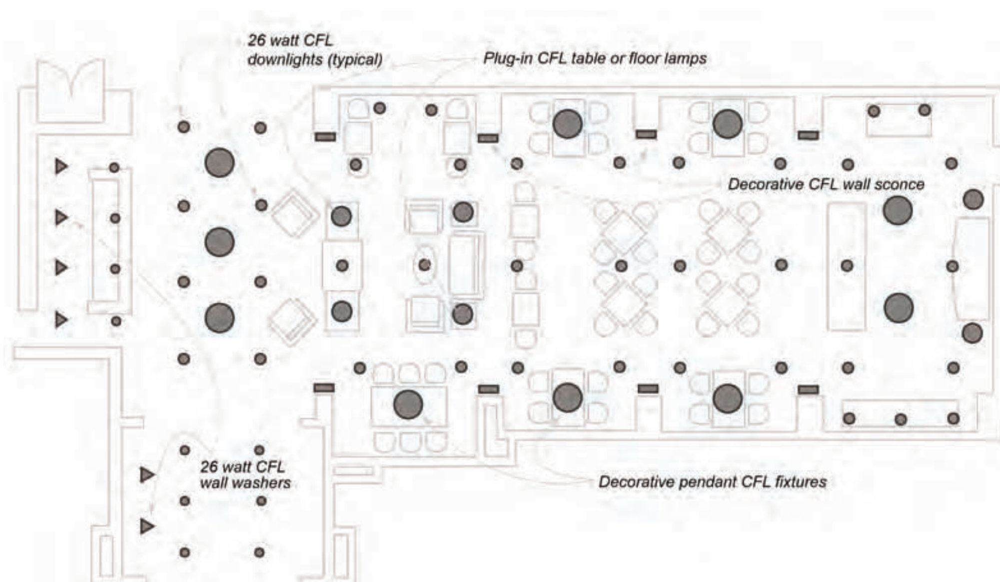


Figure 5-17. (EL16) Layout for lobby.

For meeting rooms, use three-lamp parabolic fluorescent fixtures. Use one fixture for every 100 ft^2 to achieve 0.85 W/ft^2. Add CFL wall washers to highlight the presentation wall—do not exceed 1.1 W/ft^2 total for the meeting room. Use a ceiling-mounted dual-technology occupancy sensor to control all of the lights in the room. Switch the center lamps in the three-lamp parabolics on one switch and separately switch the two outer lamps in all fixtures to provide three levels (33%, 66%, 100%) of lighting. Switch the wall washers separately from the parabolic fixtures.

For stairs use a two-lamp T-8 lensed wall or ceiling-mounted fixture at each landing. Use luminaires with an integrated occupancy sensor on all fixtures that provides a bi-level, low light level when the space is unoccupied and full light when occupied.

Lighting in other spaces including restrooms, electrical/mechanical rooms, break rooms, workshops, business centers, and other spaces should be limited to 0.9 W/ft^2, which is equivalent to about one two-lamp high-performance T-8 luminaire every 64 ft^2. Use switch-mounted occupancy sensors in spaces up to 150 ft^2. Use ceiling-mounted dual-technology occupancy sensors in spaces greater than 150 ft^2. Caution should be used in workshops and electrical/mechanical rooms when using occupancy sensors to ensure that the sensor can see all of the room, especially into areas with power tools and areas with machinery that need to be serviced. These areas should not be left controlled by only a manual switch, and electronic timers that provide a warning flash that the lights are about to turn off may be more appropriate than occupancy sensors.

References

ASHRAE. 2004. *Advanced Energy Design Guide for Small Office Buildings*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

EPRI. 1996. *EPRI Lighting Controls—Patterns for Design*. New York: Electric Power Research Institute. (available from Illuminating Engineering Society of North America)

USGBC. 2005. LEED NC Indoor Environment Quality Credit 6.1, "Controllability of Systems: Lighting." Washington, DC: U.S. Green Building Council.

Exterior Electric Lighting

Good Design Practice

Exterior lighting should be designed to maintain a safe and secure environment while limiting light pollution and light trespass off of the property. First determine your lighting zone from the table.

Parking lot lighting locations should be coordinated with landscape plantings so that tree growth does not block effective lighting from pole-mounted luminaires.

Parking lot lighting should not be significantly brighter than lighting of the adjacent street. Follow Illuminating Engineering Society of North America (IESNA) recommendations from IES RP-20-98, Table 1, for uniformity and light levels.

For parking lot and grounds lighting, do not increase luminaire wattage in order to use fewer lights and poles, which will increase contrast. Increased contrast makes it harder to see at night beyond the immediate luminaire location, making the area appear less safe. Flood lights and non-cutoff wall-packs should not be used, as they cause hazardous glare and unwanted light encroachment on neighboring properties. Limit lighting in parking and drive areas to not more than 320 watt pulse-start metal halide lamps at a maximum 20 ft mounting height in urban and suburban areas (luminaire height should be proportional to the building height). Use luminaries that produce 0% uplight (formally known as full-cutoff fixtures) to help eliminate light pollution. Parking luminaires should incorporate house side shielding and/or forward throw optics and should be located facing into the property to help eliminate light trespass.

EL18 *Exterior Lighting Power* (Climate Zones: all)

A base site allowance of 500 W for Lighting Zone 1, 600 W for Lighting Zone 2, or 750 W for Lighting Zone 3 is added to the following allowable wattage (see Table 5-3).

Calculate allowed LPD from Table 5-4 only for paved or improved areas of the site, excluding grounds that do not require lighting. Use internally illuminated or downward-facing sign lighting to minimize light trespass and light pollution.

EL19 *Exterior Lighting Sources* (Climate Zones: all)

All general lighting luminaires should utilize pulse-start metal halide, CMH, LED, fluorescent, or compact fluorescent amalgam lamps with electronic ballasts.

Standard high-pressure sodium lamps are not recommended due to their poor color-rendering characteristics. Incandescent lamps are not recommended.

For colder climates, fluorescent and CFL luminaires must be specified with cold temperature ballasts. When using CLF luminaires, specify amalgam lamps.

EL20 *Exterior Lighting Controls* (Climate Zones: all)

Use an astronomical time switch or a combination of a photo-sensor and a time switch for all exterior lighting. Astronomical time switches are capable of retaining programming and time settings during power outages for a period of at least seven days. If a building energy management system is being used to control and monitor mechanical and electrical energy use, it also can be used to schedule and manage outdoor lighting energy use. Turn off exterior lighting not designated for security purposes when the building is unoccupied.

EL21 *Decorative Façade Lighting* (Climate Zones: all)

Façade lighting can provide additional attention to guests and improve feelings of safety and security.

Following lighting zone definitions in Table 5-3, limit exterior decorative façade lighting to 0.15 W/ft^2 for Lighting Zone 3 and 0.10 W/ft^2 for Lighting Zone 2 of the illuminated surface. Due to the sensitive nature of Lighting Zone 1, façade lighting should not be used, thus no watts have been allocated to highway lodging in this area. These limits do not include lighting of walkways or entry areas of the building that may also light the building itself. Limit the lighting equipment mounting locations to the building, and do not install floodlights onto nearby parking lot lighting poles. Locate luminaires so that their light does not impact guest rooms.

Table 5-3. Lighting Zone Descriptions

Lighting Zone	Description
1	Developed areas of National Parks, State Parks, Forest Land, and Rural areas
2	Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas
3	All other areas

Table 5-4. Lighting Power Density by Space Type and Lighting Zone

	Lighting Zone 1	Lighting Zone 2	Lighting Zone3
Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2
Walkways less than 10 ft wide	0.7 W/linear foot	0.7 W/linear foot	0.8 W/linear foot
Walkways 10 ft wide or greater and plaza areas	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2
Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2

References

IESNA. 1998. *IES RP-20-1998, Lighting Parking Facilities*. New York: Illuminating Engineering Society of North America.

IESNA. 1999. *IES RP-33-99, Lighting for Exterior Environments*. New York: Illuminating Engineering Society of North America.

LRC. 1996. *Outdoor Lighting Pattern Book*. Troy, NY: Lighting Research Center. Available for purchase from www.lightingresearch.org. NBI. 2003. *Advanced Lighting Guidelines*. White Salmon, WA: New Buildings Institute. www.newbuildings.org/lighting.htm.

USGBC. 2005. LEED NC Sustainable Sites Credit 8, “Light Pollution Reduction.” Washington, DC: U.S. Green Building Council.

HVAC

Good Design Practice

HV1 *General* (Climate Zones: all)

The HVAC equipment for this Guide includes packaged unit systems and split systems generally referred to as *air conditioning* or *heat pump* units (see Figure 5-18). These systems are suitable for projects with no central plant. This Guide also covers water-source or ground-source heat pumps, but not systems that use liquid water chillers or purchased chilled water for cooling, nor oil, hot water, solar, steam, or purchased steam for heating. These systems are alternative means that may be used to achieve the energy savings target of this Guide.

The systems included in this Guide are available in pre-established increments of capacity with a refrigeration cycle and heating source. The components are factory designed and assembled and include fans, motors, filters, heating source, cooling coil, refrigerant compressor, controls, and condenser. The components can be in a single package or a split system that separates the evaporator and condenser sections.

Performance characteristics vary among manufacturers, and the selected equipment should match the calculated heating and cooling loads (sensible and latent), also taking into account the importance of meeting latent cooling loads under part-load conditions. The equipment should be listed as being in conformance with electrical and safety standards with its performance ratings certified by a nationally recognized certification program.

See HV3, for calculating the loads, HV4 for meeting latent cooling loads under part-load conditions, and HV13 for recommendations on zoning the building.

Single packaged units can be mounted on the roof, at grade level, or indoors. Split systems generally have the blower unit, including filters and coils, located indoors or in unconditioned space and the condensing unit outdoors on the roof or at grade level. On smaller systems, the blower is commonly incorporated in an indoor furnace section. The blower unit may also be located outdoors, and if so, should be mounted on the roof to avoid ductwork outside the building envelope. (See HV9 for a further discussion on the ductwork recommendations.)

The equipment should be located in a position that results in minimizing fan power, ducting, and wiring. Water-source heat pumps may be floor-mounted, console-style within the room, or suspended in ceiling space. The hydronic tempered water loop is typically equipped with a heat source, such as a boiler, to maintain the temperature of the circulating fluid above a preset minimum when the next heat extraction from the loop by the heat pumps might reduce that temperature to an unacceptable level. The circulating loop is also usually equipped with a heat rejection device such as a cooling tower or closed-circuit fluid cooler to maintain the circulating fluid temperature below a preset maximum when net heat addition to the loop might raise the temperature above

(a)

(b)

(c)

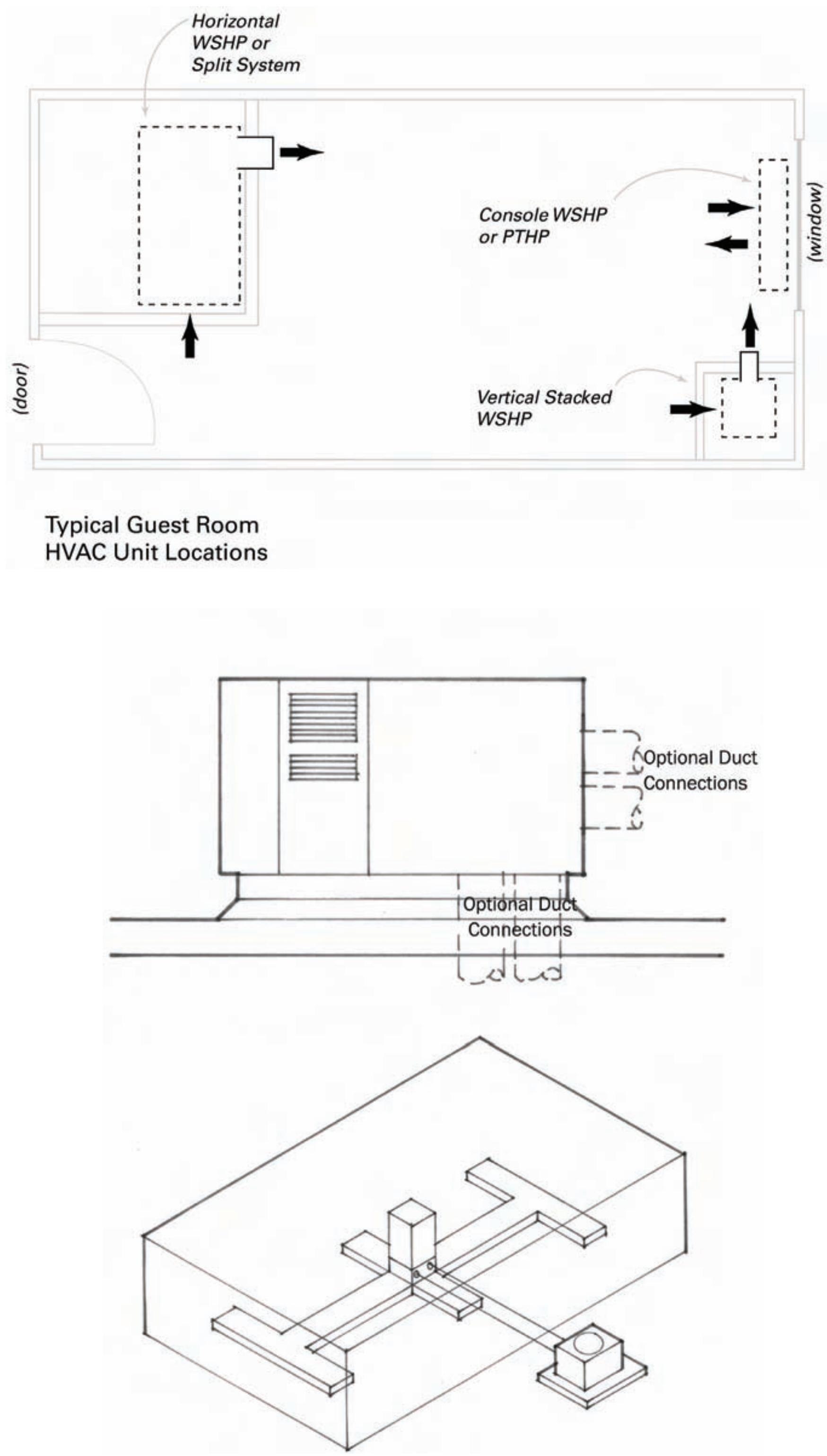


Figure 5-18. (HV1) Typical (a) guest room, (b) public space HVAC equipment, and (c) duct system layout.

operable levels. Ground coupled heat pump systems utilize the thermal mass of the earth as both a heat source and heat sink, often avoiding the necessity of a cooling tower and boiler for the circulating loop. (See Figure 5-18 for examples of typical HVAC equipment and duct system layouts.)

HV2 *HVAC System Types* (Climate Zones: all)

This Guide considers air- and water-cooled packaged unit systems and split systems with refrigerant-based direct expansion (DX) systems for electric cooling and heating by means of one of the three following options:

Option 1: Through wall air-conditioning units with either cooling-only or heat pump-compressor cycle and with optional supplemental heat, electric resistance, or fossil-fuel-fired (gas or oil) hydronic coils.

Option 2: Split system heat pump or air-conditioning units with gas- or oil-fired furnaces, or fan-coils incorporating hydronic coils served by fossil-fuel-fired boilers, or electric resistance coils.

Option 3: Water source heat pumps with gas- or oil-fired boilers for water loop heat make-up and hydronic space heating.

Option 4: Packaged variable-volume systems with electric resistance or hydronic heating coils served by fossil-fuel-fired boilers (for public areas only).

Guest rooms typically utilize one packaged unit per room to give individual on-off and thermostatic control. Public areas and back-of-house spaces may also utilize systems that condition multiple rooms with a single air-conditioning unit.

The most common air-conditioning units for guest rooms are the packaged through-wall units available with either compressorized cooling-only cycle and optional electric resistance or hydronic heat (packaged terminal air conditioning [PTAC]) or with heat pump reverse cycle heating and cooling (packaged terminal heat pump [PTHP]) and optional supplemental electric heat. Facilities utilizing through-wall units with electric heat in climate zones 2 through 6 should select PTHP units. In climate zones 6, 7, and 8, through-wall heat units (PTAC, PTHP) may not be acceptable because of excessive air infiltration and heat conduction through the wall sleeve, and split system air-source or water-source heat pumps can be used to avoid excessive envelope loads. PTHPs also typically do not operate in heat pump cycle at exterior temperatures below approximately 25°F. Air-source split system heat pumps with extended operation range (maximum 12°F) should be used for all-electric applications in climate zones 7 and 8. Electric resistance heaters can be part of the factory-assembled fan-coil unit or can be installed in the duct distribution system. Heat pumps, either split system or PTHP that operate at exterior temperatures of 40°F or below should incorporate a defrost cycle to remove ice from the exterior coils. An auxiliary heat source is required to provide heat for both the space and the defrost cycle itself while the cycle is in operation.

In the coldest climates (climate zone 8), cooling, if included at all in the facility, may not represent a significant component in energy consumption. For these applications, hydronic baseboard heaters served by high-efficiency gas or oil boilers would represent a cost-effective energy-efficient conditioning alternative.

For water-source heat pump systems, gas- or oil-fired boilers are the most common source of make-up heat for the circulating fluid. These boilers may also provide hot water at a higher temperature to meet locally intense ancillary heating requirements.

Where variable-air-volume (VAV) systems are used, the refrigeration system requires the ability to reduce capacity in response to reduced load. The packaged unit should be designed to maintain the required apparatus dew point for humidity control during part-load operation. The controls of a variable-air-volume system should be arranged to reduce the supply air to the minimum setpoint for ventilation before tempering of the air occurs. Variable-speed drives should be considered as an option to reduce airflow and fan/motor energy.

HV3 *Cooling and Heating Loads* (Climate Zones: all)

Cooling and heating system design loads should be calculated in accordance with generally accepted engineering standards and handbooks such as *ASHRAE Handbook—Fundamentals* or *ACCA Manual N*. Any safety factor applied should be done cautiously and applied only to a building's internal loads to prevent oversizing of equipment. If the unit is oversized and the cooling capacity reduction is limited, short cycling of compressors could occur and the system may not have the ability to dehumidify the building properly. Include the cooling and heating load of the outdoor air to determine the total cooling and heating requirements of the unit. In determining cooling requirements, the sensible and latent loads to cool the outdoor air to the required room dry-bulb and dew-point temperatures must be added to the building cooling load. For heating, the outdoor air brought into the space must be heated to the minimum allowable space temperature and the heat required added to the building heat loss. On VAV systems, the minimum supply airflow to a zone should be taken into account in calculating heating loads of the outdoor air.

HV4 *Temperature and Humidity Control* (Climate Zones: all)

The sensible cooling load in a building is not necessarily proportional to the latent load, and in humid climates, high relative humidity levels can occur during low sensible load periods. Select systems that maintain low apparatus dew point during part-load operation and provide humidity control during low sensible load periods. Variable-air-volume and multiple capacity or variable-speed compressors not only maintain humidity control but also provide enhanced energy efficiency during part-load operation. These systems also avoid the cycling losses that are inherent to non-unloading systems that must continuously turn on and off to avoid over cooling. Systems that employ supply air temperature reset controls must be added to ensure that the relative humidity within the space does not exceed 60%. Guest rooms, in some climate zones, may have periods of time that require some dehumidification with little or no sensible cooling load. Humidity control through ventilation air dew-point temperature management or through occasional cycling of the guest room cooling unit to provide dehumidification should be considered in those climates.

In cold climates, significant energy savings can accrue by lowering guest room space temperatures during unoccupied periods. Consider specification of guest room space thermostats that can be remotely reset according to projected occupancy.

HV5 *Equipment Efficiency* (Climate Zones: all)

The cooling equipment should meet or exceed the listed seasonal energy efficiency ratio (SEER) or energy efficiency ratio (EER) for the required capacity. The cooling equipment should also meet or exceed the integrated part-load value (IPLV) where shown. Water-source heat pumps shall exceed the listed EER for 85°F circulating water temperature.

Heating equipment should meet or exceed the listed annual fuel utilization efficiency (AFUE) or thermal efficiency for indirect gas-fired heaters at the required capacity. For heat pump applications, the heating efficiency should meet or exceed the listed heating seasonal performance factor (HSPF) or coefficient of performance (COP) for the required capacity based on 47°F outdoor air temperature or, for water source heat pumps, based upon a 68°F circulating water temperature.

HV6 *Ventilation Air* (Climate Zones: all)

The zone-level outdoor airflows and the system-level intake airflow should be determined based on the current version of ASHRAE Standard 62.1, but should not be less than the values required by local code unless approved by the authority with jurisdiction. The number of people used in computing the breathing zone ventilation rates should be based on known occupancy, local code, or the default values listed in ASHRAE Standard 62.1.

For example, for hotels, ASHRAE Standard 62.1 recommends 0.06 cfm/ft^2 of occupied floor space plus 5 or 7.5 cfm per person, depending upon occupancy type. This ventilation rate is consistent with the 25 cfm continuous exhaust requirement stipulated in many codes for private restrooms, as would be part of a hotel room.

Outdoor air may be supplied to the space either by introducing outdoor air into the airstream provided to the room by the conditioning unit or by provision of outdoor air through a separate stream (see Figure 5-19). Appropriately located manual balancing dampers and, in some cases of complex ductwork, constant-air-volume (CAV) terminals should be included in the design to insure appropriate balancing and distribution of ventilation air within the ductwork system. For dedicated outdoor air systems (DOAS), heating and/or cooling of the ventilation air is highly recommended in climates with extreme hot or cold weather conditions to avoid local discomfort near the room ventilation supply point. Low leakage outdoor air dampers with positive closure should be provided for any outdoor air system that does not operate continuously.

For non-guest-room, or other spaces with significant internal heat gains, an air economizer mode can save energy by using outdoor air for cooling in lieu of mechanical cooling when the temperature of the outdoor air is low enough to meet the cooling needs. The system should be capable of modulating the outdoor air, return air, and relief air dampers to provide up to 100% of the design supply air quantity as outdoor air for cooling.

Systems should use a motorized outdoor air damper instead of a gravity damper to prevent outdoor air from entering during unoccupied periods when the unit may recirculate air to maintain setback or setup temperatures. The motorized outdoor air damper for all climate zones should be closed during the full unoccupied period except where it may open in conjunction with an economizer cycle.

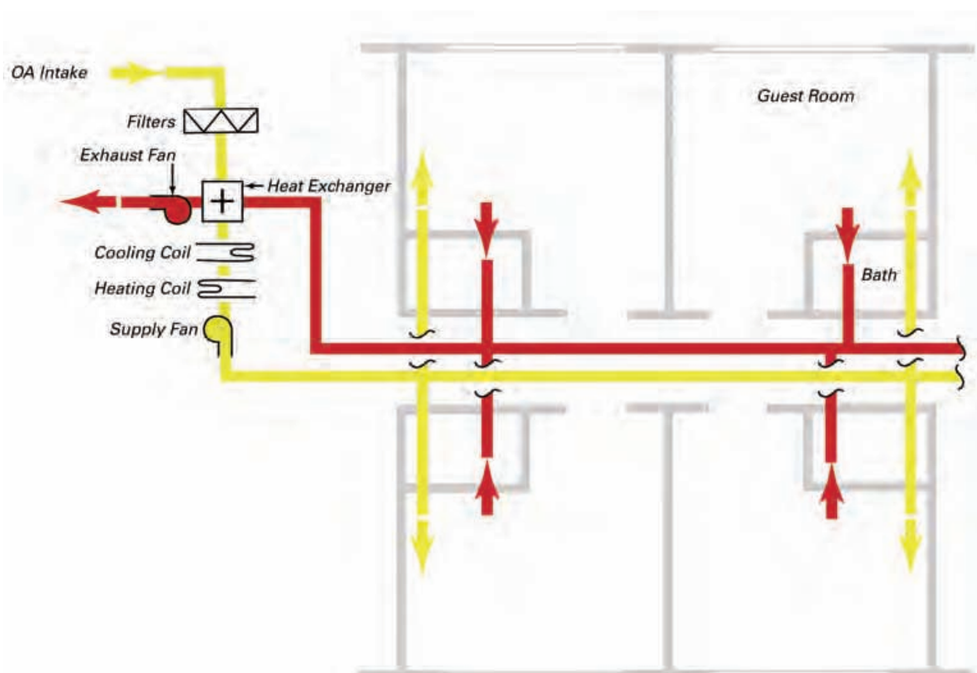


Figure 5-19. (HV6) Example of ventilation system.

Demand control ventilation (DCV) should be used in areas such as meeting and conference rooms that have varying and high-occupancy loads during the occupied periods to vary the amount of outdoor air in response to the need in a zone. The amount of outdoor air could be controlled by carbon dioxide (CO_2) sensors, as a proxy for the adequacy of ventilation, that measure the change in CO_2 levels in a zone relative to the levels in the outdoor air. A controller will operate the outdoor air, return air, and relief air dampers to maintain proper ventilation. (See VC1 for more discussion on DCV and HV14 for methods of operating the system efficiently.)

HV7 *Exhaust Air* (Climate Zones: all)

Zone exhaust airflows (for toilet rooms, janitorial closets, kitchens, etc.) should be determined based on the current version of ASHRAE Standard 62.1 or by local code, whichever is more stringent.

Guest room toilet exhaust systems will typically operate continuously, whether or not the room is occupied and whether or not the room air-conditioning unit is operating. Controlled reduction of ventilation rates to rooms determined to be unoccupied can result in additional energy savings. (See VC1 and VC2.)

Central exhaust systems for non-guest-room toilets, janitor closets, etc. should be interlocked to operate with the air-conditioning or heat pump unit except during unoccupied periods. These exhaust systems should have a motorized damper that opens and closes with the operation of the fan. The damper should be located as close as possible to the duct penetration of the building envelope to minimize conductive heat transfer through the duct wall and avoid having to insulate the duct. During unoccupied periods, the damper should remain closed and the exhaust fan turned off—even while the air-conditioning or heat pump unit is operating—to maintain setback or setup temperatures.

HV8 *Energy Recovery* (Climate Zones: all)

Total energy recovery equipment can provide an energy-efficient means to deal with the latent and sensible outdoor air cooling loads during peak summer conditions. It also can reduce the required heating of outdoor air in cold climates.

Exhaust air energy recovery can be provided through a separate energy recovery ventilator (ERV) that conditions the outdoor air before entering the air-conditioning or heat pump unit, an energy recovery unit that attaches to an air-conditioning or heat pump unit, or an air-conditioning or heat pump unit with the energy recovery unit built into it.

For maximum benefit, energy recovery designs should provide as close to balanced outdoor and exhaust airflows as is practical, taking into account the need for building pressurization and any exhaust that cannot be incorporated into the system. For hotel guest rooms, heat recovery can be provided between a central toilet exhaust system and a central ventilation air supply system.

In cold climates, make-up air for continuous toilet exhaust from guest rooms with little internal heat gains can require significant energy consumption for space heating. Heat recovery can reduce this heat loss significantly, tempering energy requirements for outdoor air heat but imposing higher fan energy consumption due to increased pressure drop through heat exchangers. Analysis is required to determine whether reduced thermal energy consumption for outdoor air tempering offsets increased fan energy consumption.

HV9 *Ductwork Distribution* (Climate Zones: all)

The lobby and public spaces of many highway lodging buildings use unitary rooftop systems with minimal to no ductwork. This is a less desirable design option that should be avoided because non-ducted systems have more difficulty achieving proper airflow and ventilation, often resulting in poor air quality.

Air should be ducted through low-pressure ductwork with system pressure classification of fewer than 2 in. Where practical, rigid ductwork is preferred. Supply air should be ducted to supply diffusers in each individual space. Return air should be ducted from return registers provided in appropriate locations for proper airflow, but not necessarily in every space. The ductwork should be as direct as possible, minimizing the number of elbows, abrupt contractions and expansions, and transitions. Long-radius elbows and 45° lateral take-offs should be used wherever possible. Where VAV systems are used, they should have single-duct air terminal units to control the volume of air to the zone based on the space temperature sensor.

In general, the following sizing criteria should be used for the duct system components:

a. Diffusers and registers should be sized with a static pressure drop no greater than 0.08 in.
b. Supply and return ductwork should be sized with a pressure drop no greater than 0.08 in. per 100 linear feet of duct run.
c. Flexible ductwork should be of the insulated type and should be
   1. limited to connections between duct branch and diffusers,
   2. limited to connections between duct branch and VAV terminal units,
   3. limited to 5 ft (fully stretched length) or less,
   4. installed without any kinks,
   5. installed with a durable elbow support when used as an elbow,
   6. installed with no more that 15% compression from fully stretched length, and
   7. hanging straps, if used, need to use a saddle to avoid crimping the inside cross-sectional area. For ducts with 12 in. or less diameter use a 3 in. saddle, for larger than 12 in. use a 5 in. saddle.

Ductwork should not be installed outside the building envelope in order to minimize heat gain to or heat loss from the ductwork due to outdoor air temperatures and solar heat gain. Ductwork on rooftop units should enter or leave the air-conditioning or heat pump unit through an insulated roof curb around the perimeter of the air-conditioning or heat pump unit's footprint.

Duct board should be airtight (duct seal level B, from ASHRAE/IESNA Standard 90.1) and should be taped and sealed with products that maintain adhesion. Duct static pressures should be designed and equipment and diffuser selections should be selected to not exceed the noise criteria for the space. (See HV23 for additional information.)

HV10 *Duct Insulation* (Climate Zones: all)

All supply air ductwork should be insulated according to the requirements of ASHRAE/IESNA Standard 90.1 or local code, whichever is more stringent. All return air ductwork located above the ceiling and below the roof should be insulated. Any outdoor air ductwork should be insulated. All exhaust and relief air ductwork between the motor-operated damper and penetration of the building exterior should be insulated.

Include a vapor barrier on the outside of the insulation where condensation is possible. The vapor barrier should be sealed to prevent air intrusion and resulting condensation in the insulation.

Exception: In conditioned spaces without a finished ceiling, only the supply air duct mains and major branches should be insulated. Individual branches and run-outs to diffusers in the space being served do not need to be insulated, except where it may be necessary to prevent condensation.

HV11 *Duct Sealing and Leakage* (Climate Zones: all)

The ductwork should be sealed for Seal Class B from ASHRAE/IESNA Standard 90.1 and leak tested at the rated pressure. The leakage should not exceed the allowable cfm/100 ft^2 of duct area for the seal and leakage class of the system's air quantity apportioned to each section tested. (*See HV15 for guidance on ensuring the air system performance.)*

HV12 *Fan and Pump Motors* (Climate Zones: all)

Motors for fans or pumps 1 horsepower or greater should meet National Electric Manufacturers Association (NEMA) premium efficiency motor guidelines when available.

HV13 *Thermal Zones* (Climate Zones: all)

Public spaces for highway lodging should be divided into thermal zones based on building size, part-load performance requirements, space layout and function, number of occupants, and the needs of the user. Each guest room in a highway lodging building should be a separate temperature control zone. The lobby also should have a separate temperature control because of entranceway infiltration zones. Each meeting room should also be a separate temperature control zone. Large rooms with exterior exposure may require separate zoning for perimeter and interior areas.

Zoning also can be accomplished using multiple air-handling units or by having multiple zone control with a single air-handling unit. The temperature sensor for a zone should be installed in a location representative of that entire zone.

HV14 *Control Strategies* (Climate Zones: all)

Control strategies can be designed to help reduce energy. Time-of-day scheduling is useful when it is known which portions of the building public space will have reduced occupancy. Control of the ventilation air system can be tied into this control strategy.

Having a setback temperature for unoccupied periods during the heating season or setup temperature during the cooling season will help to save energy. A pre-occupancy operation period will help purge the building of contaminants that build up overnight from the out-gassing of products and packaging materials. In hot, humid climates, care should be taken to avoid excessive relative humidity conditions during unoccupied periods.

In guest rooms, limiting conditioning during unoccupied periods can save significant amounts of energy in most climate zones. Guest room energy management control systems should be installed to manage the guest room air-conditioning system for occupied and unoccupied time periods. The guest room thermostat automatically reverts to unoccupied setpoints (usually 4°F from setpoint) when the passive infrared (PIR) sensor in conjunction with the door switch determines that the room is indeed unoccupied.

In addition, the same occupancy controls can interface with low-voltage guest room lighting controls, allowing the guest room lighting to be off when the thermostat determines that the room is unoccupied. The lighting devices are controlled by the guest when in the room but turn off automatically when the guest leaves the room. Entry lights are energized when the guest door opens, allowing the guest to always enter a lighted room. (See EL9, EL10, and EL13 for additional lighting control recommendations.**)**

This method of control also complies with the intent of the National Electric Code (NEC) requirements for a master switch. The same occupancy controls could also be used to shut off (or reduce) ventilation and exhaust airflows. While these strategies are not needed to achieve 30% are energy savings, they are discussed in the Bonus Savings section (see VC1).

HV15 *Testing, Adjusting, and Balancing (TAB)* (Climate Zones: all)

After the system has been installed, cleaned, and placed in operation, the system should be tested, adjusted, and balanced for proper operation. This procedure will help to ensure that the correctly sized diffusers, registers, and grilles have been installed, each space receives the required airflow, the equipment meets the intended performance, and the controls operate as intended. The TAB subcontractor should certify that the instruments used in the measurement have been calibrated within 12 months prior to use. A written report should be submitted for inclusion in the O&M manuals.

HV16 *Filters* (Climate Zones: all)

Air-conditioning and heat pump unit filters are included as part of the factory-assembled unit and should be at least MERV 8, based on ASHRAE Standard 52.2. On constant-volume systems, use a filter differential pressure gauge to monitor the pressure drop across the filters. The gauge should be checked and the filter inspected on a routine basis. Filters should be replaced when the filter's pressure drop exceeds the filter manufacturer's recommendations for replacement or when visual inspection indicates the need. A monitor should be included to send an alarm if the predetermined pressure drop is exceeded. Upon completion of construction, all filters should be replaced prior to building occupancy.

HV17 *Boilers* (Climate Zones: ❸ ❹ ❺ ❻ ❼ ❽)

Boilers used for heat make-up for water-source heat pump systems should take advantage of the extremely low temperatures at which this heat can be delivered. The typical operating temperature range for the circulating loop for water-source heat pumps is between 60°F and 90°F. The boiler is cycled on to provide make-up heat when the loop temperature reaches the lower limit of the range. Condensing-type boilers can deliver efficiencies of as high as 94% when used with entering water temperatures below 70°F.

HV18 *Pumping Systems for Water-Source Heat Pumps* (Climate Zones: all)

Pumping energy can contribute significantly to the energy consumption of water-source heat pump systems. Pumps for water source heat pumps should be variable speed and individual heat pumps should incorporate solenoid valves that shut when the heat pump compressor is inoperative.

HV19 *Cooling Towers for Water-Source Heat Pumps* (Climate Zones: all)

The energy consumption of water-source heat pumps in cooling mode can rise more than 1% for each degree Fahrenheit rise in water temperature above 70°F. Cooling towers should be equipped with controls and with variable-speed fan drives to enable them to operate at varying water flow conditions to achieve the lowest circulating loop water temperature above 70°F.

HV 20 *Water-Source Heat Pump Circulating Loop Water Quality* (Climate Zones: all)

The energy efficiency of heat pumps is significantly affected by a fouling factor that, as it increases, impedes heat transfer between the refrigerant in the unit and the circulating water loop. Use a plate and frame heat exchanger or a closed-circuit fluid cooler to separate the circulating loop fluid from the open-loop evaporative water cycle to reduce the fouling factor in the heat pump units. Consistent use of appropriate cooling tower water treatment, including appropriate biocides, will reduce fouling and improve heat transfer on the open side of the heat exchanger.

Cautions

HV21 *Heating Sources* (Climate Zones: all)

Forced air electric resistance and gas-fired heaters require a minimum airflow rate to operate safely. These systems, whether stand-alone or incorporated into an air-conditioning or heat pump unit, should include factory-installed controls to shut down the heater when there is inadequate airflow resulting in high air temperatures.

HV22 *Relief and Return Air* (Climate Zones: all)

Relief (rather than return) fans or blowers should be used when necessary to maintain building pressurization in public areas during economizer operation. However, where return duct static pressure drop exceeds 0.5 in. of water, return fans may be needed.

HV23 *Noise Control* (Climate Zones: all)

Acoustical requirements may necessitate attenuation of the noise associated with the supply and/or return air, but the impact on fan energy consumption should also be considered and, if possible, compensated for in other duct or fan components. Acoustical concerns may be particularly critical in short, direct runs of ductwork between the fan and supply or return outlet.

Where practical, avoid installation of the air-conditioning or heat pump units above office and break areas. Consider locations above less critical spaces such as storage areas, toilet rooms, corridors, etc. (See Figures 5-20 and 5-21 for typical noise paths for HVAC units).

HV24 *Heating Supply Air Temperatures* (Climate Zones: all)

Ducts and supply air registers should be selected based on discharge air temperature and flow rate. Supply temperature should be selected by optimizing for highest energy efficiency of heating and cooling sources, reduced thermal transport energy (fans and pumps), ventilation effectiveness, and space air distribution (avoiding unwanted stratification).

HV25 *Zone Temperature Control* (Climate Zones: all)

The number of spaces in a zone and the location of the temperature-sensing point will affect the control of temperature in the various spaces of a zone. Locating the thermostat in one room of a zone with multiple spaces only provides feedback based on the conditions of that room. Locating a single thermostat in a large open area may provide a better response to the conditions of the zone with multiple spaces. Selecting the room or space that will best represent the thermal characteristics of the space due to both external and internal loads will provide the greatest comfort level.

To prevent misreading of the space temperature, zone thermostats should not be mounted on exterior walls. Where this is unavoidable, use an insulated sub-base for the thermostat.

HV26 *Economizers* (Climate Zones: 3 4 5 6 7 8)

Economizers, when recommended, should be employed on air conditioners for public areas to help save energy by providing free cooling when ambient conditions are

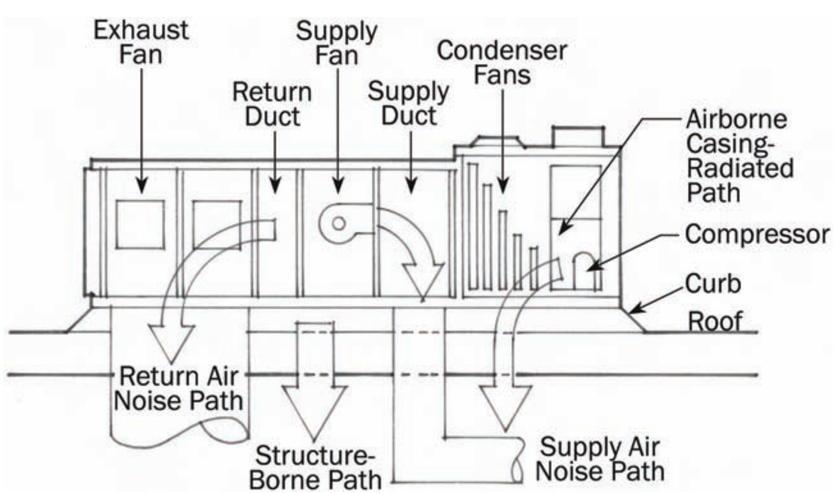


Figure 5-20. (HV23) Typical noise paths for rooftop-mounted HVAC units.

suitable to meet all or part of the space cooling load. Consider using enthalpy controls (vs. dry-bulb temperature controls) to help ensure that unwanted moisture is not introduced into the space in hot, humid climates. Economizers are not recommended in climate zone 1. There may be some applicability in dry climate areas in climate zone 2. Periodic maintenance is important with economizers as dysfunctional economizers can cause substantial excess energy consumption due to malfunctioning dampers and/or sensors.

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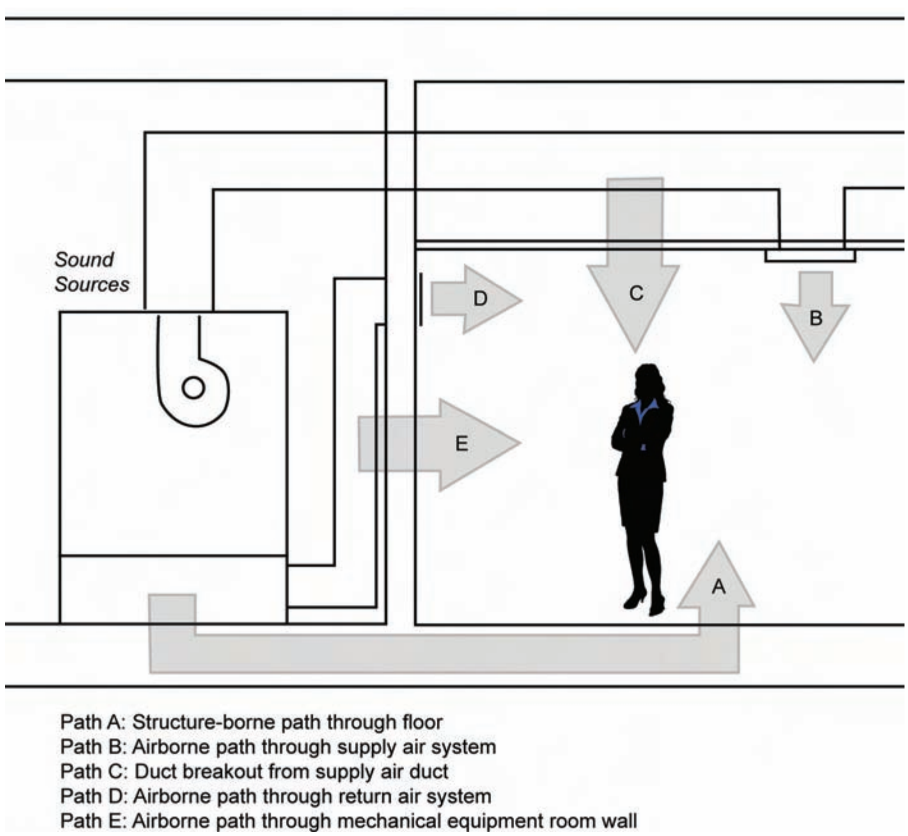

Figure 5-21. (HV23) Typical noise paths for interior-mounted HVAC units.

SERVICE WATER HEATING

Good Design Practice

WH1 Service Water Heating Types (Climate Zones: all)

Service water heating (SWH) constitutes a significant fraction of the total energy usage of highway lodging facilities in all climate zones. Significant energy savings can be achieved by examining each of the components that provide the heated water and control its use.

Recommendations on the SWH equipment for this guide take into account the type of fuel source used for the HVAC heating system. This Guide does not cover systems that use oil, hot water, steam, or purchased steam for generating service water SWH. The Guide also does not address the use of solar or site-recovered energy (including heat pump water heaters). These systems are alternative means that may be used to achieve 30% or greater savings over ASHRAE/IESNA Standard 90.1 and, where used, the basic principles of this Guide would apply.

The SWH equipment included in this Guide for the HVAC options listed in HV2 are the gas-fired water heater and the electric water heater.

Both natural gas and propane fuel sources are available options for gas-fired units.

WH2 Service Water Heating System Descriptions (Climate Zones: all)

1. **Gas-fired storage water heater.** A water heater with a vertical or horizontal water storage tank. A thermostat controls the delivery of gas to the heater's burner. The heater requires a vent to exhaust the products of combustion.

2. **Gas-fired instantaneous water heater.** A water heater with minimal water storage capacity. The heater requires a vent to exhaust the products of combustion. An electronic ignition is recommended to avoid the energy losses from a standing pilot.

3. **Electric resistance storage water heater.** Water heater consisting of a vertical or horizontal storage tank with one or more immersion heating elements. Thermostats controlling heating elements may be of the immersion or surface-mounted type. For typical highway lodging office applications, small water heaters are available from 2–20 gal.

4. **Electric resistance instantaneous water heater.** Compact, under-cabinet or wall-mounted type with insulated enclosure and minimal water storage capacity. A thermostat controls the heating element, which may be of the immersion or surface-mounted type. Instantaneous, point-of-use water heaters should provide water at a constant temperature regardless of input water temperature.

WH3 Service Water Heater Sizing (Climate Zones: all)

The water heating system should be sized to meet the anticipated peak hot water load, typically occurring early morning in most highway lodging facilities. Each occupant of the facility can be expected to utilize between 15 and 20 gal of hot water during the morning period. While shower faucets are required by code to utilize thermostatic mixing valves to avoid injuries due to scalding, the supply water temperature should be no higher than 130°F to avoid lavatory scalding incidents.

WH4 Service Water Heating Equipment Efficiency (Climate Zones: all)

Efficiency levels are provided in this Guide for gas-fired instantaneous, gas-fired storage, and electric resistance storage water heaters. For gas-fired instantaneous water heaters, the energy factor and thermal efficiency levels correspond to commonly available instantaneous water heaters.

The gas-fired storage water heater efficiency levels correspond to condensing storage water heaters. High-efficiency, condensing gas storage water heaters (energy factor > 0.90

or thermal efficiency > 0.90) are alternatives to the use of gas-fired instantaneous water heaters.

Electric storage water heater efficiency should be calculated as 0.99 – 0.0012 × water heater volume. Instantaneous electric water heaters are an acceptable alternative to high-efficiency storage water heaters for fixtures remote from the guest rooms. Electric instantaneous water heaters are more efficient than electric storage water heaters, and point-of-use versions will minimize piping losses. However, their impact on building peak electric demand can be significant and should be taken into account during design.

WH5 *Low-Flow Shower Heads and Lavatory Faucets* (Climate Zones: all)

The least expensive means of reducing SWH energy consumption is by reducing service hot water consumption. Lower-flow shower heads can reduce hot water demand during showers from approximately 1.8 gpm to less than 1.5 gpm. Low-flow lavatory faucets can produce similar hot water usage reductions for each lavatory.

WH6 *Service Water Heater Location* (Climate Zones: all)

Showers and lavatories in highway lodging facilities almost always utilize recirculation pumps to minimize the wait time for hot water service to the fixtures. The water heater distribution system should be designed to reduce heat loss through the hot water return loop, both by minimizing the length of the runs to service guest room facilities and by minimizing the number of separate recirculation loops required for the facility. Remote lavatories or wash basins should be served by local water heaters rather than providing lengthy piping for connection to the central recirculated service water system.

High-temperature service hot water requirements, such as for food service establishments or laundries, should be provided by a separate local higher-temperature service hot water system.

WH7 *Pipe Insulation* (Climate Zones: all)

All SWH piping should be installed in accordance with accepted industry standards. Insulation levels should be in accordance with the recommendation levels in Chapter 3 of this Guide, and the insulation should be protected from damage. A vapor retardant should be included on the outside of all insulation.

WH8 *Heat Recovery* (Climate Zones: ❻ ❼ ❽)

Potable water supply temperature to the building in winter in cold climates can be extremely low, often below 50°F, but shower drain stack heat recovery units can raise the temperature of cold water supply. Typical shower drain heat recovery units are only applicable to multi-story buildings or buildings with basements because they require a full story of vertical drop for the integral shower drain stack heat exchanger.

For hotel laundries, heat recovery units recover heat for either the cold water supply to the washer or from the make-up water to the water heater. Either approach can significantly reduce water heating energy consumption in cold climates.

Reference

ASHRAE. 2007. *2007 ASHRAE Handbook—HVAC Applications*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

MISCELLANEOUS APPLIANCES

Good Design Practice

MA1 *Guest Room Mini-Refrigerators* (Climate Zones: all)

Many highway lodging facilities are incorporating small refrigerators in guest rooms, either for in-room vending or as an amenity for guests. These refrigerators, while a relatively small load, run intermittently throughout the entire day to maintain cool temperatures within the cabinet. Conventional technology for such appliances utilizes a compression refrigeration cycle for cooling the refrigerator. Average power draw for such appliances is approximately 52 W continuously for the entire year. A new technology utilizing an electric-driven absorption refrigeration cycle reduces the average power draw for mini-refrigerators to 33 W. Products using this technology are available from a number of manufacturers. Utilize mini-refrigerators that use no more than 33 W continuously throughout the year.

MA2 *High-Performance Laundry Equipment* (Climate Zones: all)

Laundering of bed linens and towels consumes significant amounts of energy in highway lodging facilities. Industry averages for laundry usage are approximately 9 lb of laundry per room per day. Conventional commercial washers consume approximately 1.2 gal of hot water per pound of laundry. Water-conserving commercial washers consume approximately 0.9 gal of hot water per pound of laundry. An even more important characteristic of commercial washers is the amount of water extracted during the spin cycle. Extraction capability is a function of the G force generated in the washer drum by the rotational speed of the drum. Standard washers generate a G force of only about 85 G. High-performance washers generate G forces over 300 G. The retained water for the standard washer is approximately 87.5% of the dry weight of the laundry. The greater mass of water remaining in the laundry processed by the standard dryer must be removed by heat in the dryer. For the high-performance washer, the retained water percentage is only 52.5%. This savings is partially offset by the greater electrical consumption of the more powerful motors required to generate the high rotational speeds required to produce elevated G extractor forces. Typically, the electrical consumption of high-performance washers is about 25% greater than that of standard washers. Overall, however, savings from dryer energy consumption and hot water generation more than offset the additional electrical energy required for the washer motor. Utilize washer/extractors that generate high G forces to reduce retained water percentage to 52.5% and that utilize only 0.9 gal of hot water per pound of laundry.

In general, because they are direct-fired appliances, sending both heated air and products of combustion through the bin containing the clothes to be dried, dryers demonstrate very little efficiency difference. The key to reducing dryer energy consumption is to reduce the retained moisture content of the clothes before they are put through the dryer cycle.

BONUS SAVINGS

Ventilation Control

VC1 *Demand-Controlled Ventilation* (Climate Zones: all)

Demand-controlled ventilation (DCV) can reduce the energy required to condition outdoor air for ventilation. For highway lodging facilities, DCV using a CO_2 sensor is recommended for zones which are densely occupied with highly variable occupancy patterns, such as meeting and conference rooms. DCV for guest rooms can also be implemented but may result in increased construction and maintenance costs.

In these zones, the CO_2 sensor measures the change in CO_2 level in a zone relative to the level in the outdoor air, as a proxy for ventilation airflow per person. For a single-zone system, a controller then operates the outdoor air, return air, and relief air dampers to maintain proper ventilation. Multi-zone recirculating systems with variable primary airflow require more complex systems that include terminals with adjustable minimum flow and reheat to maintain primary and ventilation airflow at levels required by ASHRAE/IESNA Standard 90.1.

Because the required ventilation rate consists of both a component that is a constant because it is a function of the area served and a component that varies with the number of occupants, the outside airflow cannot simply be controlled to maintain a constant

CO_2 concentration differential between inside and outside. Instead, a more complex system must be designed involving the calculation of minimum allowable supply air volume to each space, minimum outside airflow to each space and through the system, outside airflow to each space and through the system, and varying CO_2 concentration differentials coincident with varying levels of occupancy. Refer to the *ASHRAE Standard 62.1 User's Manual* for specific guidance. Design of such systems may require the participation of an experienced professional or system vendor.

For a multiple-zone, recirculating system (such as a VAV system), special attention is required to ensure adequate outdoor air is supplied to all zones under varying loads. To maintain acceptable indoor air quality, the setpoints (limits) and control sequence must comply with ASHRAE Standard 62.1.

If occupancy controls are being used for temperature setback and lighting control in the guest rooms (see HV14), additional savings can be accrued by using the same occupancy signal to shut off (or reduce) ventilation and exhaust airflows to the room. This measure would require operable dampers for both the exhaust outlet and the ventilation inlet for each room, along with coordinated variable volume controls for both the central exhaust and central ventilation supply fan.

When DCV is used, particularly in public spaces, the controls should prevent negative building pressure. If the amount of air exhausted remains constant while the intake airflow decreases, the building may be under a negative pressure relative to outdoors. When air is exhausted directly from the zone, the DCV control strategy must avoid reducing intake airflow below the amount required to replace the air being exhausted.

VC2 *Carbon Dioxide Sensors* (Climate Zones: all)

The number and location of carbon dioxide (CO_2) sensors for DCV can affect the ability to accurately reflect the building or zone occupancy. A minimum of one CO_2 sensor per zone is recommended for systems with greater than 500 cfm of outdoor air. Multiple sensors may be necessary if the ventilation system serves spaces with significantly different occupancy expectations. Where multiple sensors are used, the ventilation should be based on the sensor recording the highest concentration of CO_2.

Sensors used in spaces with dense occupancy and high outdoor air requirements may be installed in the return air ducts to provide an average CO_2 measure for the zone. For sensors mounted in return air ducts, adequate access for sensor calibration and field testing must be provided. The number and location of sensors should take into account the sensor manufacturer's recommendations for their particular products.

Selection of the CO_2 sensors is critical in both accuracy and response ranges. CO_2 sensors should be certified by the manufacturer to have an error of 75 ppm or less and be factory calibrated. Inaccurate CO_2 sensors can cause excessive energy use or poor indoor air quality, so they should be calibrated as recommended by the manufacturer.

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Ground Coupled Heat Pump Systems

GCHP1 *Ground Coupled Loop for Water-Source Heat Pumps* (Climate Zones: all)

The cooling tower for heat rejection and the boiler for heat addition to the circulating loop for water-source heat pumps can be deleted from the system with a properly designed ground coupling system for the circulating loop. The ground coupling system can take the form of individual closed-loop ground wells, horizontal ground loop mats, or open-loop wells, such as standing column wells. Significant energy savings can be accrued by utilizing the thermal capacitance of the earth to avoid make-up heating or cooling to the loop. Such systems should be designed and built by experienced professionals familiar with the local geo-technology. Design-build provision of these systems based upon a performance specification is the best way to provide these systems for smaller projects.

Water Conservation

WC1 *Water-Conserving Equipment* (Climate Zones: all)

Highway lodging facilities are large water consumers due to heavy customer and laundry usage. As mentioned in WH5, low-flow shower heads and faucets can significantly reduce service hot water usage, reducing energy requirements for water heating. Significant savings also can be achieved with low water usage washing machines. Typical washing machines utilize approximately 1 gal of hot water per pound of laundry. Water conserving washers can reduce that hot water requirement by more than 50%.

Plug Loads

Building owners and other users of this Guide can benefit from additional energy savings by outfitting highway lodging buildings with efficient appliances, office equipment, and other devices plugged into electric outlets. In addition to their own energy requirements, plug loads are also a source of internal heat gains that increase air-conditioning energy use in spaces that are cooled. There is a large variation of these loads depending on the amount of office space in the highway lodging as well as the need for charging equipment, communications, and other electrical devices.

The following recommendations for purchase and operation of plug load equipment (Table 5-5) are an integral part of this Guide, but the energy savings from the plug load recommendations are expected to be in addition to the target 30% savings.

Table 5-5. Recommendations for Efficient Plug Load Equipment

Equipment/Appliance Type	Purchase Recommendation	Operating Recommendation
Desktop computer	ENERGY STAR® only	Implement sleep mode software
Electronic cash registers and point-of-sale devices	Purchase with flat-screens with sleep modes	Many of these items are only used during peak times and excess equipment should be turned-off
Laptop computer—use where practical instead of desktops to minimize energy use	ENERGY STAR only	Implement sleep mode software
Computer monitors (may include point-of-sale monitors)	ENERGY STAR flat screen monitors only	Implement sleep mode software
Printer	ENERGY STAR only	Implement sleep mode software
Copy machine	ENERGY STAR only	Implement sleep mode software
Fax machine	ENERGY STAR only	Implement sleep mode software
Water cooler	ENERGY STAR only	N/A
Refrigerator (full size)	ENERGY STAR only	N/A
Vending machines	ENERGY STAR only	N/A

PL1 *Purchase Energy-Efficient Equipment* (Climate Zones: all)

Many of the plug load items in highway lodging buildings can be specified to be energy efficient. ENERGY STAR® labels apply for computer equipment, office equipment, vending machine, and refrigerators for break rooms. To further reduce energy usage, make sure that the ENERGY STAR sleep modes are enabled on computer and copier equipment. The use of such equipment in most highway lodging operations is limited, and short delays to sleep mode are appropriate.

PL2 *Use Time Clocks to Disable Plug Loads* (Climate Zones: all)

Time clocks can be used to effectively disable loads when these loads are not needed. Office lighting can be turned off when the highway lodging offices are closed. It may be possible to use common electrical circuits on central time clocks or the energy management system. This technique can also be used to turn off vending machines, coffee makers, point-of-sale devices, calculators, credit card dialers, and other miscellaneous loads when the building is not occupied. Care must be exercised not to turn on all the loads when the HVAC and lighting is energized to avoid a peak demand on start-up.

PL3 *Use Motion-Based Plug Strips* (Climate Zones: all)

Plug strips with motion sensors can be deployed in break rooms and offices to turn off plug loads such as vending machines, computer monitors, calculators, and other equipment that plugs in (usually identified with power packs or cubes).

PL4 *Delay Loads to Off-Peak Hours* (Climate Zones: all)

Delaying loads to off-peak hours probably will not save energy but may save on utility costs. Examples might be dishwashers in kitchen areas and washing machines available to staff.

PL5 *Identify Unnecessary Loads* (Climate Zones: all)

Some loads can be disconnected. Quite often in cooler climates, water coolers run refrigerated units even when the temperature of the street water is adequate. Excess equipment should be disconnected. Point-of-sale equipment should only be energized when necessary. Vending machines can be delamped in non-public areas.

Reference

DOE. ENERGY STAR®. Washington, DC: U.S. Department of Energy. www.energystar.gov.

Daylighting

DL1 *Savings and Occupant Acceptance with Daylighting* (Climate Zones: all)

When using daylight harvesting, windows or skylights along with automatic electric lighting controls to reduce the electric lighting when daylight is present, it is vitally important to commission the control system. A good daylight harvesting system will be invisible to guests, but the staff should be educated on the energy-saving benefits of the system and to spot and report systems that appear to be malfunctioning.

In highway lodging, spaces in which daylighting can work well are office, meeting, top floor corridors, and lobbies.

Automatic lighting controls increase the probability that daylighting will save energy. It is also important that heat gain and loss through glazing is controlled in conditioned spaces.

DL2 *Surface Reflectance* (Climate Zones: all)

The use of light-colored materials and matte finishes in all daylighted spaces increases efficiency through inter-reflections and greatly increases visual comfort.

DL3 *Control of Direct Sun Penetration* (Climate Zones: all)

Daylighting utilizes light from the sky, not the direct sun. To control this light source, use exterior and interior sun control devices. Exterior sun control and overhangs help reduce both direct sun penetration and heat gain from vertical glazing surfaces.

DL4 *Skylight Layout* (Climate Zones: ❶ ❷ ❸ ❹ ❺ ❻ ❼—Skylights not Recommended in Zone 8)

Install prismatic diffusing skylights to meet 5%–7% of the corridor floor area. Do not space skylights more than 1.4 times the ceiling height apart to maintain even daylight illumination. The daylighted area is the outline of the opening beneath the skylight plus 70% of the ceiling height in each horizontal direction. (See DL7.)

Use smaller-aperture skylights on a closer spacing rather than larger skylights on a farther spacing to gain maximum usable daylight with the least thermal heat transfer.

For daylight harvesting, the visible transmittance (VT) must be at least 45% and a haze of 90% as measured according to ASTM D 1003. Skylights also must incorporate fall protection and internal gutters to collect and dispose of condensation.

DL5 *Skylight Thermal Transmittance* (Climate Zones: ❶ ❷ ❸ ❹ ❺ ❻ ❼)

Clerestories offer a viable alternative to traditional skylights. Never use east- or west-facing clerestories due to excessive summer heat gain and the difficulty of controlling direct sunlight. Clerestories with operable glazing may also help provide natural ventilation in temperate seasons. Typically, north-facing clerestories have one-sixth the heat gain of skylights but provide less than one-third of the daylighting potential per square foot of prismatic skylights.

Shade south-facing clerestories and skylights with exterior/interior controls such as screens, baffles, or fins. (See DL3.)

Insulate the skylight curb above the roof line with continuous rigid insulation in conditioned spaces.

In hot climates, use skylights or north-facing clerestories for skylighting to eliminate excessive solar heat gain and glare. Reduce thermal gain during the cooling season by using skylights with a low overall thermal transmittance (U-factor).

In moderate and cooler climates, use skylights or either north- or south-facing clerestories for skylighting to eliminate excessive solar heat gain and glare. Reduce summer heat gain as well as winter heat loss by using skylights with a low overall thermal transmittance. Use a skylight frame that has a thermal break to prevent excessive heat loss/gain and winter moisture condensation on the frame.

DL6 *Interactions* (Climate Zones: ❶ ❷ ❸ ❹ ❺ ❻ ❼)

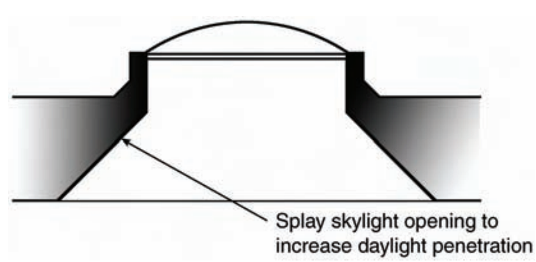

Figure 5-22. (DL6) Skylight (horizontal fenestration).

Skylight well height (side walls below the skylight) should be as short as possible. If skylight well is more than 2 ft high, splay skylight opening at 45° to maximize daylight distribution and minimize glare (see Figure 5-22).

Ceiling reflectance values should be a minimum of 80% to reduce contrast between skylight and ceiling.

DL7 *Expanded Recommendations for Electric Lighting Controls in Daylight Zones* (Climate Zones: all)

The "daylight zone" for skylights is the area of the skylight plus 70% of the floor-to-ceiling dimension in all directions from the edge of the skylight (see Figure 5-23).

The daylight zone for windows is: depth equals the distance from the exterior windows equal to the head height of the windows; width equals the width of the window plus 2 ft on each side of the window.

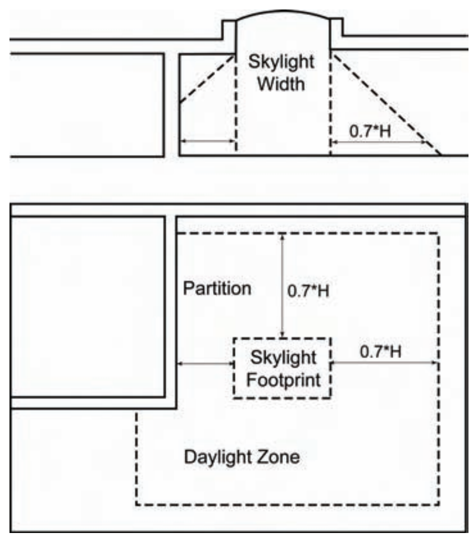

Figure 5-23. (DL7) Daylight zone under skylight.

Automatic daylight harvesting controls. In corridor areas, continuously dim or switch electric lights in response to daylight. Control luminaires in groups around skylights, and when daylight zones overlap a single control zone may be used. The daylighting control system and/or photo-sensor should include a five-minute time delay or other means to avoid cycling caused by rapidly changing sky conditions and a one-minute fade rate to change the light levels by dimming.

Dimming controls. Specify dimming ballasts that dim down to at least 20% of full output. Photo-sensors should include a one-minute fade rate to change the light levels by dimming and must achieve a slow, smooth linear response. New lamps must be burned in 100 hours or per manufacturer recommendation prior to dimming. Follow the manufacturer's recommendations for setup and calibration setting.

Switching controls. Specify luminaires with two-lamp tandem wired ballasts and circuit switch legs to luminaires capable of multi-level daylight control to provide 100%/50%/0% or 100%/66%/33%/0% light levels. Follow control manufacturer recommendations for setup and calibration setting of photo-controls.

DL8 *Photosensor Placement* (Climate Zones: all)

Photosensors should be specified for indoor illumination range. Open-loop photosensors are best used in corridor spaces, and the best location for the photosensor is inside the skylight well. An open-loop system is one in which the photocell responds only to daylight levels but is still calibrated to the desired light level received on the floor.

Closed-loop photosensors are best used in office spaces but may be used in corridors. A closed-loop system is one in which the interior photocell responds to the combination of daylight and electric light in the area. The best location for the photocell is above an unobstructed location such as a circulation path. If using a lighting system that provides an indirect component, mount the photosensor at the same height as the luminaire or in a location that is not impacted by the uplight from the luminaire.

DL9 *Calibration and Commissioning* (Climate Zones: all)

Even a few days of occupancy with poorly calibrated controls can lead to permanent overriding of the system and loss of all savings. All lighting controls must be calibrated and commissioned after the finishes are completed. Locate photo-control so that calibration and setpoint adjustment controls are easily accessible. Follow manufacturer recommendations for setup and calibration setting (most photosensors require daytime and nighttime calibration settings). The photosensor manufacturer and the QA provider should be involved in the calibration. Document the calibration and commissioning settings and calendar intervals for future re-calibration. Systems should be checked for proper calibration and operation at least every two years.

DL10 *Skylight Area as a Percentage of Gross Roof Area* (Climate Zones: all)

This is the percentage resulting from dividing the total skylight product area of the building by the gross roof area. Skylights provide increased daylight and a potential reduction in lighting energy consumption at the expense of increasing cooling loads in warmer climates and increasing heating loads in cooler climates. To achieve the lighting energy savings, the lighting in fixtures within 10 ft of the skylight edge must have automatic controls that dim the lighting in response to available daylight. (See DL7 for guidance.)

DL11 *Skylight Design* (Climate Zones: ❶ ❷ ❸ ❹ ❺ ❻ ❼)

Skylights should allow diffuse daylight into the space, not direct sunlight. Skylights must meet the thermal transmittance and solar heat gain coefficient (SHGC) values listed in the Recommendation Tables of Chapter 3. For daylight harvesting, the VT must be at least 45% and a haze of 90% as measured according to ASTM D 1003. Skylights also must incorporate fall protection and internal gutters to collect and dispose of condensation. The parameters for skylight design are the following:

- Condensate gutter or other method that captures condensate from skylight glazing.
- VT at least 45%. U-factor as recommended in Chapter 3.
- Haze as measured according to ASTM D1003 of at least 90%.
- General lighting in skylighted area controlled by multi-level (including continuous dimming) photocontrols.
- Fall protection required—most reliable form is burglar bars or mesh in curb or light well. Plastic skylights rated to comply with Occupational Safety and Health Administration fall protection may not provide adequate protection as the plastic ages.

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Appendix A
Envelope Thermal Performance Factors

The Recommendation Tables in Chapter 3 present the opaque envelope recommendations in a standard format. This is a simple approach, but it limits the construction options. In order to allow for alternative constructions, the recommendations can also be represented by thermal performance factors, such as U-factors for above-grade components or F-factors for slabs-on-grade; see Table A-1. Any alternative construction that is less than or equal to these thermal performance factors will be acceptable alternatives to the recommendations.

Table A-1. Envelope Thermal Performance Factors

Opaque Construction Options					
Roof Assemblies		**Walls, Exterior**		**Slabs**	
Insulation Entirely Above Deck		**Mass Walls**		**Unheated**	
R	**U**	**R**	**U**	**R-in.**	**F**
20	0.048	5.7 c.i.	0.151	10.0-24	0.54
25	0.039	7.6 c.i.	0.123	15.0-24	0.52
30	0.032	9.5 c.i.	0.104	20.0-24	0.51
Attic		11.4 c.i.	0.090		
R	**U**	13.3 c.i.	0.080		
38	0.027	15.2 c.i.	0.071		
60	0.017	25.0 c.i.	0.049		
Single Rafter Roof		**Steel-Framed**			
R	**U**	**R**	**U**		
38	0.028	13	0.124		
38+5.0 c.i.	0.024	13+7.5 c.i.	0.064		
38+10.0 c.i.	0.022	13+15.6 c.i.	0.042		
		13+21.6 c.i.	0.034		
		Wood-Framed and Other			
		R	**U**		
		13	0.089		
		13+3.8 c.i.	0.064		
		13+7.5 c.i.	0.051		
		13+10.0 c.i.	0.045		
		13+15.6 c.i.	0.036		

Appendix B
Climatic Zones for Canada and Mexico

The tables in this appendix show the climate zone definitions applicable to any location and the climate number for a variety of cities. These tables are based on information in ANSI/ASHRAE/IESNA Standard 90.1-2007, Normative Appendix B—Building Envelope Climate Criteria, Tables B-2, B-3, and B-4. Weather data is needed in order to use the climate zone definitions for a particular city. Weather data by city is available for a large number of international cities in the *ASHRAE Handbook—Fundamentals*.

Table B-1. International Climate Zone Definitions

Climate Zone Number	Name	Thermal Criteria
1A and 1B	Very Hot–Humid (1A) Dry (1B)	9000 < CDD50°F
2A and 2B	Hot–Humid (2A) Dry (2B)	6300 < CDD50°F ≤ 9000
3A and 3B	Warm–Humid (3A) Dry (3B)	4500 < CDD50°F ≤ 6300
3C	Warm–Marine (3C)	CDD50°F £ 4500 AND HDD65°F ≤ 3600
4A and 4B	Mixed–Humid (4A) Dry (4B)	CDD50°F £ 4500 AND 3600 < HDD65°F ≤ 5400
4C	Mixed–Marine (4C)	3600 < HDD65°F ≤ 5400
5A, 5B, and 5C	Cool–Humid (5A) Dry (5B) Marine (5C)	5400 < HDD65°F ≤ 7200
6A and 6B	Cold–Humid (6A) Dry (6B)	7200 < HDD65°F ≤ 9000
7	Very Cold	9000 < HDD65°F ≤ 12600
8	Subarctic	12600 < HDD65°F

Table B-2. Mexican Climate Zones

Country		Country	
City	Zone	City	Zone
Mexico		Mexico	
Mexico City (Distrito Federal)	3	Tampico (Tamaulipas)	1
Guadalajara (Jalisco)	1	Veracruz (Veracruz)	4
Monterrey (Nuevo Laredo)	3	Merida (Yucatan)	1

Marine (C) definition—Locations meeting all four of the following criteria:

1. Mean temperature of coldest month between 27°F (–3°C) and 65°F (18°C)
2. Warmest month mean < 72°F (22°C)
3. At least four months with mean temperatures over 50°F (10°C)
4. Dry season in summer. The month with the heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation in the rest of the year. The cold season is October through March in the Northern Hemisphere and April through September in the Southern Hemisphere.

Dry (B) definition—Locations meeting the following criteria:

Not marine and

$P < 0.44 \times (T - 19.5)$

where:

P = annual precipitation in in. and

T = annual mean temperature in °F.

Moist (A) definition—Locations that are not marine and not dry.

Table B-3. Canadian Climate Zones

City	Zone
Alberta (AB)	
Calgary International A	7
Edmonton International A	7
Grande Prairie A	7
Jasper	7
Lethbridge A	6
Medicine Hat A	6
Red Deer A	7
British Columbia (BC)	
Dawson Creek A	7
Ft Nelson A	8
Kamloops	5
Nanaimo A	5
New Westminster BC Pen	5
Penticton A	5
Prince George	7
Prince Rupert A	6
Vancouver International A	5
Victoria Gonzales Hts	5
Manitoba (MB)	
Brandon CDA	7
Churchill A	9
Dauphin A	7
Flin Flon	7
Portage La Prairie A	7
The Pas A	7
Winnipeg International A	7
New Brunswick (NB)	
Chatham A	7
Fredericton A	6
Moncton A	6
Saint John A	6
Newfoundland (NF)	
Corner Brook	6
Gander International A	7
Goose A	7
St John's A	6
Stephenville A	6
Northwest Territories (NW)	
Ft Smith A	8
Inuvik A	8
Yellowknife A	8
Nova Scotia (NS)	
Halifax International A	6
Kentville CDA	6
Sydney A	6
Truro	6
Yarmouth A	6
Nunavut	
Resolute A	8
Ontario (ON)	
Belleville	6
Cornwall	6
Hamilton RBG	5
Kapuskasing A	7
Kenora A	7
Kingston A	6
London A	6
North Bay A	7
Oshawa WPCP	6
Ottawa International A	6
Owen Sound MOE	6
Petersborough	6
St Catharines	5
Sudbury A	7
Thunder Bay A	7
Timmins A	7
Toronto Downsview A	6
Windsor A	5
Prince Edward (PE)	
Charlottetown A	6
Summerside A	6
Quebec (PQ)	
Bagotville A	7
Drummondville	6
Granby	6
Montreal Dorval Int'l A	6
Quebec A	7
Rimouski	7
Septles A	7
Shawinigan	7
Sherbrooke A	7
St Jean de Cherbourg	7
St Jerome	7
Thetford Mines	7
Trois Rivieres	7
Val d'Or A	7
Valleyfield	6
Saskatchewan (SK)	
Estevan A	7
Moose Jaw A	7
North Battleford A	7
Prince Albert A	7
Regina A	7
Saskatoon A	7
Swift Current A	7
Yorkton A	7
Yukon Territory (YT)	
Whitehorse A	8

Appendix C
Additional Resources

BOOKS AND STANDARDS

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USGBC. 2005. LEED NC Sustainable Sites Credit 8, "Light Pollution Reduction." Washington, DC: U.S. Green Building Council.

WEB SITES

3E Plus (Insulation Thickness Computer Program)
  www.pipeinsulation.org
AACA—Air Conditioning Contractors of America
  www.aaca.org
AAMA—American Architectural Manufacturers Association
  www.aamanet.org
Advanced Lighting Guidelines, NBI
  www.newbuildings.org/lighting.htm
AIA—American Institute of Architects
  www.aia.org
AIA Committee on the Environment Top Ten Awards
  www.aiatopten.org
AAMA – American Architectural Manufacturers Association
  www.aamanet.org
ANSI—American National Standards Institute
  www.ansi.org
API—Alliance for the Polyurethanes Industry
  www.polyurethane.org
ASHRAE—American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
  www.ashrae.org
ASTM—ASTM International
  www.astm.org
Building Energy Codes Program, EERE, DOE
  www.energycodes.gov
Building Energy Codes Resources Center, PNNL
  http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter
CBECS—Commercial Buildings Energy Consumption Survey, EIA
  www.eia.doe.gov/emeu/cbecs/contents.html
CRRC—Cool Roof Rating Council
  www.coolroofs.org
DesignLights Consortium
  www.designlights.org
DOE—U.S. Department of Energy
  www.energy.gov
  www.energycodes.gov
EIA—Energy Information Administration
  www.eia.doe.gov
EERE—Energy Efficiency and Renewable Energy, DOE
  www.eere.energy.gov

ENERGY STAR®
www.energystar.gov
EPS Molders Association
www.epsmolders.org
High Performance Buildings Database, EERE Buildings Program, DOE
www.eere.energy.gov/buildings/database/
IESNA—Illuminating Engineering Society of North America
www.ies.org
LBNL—Lawrence Berkeley National Laboratory
www.lbl.gov
LEED—Leadership in Energy and Environmental Design
www.usgbc.org/LEED
Lessons Learned from Case Studies of Six High-Performance Buildings, NREL
www.nrel.gov/docs/fy06osti/37542.pdf.
LRC—Lighting Research Center
www.lightingresearch.org
NAIMA—North American Insulation Manufacturers Association
www.naima.org
NBI—New Buildings Institute
www.newbuildings.org
NEEP—Northeast Energy Efficiency Partnerships
www.neep.org
NEMA—National Electrical Manufacturers Association
www.nema.org
NFRC—National Fenestration Rating Council
www.nfrc.org
NREL—National Renewable Energy Laboratory
www.nrel.gov
ORNL - Oak Ridge National Laboratory
www.ornl.gov/sci/engineering_science_technology/buildings.shtm
PIMA—Polyisocyanurate Insulation Manufacturers Association
www.polyiso.org
RPI—Rensselaer Polytechnic Institute
www.rpi.edu
SRI Calculator, ORNL
www.ornl.gov/sci/roofs+walls/calculators/ssreflect/index.htm
"Tips for Daylighting with Windows," *Daylight and Windows*
http://windows.lbl.gov/daylighting/designguide/designguide.html
USGBC—U.S. Green Building Council
www.usgbc.org
The Whole Building Design Guide
http://wbdg.org/
XPSA—Extruded Polystyrene Foam Association
www.xpsa.com

For more information or to provide feedback on the *Advanced Energy Design Guide* series, please visit www.ashrae.org/aedg.

Advanced Energy Design Guide for Highway Lodging

This guide was prepared under ASHRAE Special Project 113.

The Advanced Energy Design Guide for Highway Lodging is the fifth in a series designed to provide recommendations for achieving 30% energy savings over the minimum code requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999. The energy savings target of 30% is the first step in the process toward achieving a net zero energy building, which is defined as a building that, on an annual basis, draws from outside resources equal or less energy than it provides using on-site renewable energy sources. ANSI/ASHRAE/IESNA Standard 90.1-1999, the energy-conservation standard published at the turn of the millennium, provides the fixed reference point for all of the Guides in this series. The primary reason for this choice as a reference point is to maintain a consistent baseline and scale for all of the 30% AEDG series documents.

This Guide focuses on typical hotels found along highways having up to 80 rooms, generally four stories or less, that use unitary heating and air-conditioning equipment. Buildings of this type with these HVAC system configurations represent a significant amount of commercial hotel space in the United States.

The recommendations in this Guide will allow contractors, consulting engineers, architects, and designers to easily achieve advanced levels of energy savings without having to resort to detailed calculations or analyses. All of the energy-saving recommendations for each of the eight U.S. climate zones are contained in a single table, thus facilitating the Guide's use. Additional recommendations identify other opportunities to incorporate greater energy savings into the design of the building.

Those looking for help in implementing the recommendations of this Guide will find an expanded section of tips and approaches in the "How to Implement Recommendations" chapter of the Guide. To further facilitate its use, the Guide cross-references the how-to information with the numbered tips and the color-coded climate zone maps inside. Examples of advanced highway lodging energy designs are also provided in various case studies to illustrate the recommendations and to demonstrate the flexibility offered in achieving the advanced energy savings levels provided within the Guide.

For more information on the entire
Advanced Energy Design Guide series,
please visit www.ashrae.org/aedg.

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Page 73: Section EL10 refers readers to EL19 for more information on vacancy sensors; it should actually refer readers to **EL9**.

Page 39: In the "Roof" row under the column heading "Component," "Metal building" should read "**Attic and other**."