advanced buildings

New Construction

A prescriptive guide to achieve significant, predictable energy savings in new commercial buildings

PROJECT PROFILE

Goodyear School

The Goodyear Elementary School, which appears on the cover, is a modern 67,000 square foot facility that serves 320 students in grades K-5. This structure was built to replace the old elementary school which was located on a constrained, urban site. The new facility features an efficient layout with a variety of teaching spaces, easy community access and full technology implementation. Other sustainable design strategies included materials with recycled content, high indoor air quality, low energy use and a children's garden with a water collection tank.

Technologies and Design Strategies:

ENVELOPE. Selected high performance glazing and frame windows; continuous rigid insulation on the outside of structural framing to prevent thermal bridging; and roof insulation 50% beyond code minimum.

HVAC. The mechanical design includes two high efficiency condensing boilers that are rated at 91% thermal efficiency at full load supplying 120°F return water; heat recovery effectiveness that exceeds code; and enhanced controls for major mechanical systems.

MOTORS AND PUMPS. Premium efficiency motors for all fans and pumps that exceeded 1 hp.

By The Numbers

TOTAL PROJECT COST:
$19.7 million

NSTAR INCENTIVE:
$57,852

ESTIMATED ANNUAL COST SAVINGS:
$34,461

ESTIMATED ANNUAL ENERGY SAVINGS:
32.8% less energy than a comparable baseline building (regulated loads only)

Cover Photo: The Goodyear Elementary School. Greg Premru Photography

Overview

SITE OVERVIEW

- New construction
- Completed August 2011
- Elementary School
- 67,277 square feet
- Located in Woburn, Massachusetts

KEY OBJECTIVES

- Embrace energy efficiency
- Provide a healthy learning environment
- Reduce operating costs

Project Team

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City of Woburn

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Boston, Massachusetts

OWNER'S PROJECT MANAGER
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MECHANICAL AND ELECTRICAL ENGINEERING
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CIVIL ENGINEERING
Nitsch Engineering
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ENERGY MODELING
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advanced buildings

Energy performance solutions from NBI

New Construction Guide

A prescriptive guide to achieve significant, predictable energy savings in new commercial buildings

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Important Notice

Access to Update and Errata Sheets

Periodic review of the Advanced Buildings *New Construction Guide* results in creation of Update and Errata Sheets that document any changes. Users of the *Guide* can access these sheets online at http://newbuildings.org/resource/new-construction-guide-errata

Questions? Contact info@newbuildings.org

ACKNOWLEDGEMENTS

About New Buildings Institute

New Buildings Institute (NBI) is a nonprofit organization working to improve the energy performance of commercial buildings. We work collaboratively with commercial building market players—government, utilities, energy efficiency advocates and building professionals—to remove barriers to energy efficiency, including promoting advanced design practices, improved technologies, public policies and programs that improve energy efficiency.

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Development process for *Advanced Buildings New Construction Guide*

The Criteria and information provided in *Advanced Buildings New Construction Guide* is based on NBI's previous *Advanced Buildings* protocols, *Core Performance* and *Benchmark.* New Buildings Institute developed *Benchmark* following a set of requirements largely based on the ANSI Procedures for the Development and Coordination of American National Standards©.

In accordance with those requirements, a national Criteria Review Committee consisting of a balance of code officials, utility new construction program staff, and interested and affected parties representing the design, construction, real estate and manufacturing communities reviewed, voted on and approved the *Benchmark.*

As the next version of *Benchmark* and *Core Performance,* the *New Construction Guide* has retained some of the original publication's content in terms of process and priorities. However, based on varying level of code stringencies and the need for additional energy savings, information in the *New Construction Guide* has been reorganized and updated to facilitate ease of use and application.

We want to acknowledge *Benchmark's* author, Jeff Johnson, former executive director of NBI. His dedication to the cause of high performance building made development of *Benchmark* and the *Advanced Buildings* program possible.

Authorization

Disclaimer of Warranties

Limitation of Liability

Table of

Contents

Introduction

This section provides an explanation of the *Advanced Buildings New Construction Guide* and how it was developed.

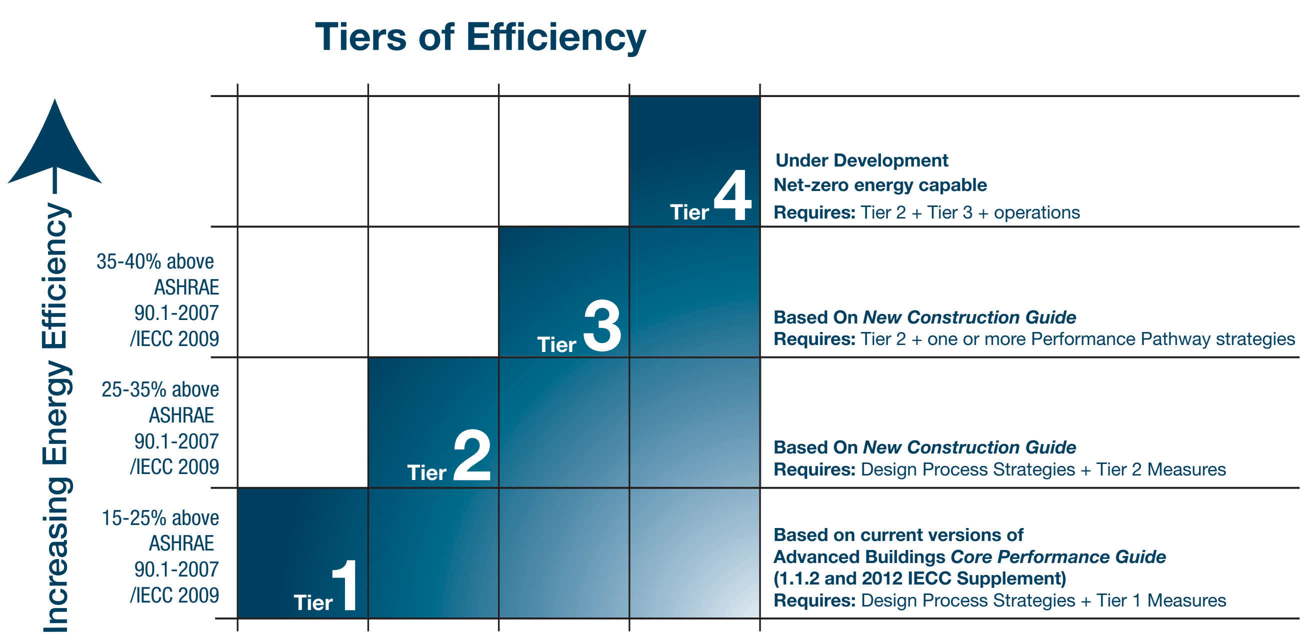
INTRODUCTION TO *ADVANCED BUILDINGS NEW CONSTRUCTION GUIDE*

Core Performance Building: Goodyear Elementary School, Woburn, MA. Photo credit: Greg Premru Photography

The Advanced Buildings New Construction Guide is a comprehensive guide to achieve significant, predictable energy savings in new commercial construction. The *Guide* describes a set of simple, discrete integrated design strategies and building features. When applied as a package, they result in significant energy savings beyond energy code baseline. These savings vary by climate region, building type and by which base code the program is compared to. This *Guide* also includes enhanced and alternate strategies which allow projects to target increased levels of savings over the base program requirements.

Recent advancements in model energy codes have resulted in a widely diverse landscape of stringency in code baselines. *The Advanced Buildings New Construction Guide* has been developed in a series of increasingly efficient tiers to consistently deliver savings over increasingly more stringent code baselines. This version of the *Guide* contains comprehensive strategies for two tiers of savings, representing approaches to exceed different levels of base codes that may be in effect in local regions. The *Guide* also contains additional optional strategies for savings representing a third tier of performance. The tiered structure of the program is designed to accommodate different code baselines and performance targets, and provides a structure which can evolve with future code stringency increases.

Figure 1: The four tiers of the Advanced Buildings platform



In addition to providing prescriptive guidance to project teams targeting increased energy performance, this *Advanced Buildings New Construction Guide* is intended to be used by utility programs as the basis for whole-building efficiency incentive programs targeting small to mid-size commercial buildings under 100,000 sf. Utilities that have adopted the program provide specific incentives to projects that follow the strategies identified in this Guide. Incentives are determined by individual utilities, and projects should coordinate with local utilities to identify incentive opportunities. The USGBC has also determined that this program can be used as the basis for achievement of energy prerequisites and credits in the LEED program. This achievement depends on which version of LEED is used, and projects should verify LEED applicability directly with the USGBC.

Note that this Guide is not intended to completely replace the requirements of the energy code. Strategies can be implemented to exceed specific code requirements, but the Guide is not a comprehensive code, and other measures in current energy codes must still be addressed by any project using this Guide.

Savings and Code Baselines

The *Advanced Buildings®* program is designed to achieve significant whole-building energy savings over code baseline energy performance. Because energy code baselines vary, the savings associated with the *Advanced Buildings* program vary depending on which code it is compared to. Savings also vary depending on climate, project type and design strategies. The Guide also incorporates enhanced and alternate design strategies that can lead to increased savings opportunities. Therefore the savings associated with this program are best considered as a range that reflects these variables. The table below describes the savings range anticipated for projects that follow the basic requirements of the program, at the performance Tier level appropriate for locally applicable code requirements. This Guide includes three basic performance levels, or Tiers, reflecting applicability to different energy code stringency in force where it is applied. Tier levels in Advanced Buildings are described in the Program Layout section below.

Approximate Range of Savings from Advanced Buildings Requirements

Base Code and Year		Range of Savings		
ASHRAE 90.1	**IECC**	**Tier 1**	**Tier 2**	**Tier 3**
2004	2006	20-30%		
2007	2009	15-25%	25-35%	35-40%
2010	2012	n/a	15-25%	25-35%

The analysis used to determine these savings levels is described in more detail in the Analysis section below. Additional analysis that compares *Advanced Buildings* to other local and regional codes may also be available. Contact NBI for more information on other code baseline comparisons.

Tier One of the *Advanced Buildings New Construction Guide* is designed to align well with the requirements of IECC 2012 and may therefore support stretch code implementation in jurisdictions moving toward that code. See additional discussion of this topic at the beginning of Section One of the Guide.

Although *Advanced Buildings* achieves energy savings beyond code requirements, the Guide does not include a full breadth of energy requirements compared to energy codes. This program is intended to be used in conjunction with energy code requirements, exceeding a number of code strategies but not replacing the entire set of code requirements. Projects that use this Guide should always plan to meet all baseline energy code requirements before applying the strategies listed here.

Prototypes

The *Advanced Buildings* program is focused on the small to mid-size commercial building sector. The savings analysis utilized prototypes that represent this commercial sector. The prototype buildings used in this analysis were developed by the US Department of Energy (DOE) to represent US building stock. DOE has developed 12 discrete building prototypes, which are used to evaluate comparative code stringency by DOE or their contractors when they conduct determination analyses to prove that new code versions are more stringent than previous versions as required by law. The DOE prototypes are also widely used in the industry as the basis for research on building performance strategies.

Because this program is focused on small commercial buildings, only a subset of the commercial prototypes was evaluated. These included medium office, small retail, elementary school, small warehouse and multifamily. Taken together, these building types represent over two-thirds of the commercial building stock in this country. And small commercial buildings under 50,000 sf of floor area represent 95% of all commercial buildings (by number of buildings) in the country.

For each prototype, three to five different HVAC system types were analyzed to represent the range of different system design strategies that might be applied in the market to these buildings.

Analysis Supporting the *Advanced Buildings New Construction Guide*

An extensive energy modeling protocol has been implemented to support development of the *Advanced Buildings New Construction Guide.* The results of over 100,000 energy modeling runs using eQUEST software to run DOE-2 have been evaluated using a batch analysis protocol built into the eQUEST energy modeling tool.

For each of the prototype buildings, three to five typical mechanical systems were defined to represent typical construction practice. Sixteen representative US cities were identified to serve as “typical” climate representatives of the eight ASHRAE climate zones and the various permutations identified within those climate zones by ASHRAE.

A baseline building that meets the requirements of each base code was defined for each permutation of the above Criteria (building type, system type and climate). Note that the baseline building is defined using the prescriptive requirements of the applicable code. As a prescriptive standard, the *Advanced Buildings New Construction Guide* is meant to be applied to buildings that would typically not complete energy modeling, and therefore the prescriptive requirements of code more accurately represent the target market for this program.

The measures considered for inclusion in the program were applied to each prototype, climate and system permutation to identify energy savings beyond the baseline buildings. Measures were only included in the program if they demonstrated positive savings for all permutations. Measures which were not applicable in all cases but which demonstrated significant savings opportunities in many permutations were included in the enhanced or pathway sections of the program, rather than in sections that are basic program requirements.

Once these measures were identified, all were applied as a package to each of the prototypes and permutations to identify the predicted savings associated with the program as a whole.

Applicability of the *Advanced Buildings New Construction Guide*

Building Size

Small to mid-size buildings are the focus of the *New Construction Guide.* In general, the requirements are best suited to smaller commercial buildings ranging from less than 10,000 to up to 100,000 square feet. While the design strategies, envelope, lighting and most system measures in the *Guide* are applicable to buildings of any size, larger building types are more likely to adopt more complicated systems and energy conservation strategies that are not as predictably described in a prescriptive standard. Larger buildings have opportunities for more robust systems and controls and are also more likely to benefit from full-scale energy modeling. For larger and more complex projects, the design team should evaluate the complexity of the HVAC systems to determine if the project would be better served by an effective energy modeling strategy.

Building Type

The *Advanced Buildings New Construction Guide* was developed on the basis of prototype analysis of several major project categories. The prototype buildings used in the analysis represent approximately two-thirds of commercial buildings, according to the Commercial Building Energy Consumption Survey (CBECS). In addition, a number of other project types have strong similarities to these project types in the context of the energy performance measures in *Advanced Buildings.*

The primary focus of the Guide is on smaller commercial buildings, including office, school, retail and warehouse use types. A majority of the strategies in this program can also be effectively applied to related use types, such as community centers, religious worship buildings, libraries and other civic buildings, etc. Many of the strategies identified in the Guide are also applicable to multifamily buildings, particularly the common and shared areas of these projects. For those projects identified above as partially compatible with the Guide, it may be necessary to identify a specific subset of the Criteria appropriate to the context of the project. All projects may have special conditions requiring the project team to use professional judgment on the application of specific Criteria.

Advanced Buildings and Energy Modeling

The *Advanced Buildings New Construction Guide* is designed to provide prescriptive guidance for achieving whole-building energy savings without energy modeling. However, the Guide can also be used to support a more effective energy modeling process. The Guide is based on an extensive energy modeling protocol to identify effective efficiency strategies. Therefore, the specific Criteria included in the Guide represent an excellent starting point for any project undertaking energy modeling. Using the Criteria as a starting point in an energy modeling exercise allows projects to focus modeling resources on analyzing more advanced design strategies, rather than on answering basic performance questions. For projects targeting more aggressive savings energy modeling can be used to help identify which Enhanced measures or Tier Three Pathways Strategies might be most effective for any given project. Energy modeling may also be used by some projects to demonstrate equivalent performance to the prescriptive standard with greater flexibility. Projects that cannot meet certain required Criteria may choose to use energy modeling to demonstrate that alternate strategies achieve the same level of energy performance.

Advanced Buildings New Construction Guide and LEED

There are a number of parallel strategies between the *Advanced Buildings New Construction Guide* and the US Green Building Council's (USGBC) LEED program. Specific Criteria within *Advanced Buildings* are directly aligned with specific LEED credits and represent strategies that partially or completely achieve specific LEED credits. The USGBC has adopted the *Advanced Buildings Core Performance®* program (Tier 1) as a prescriptive path to meet energy performance requirements of the LEED NC program in versions of LEED up to LEED 2009. For these versions of LEED, the program can be used in lieu of energy modeling to demonstrate achievement of EA credit 1 (Optimizing Energy Performance). Specific strategies from earlier versions of *Advanced Buildings* are also written into specific LEED credit achievement strategies in the LEED Core and Shell and LEED Commercial Interiors programs. Users should review the *LEED Reference Guide* to identify specific requirements and credit achievement opportunities. The USGBC determines how *Core Performance* is recognized by LEED. Projects should confirm LEED requirements with USGBC.

Layout of the Guide

Different sections of the Guide are intended to be applied to projects, depending on base code requirements, utility program requirements and project conditions. The following narrative describes how these different sections are intended to be applied.

Section Zero–Design Process Strategies (Prerequisite for all Tiers)

The measures described in this section are referred to as Design Process Strategies, and all projects using this Guide should implement all of the strategies described in this chapter. These strategies have been developed to make the design process more effective, leading to better integrated design outcomes. This category defines specific steps which are required to comply with program requirements. These include defining and documenting design intent with respect to energy performance, analysis of building configuration alternatives, part-load evaluation of mechanical loads, and operator training at building handoff. All Design Process Strategies must be met to fully comply with the *Advanced Building* program.

Section One–Tier One

The measures in this section represent the basic requirements of Version 1 of the *Advanced Buildings* program, referred to as *Advanced Buildings: Core Performance,* or just *Core Performance.* This section is intended to be applied by projects which are striving to exceed energy code versions from prior to 2010, including the IECC 2009, or ASHRAE 90.1-2007, and earlier versions of these codes. For projects in jurisdictions enforcing these codes, all of the measures in this section should be followed (as well as the Design Process Strategies) to meet the requirements of the program. Projects should also check with local utilities to identify local program requirements to achieve incentives. Tier One of the *New Construction Guide* is based on the *Advanced Buildings: Core Performance Guide* and the *2012 IECC Supplement.*

In the context of the larger *Advanced Buildings* program, the measures described in Sections Zero and One together represent Tier One of the *Advanced Buildings* program.

Section Two–Tier Two

The next section of the Guide incorporates strategies designed to provide a pathway for whole-building performance that exceeds the more recent code versions, such as IECC 2012 and ASHRAE 90.1-2010. Projects in jurisdictions that have adopted and enforce these codes must follow the requirements of this section to achieve significant savings beyond code. The measures in Section Two supersede the strategies listed in Section One above.

This section is divided into two parts: the basic requirements of the program (for advanced code jurisdictions) and some optional additional enhanced strategies which may be adopted by individual projects. All of the measures up to and including measure 2.17 (and including the measures in Section 0-Design Process Strategies) are basic requirements of the program. Measures in this section numbered 2.18 and above are considered enhanced measures. Note that some of these enhanced measures may be required by individual utility incentive programs and/or may qualify for additional incentives.

The measures in this section can also be used individually or in combination by projects that are following the requirements of Section One as enhanced measures to achieve additional savings beyond the level of savings delivered by Section One alone. Additional incentives may be available for projects exceeding basic requirements; check with the local utility.

In the *Advanced Buildings* program, the measures described in Sections Zero and Two together represent Tier Two of the *Advanced Buildings* program.

Section Three–Tier Three

The Performance Pathways section of the *Advanced Buildings New Construction Guide* is designed to provide strategies for additional savings to projects which might be able to undertake additional efforts to increase energy efficiency levels. These pathways represent broader design strategies that require an integrated and informed design approach to more advanced efficiency strategies than those represented by individual savings measures. They may also require deeper analysis or expertise from the design team and may not be applicable to all project types or conditions. However, these design pathways often represent an opportunity for significant additional savings beyond the basic requirements of the *Advanced Buildings* program. For this reason they are considered as Tier Three of the program.

Additional information about how to determine which pathway strategies might be appropriate to specific projects can be found in the Introduction to Section Three.

Achieving Tier Three in the *Advanced Buildings New Construction Guide* requires that projects follow the requirements of Section Zero, Section Two, and one or more Performance Pathway strategies from Section Three.

Section Four–Tier Four (Under Development)

As energy codes become more stringent, it becomes more difficult to achieve more savings from the subset of building attributes that are actually regulated by energy codes. At the same time, it is widely recognized that building occupants and operations are significant drivers of building energy use, reflecting an ever-increasing percentage of total building energy use as building physical features become more efficient. In order to achieve broadly adopted net-zero energy performance goals, it will be critical to address these aspects of building energy use.

Strategies to address building operating efficiency and tenant behavior characteristics (such as plug load use) are difficult to address in the context of energy code and incentive programs that focus on the design phase of building delivery. New strategies must be developed and deployed to tap into the significant savings opportunities represented by improved operation and occupant habits.

The next phase of development of the *Advanced Buildings* program is focused on the significant savings opportunities represented by influencing operational practices and tenant interactions with the building over the course of building occupancy.

Program Outline

Section Zero–Design Process Strategies

Prerequisite for Tier One, Tier Two and Tier Three

The Criteria in this section describe required steps for the design team to effectively implement the *Advanced Buildings New Construction Guide.* These strategies provide a framework for successful design integration and protocols to verify the intent, implementation and outcome of the design process. The Criteria in this section should be followed by **all** projects using the *Advanced Buildings* program, regardless of which performance Tier the project is targeting.

0.1 Identify Design Intent

Conduct a team meeting to identify key energy goals for the project and coordinate subsequent efforts among team members. Document the meeting summary/goals statement for use in subsequent steps and use Energy Star Target Finder to set specific performance goals.

0. 2 Design Intent Documentation

Develop key information about project performance requirements to insure design goals are translated forward through the design process. Project goals are converted into documentation which is incorporated into each phase to guide design, sequence of operation, specifications, bid submittals, construction, acceptance testing and building operation.

0.3 Building Configuration Alternatives

Consider the implications of alternate building configurations to maximize building energy performance, functionality and daylighting. Identify the pros and cons of several alternate building configurations using existing analysis tools, consultants, reference material or other resources.

0.4 Mechanical System Design

Use project-specific load calculations based on *Core Performance* requirements and part-load conditions to properly size mechanical equipment, rather than relying on generic rule-of-thumb sizing Criteria.

0.5 Operator Training and Documentation

Collect a full set of construction documents and specifications, systems manuals, maintenance and calibration requirements, control protocols, etc., for use by the building operations team. Conduct an operator training session to make sure the building operators understand the systems and operation of the building. Information should be collected in a set of manuals designed to facilitate building operation and future communication of this information to new operating staff. Work with the building owner to identify the best way to collect, store and distribute the information.

Section One–Requirements

All of the Criteria listed in this section are required components of *Core Performance,* originally published as Version 1 of the *Advanced Buildings* Program. These requirements are applicable for projects comparing to an energy code baseline of 2010 or earlier (such as ASHRAE90.1-2010, or IECC 2009). Energy savings projections for this Tier of *Advanced Buildings* are predicted in comparison to these earlier versions of code and are based on the implementation of all applicable measures in this section.

1.1 Mandatory Minimums (Prescriptive Requirements)

In addition to implementing the requirements of Tier One, projects using the program must meet all local energy code requirements or the prescriptive requirements of IECC 2009, whichever is more stringent.

1.2 Air Barrier Performance

During design and construction, develop and implement air sealing details and protocols to reduce uncontrolled air movement through the building envelope and duct systems.

1.3 Opaque Envelope Performance

Meet specific insulation Criteria for each building envelope assembly.

1.4 Fenestration Performance

Meet specific window performance Criteria for u-value and solar heat gain coefficient, based on NFRC ratings. Performance requirements are based on entire window assembly, not glazing alone.

1.5 Indoor Air Quality

Implement protocols to insure acceptable indoor air quality, including meeting or exceeding ASHRAE Standard 62-2001, developing and implementing air quality management plans for construction and operation, and conducting a building flush-out prior to occupancy.

1.6 Lighting Controls

Install control systems throughout the building, including occupancy sensors and time clock controls. Daylit areas are encouraged to incorporate daylight controls; at a minimum these areas must be provided with separate switching to facilitate future incorporation of daylight control systems.

1.7 Lighting Power Density

Projects may not exceed the lighting power density limits indicated in this Criteria.

1.8 Cool Roofs

On flat roofs, install a cool roof meeting emissivity and reflectance requirements.

1.9 Mechanical Equipment Efficiency Requirements

Mechanical equipment must meet the performance Criteria developed by the Consortium for Energy Efficiency (CEE) labeled as Tier 2 performance requirements.

1.10 Fundamental Economizer Performance

This Criteria includes a list of features and performance verification strategies to insure proper and effective economizer operation.

1.11 Energy Recovery Ventilation

Incorporate a heat recovery system in the ventilation air exhaust stream for spaces with high occupancy or high outdoor air ventilation requirements.

1.12 Demand Control Ventilation

Outside airflow should be controlled by a system which measures CO_2 and provides airflow based on occupant density, as measured by the CO_2 sensor.

1.13 Acceptance Testing

Implement an Acceptance Testing protocol to test and document the operational characteristics of installed systems to ensure proper operation. Specific guidance on test protocols are provided in Appendix A.

1.14 Additional Efficiency Package Requirement

Implement at least one of the following three additional efficiency packages: Increased HVAC Efficiency, Increased Lighting Efficiency, Minimum Onsite Renewable Energy Production.

Section Two–Tier Two

2.1 Mandatory Minimums

In addition to implementing the requirements of Tier Two of the *Advanced Buildings New Construction Guide,* projects must meet all local energy code requirements or the prescriptive requirements of IECC-2012, whichever is more stringent.

2.2 Air Barrier Commissioning

Conduct commissioning on the air barrier to ensure code requirements are being met.

2.3 Opaque Envelope Requirements

Meet specific insulation performance requirements for each building envelope assembly.

2.4 Fenestration Performance

Meet specific window and skylight performance requirements for u-value and solar heat gain coefficient, based on NFRC ratings. Performance requirements are based on entire window assembly, not glazing alone.

2.5 Daylighting

Include a minimum portion of the building within a daylight area provided with automatic lighting controls.

2.6 Lighting Controls

Install control systems throughout the building, including occupancy sensors and time clock controls.

2.7 Lighting Power Density

Projects may not exceed the lighting power density limits indicated in this Criterion.

2.8 Exterior Lighting

Meet efficiency requirements for lamps and control requirements for sites with large exterior lighting loads.

2.9 HVAC Efficiency

Mechanical equipment must meet the performance Criteria developed by the Consortium for Energy Efficiency (CEE) labeled as Tier 2 performance requirements.

2.10 Economizers

This Criteria includes a list of features and performance verification strategies to insure proper and effective economizer operation.

2.11 Duct Construction

Meet a minimum set of requirements for the placement, insulation and sealing of ductwork serving the building.

2.12 Fan Power Reduction

The Criteria includes an upper W/CFM limit for fan power and requirements for fan efficiency as well as guidance for meeting the fan power requirement.

2.13 HVAC Controls
A set of required capabilities for HVAC controls, including requirements for specific HVAC applications

2.14 Fault Detection and Diagnostics
The Criteria ensures the proper ongoing functioning of HVAC equipment through the installation of a minimum standard of FDD equipment.

2.15 Alternate Hot Water
A set of requirements for the production, storage and distribution of hot water.

2.16 Acceptance Testing
Implement an Acceptance Testing protocol to test and document the operational characteristics of installed systems to ensure proper operation. Specific guidance on test protocols are provided in Appendix A.

2.17 Whole-Building Monitoring
Install metering equipment meeting a minimum set of standards so that the energy performance of the building can be monitored.

Enhanced Measures

2.18 Enhanced Opaque Walls
A set of increased insulation performance requirements for wall, roof and floor assemblies.

2.19 Enhanced Glazing System Performance
A set of increased glazing performance requirements for vertical fenestration and skylights that places limits on Visible Light Transmission (VLT) of the assembly as a function of Solar Heat Gain Coefficient (SHGC).

2.20 Enhanced Requirements for Lighting Power Density
A set of reduced lighting power density values based on luminaire efficiency.

2.21 Premium Roof Top Unit (RTU) Systems
An HVAC system that utilizes the very best equipment available on the market that meets the requirements of the DOE RTU Challenge.

2.22 Energy Recovery
An expanded set of conditions where energy recovery shall be required on ventilation systems and a minimum set of standards for all installed Energy Recovery Ventilation Systems.

2.23 Demand Control Ventilation
Control outdoor air (OA) by actual occupant density as determined by CO_2 sensors.

Section Three–Tier Three

3.1 Pathway Prerequisite
A minimum set of standards that projects must meet in addition to implementing the requirements of Tier Three of the *Advanced Buildings New Construction Guide.*

3.2 Advanced Envelope Performance
A highly insulated building shell with very low infiltration rates combined with fenestration area restrictions.

3.3 Advanced Daylighting
Pervasive daylighting and automatic lighting controls that result in a building that is almost entirely daylit.

3.4 Advanced Office Lighting Design
A highly integrated lighting design for offices comprised of requirements addressing lighting power, control and the design of the space.

3.5 Ground-Source Heat Pump (GSHP)
An HVAC system that utilizes the thermal advantages of a Ground-Source Heat Pump (GSHP) system that meets a set of requirements to ensure efficient operation.

3.6 Variable Refrigerant Flow (VRF)
An HVAC system that utilizes a Variable Capacity Heat Pump (VCHP) such as VRF or VRV combined with a highly efficient Dedicated Outdoor Air System (DOAS) to provide ventilation.

3.7 Radiant Heating and Cooling
An HVAC system that utilizes radiant heating and cooling to condition the space combined with a highly efficient Dedicated Outdoor Air System (DOAS) to provide ventilation.

3.8 Plug Load Controls
Reduce energy use associated with plug loads through the automatic control of a portion of the circuits that serve plug loads and the selection of more efficient equipment.

Design Process Strategies

The Criteria in this section describe required steps for the design team to effectively implement the *Advanced Buildings New Construction Guide.* These strategies provide a framework for successful design integration and protocols to verify the intent, implementation and outcome of the design process. The Criteria in this section should be followed by all projects using the *Advanced Buildings* program, regardless of which performance Tier the project is targeting.

NREL's Research Support Facilities (RSF), Golden, CO. Photo Credit: Dennis Schroeder/NREL

0.0 INTRODUCTION

Design Process Strategies (Prerequisite for all Tiers)

The measures described in this section are referred to as Design Process Strategies, and all projects using this Guide should implement all of the strategies described in this chapter. These strategies have been developed to make the design process more effective, leading to better integrated design outcomes. This category defines specific steps which are necessary to comply with the requirements of the *Guide.*

The focus of these requirements is on the development of specific building performance goals, the integration of these goals into the design process, and the effective communication of building performance goals and strategies through the design process. It is also critical that clear and effective documentation of building performance and operations criteria are developed and transferred from early design stages, through the design and construction process, and on to the operations team and occupants so the building can maintain operating efficiency over the long term.

These requirements include defining and documenting design intent with respect to energy performance, analysis of building configuration alternatives, part-load evaluation of mechanical loads, clear and effective building operation manuals, development of building performance tracking protocols, and effective operator training at building handoff.

All Design Process Strategies must be implemented as part of any of the Tiers in the *Advanced Buildings New Construction Guide.*

0.1 IDENTIFY DESIGN INTENT

Core Performance Building: Brooks School, North Andover, MA. Photo credit: Architerra

Purpose

Develop consensus among the project team and owner as to the performance goals of the project and identify design strategies to achieve these goals. Ensure the design is developed in a way that meets the objectives of the building program including energy and environmental needs. Discuss *Advanced Buildings New Construction Guide* requirements and identify implementation strategies.

Criteria

The project team shall conduct a team meeting to identify key energy and environmental goals and principles. This meeting should consist of a facilitated discussion ***before*** the schematic design process has concluded. Discussion should include how *Advanced Buildings New Construction Guide* criteria will be implemented. If the *AB:NC* program is initiated later in the design process, complete this step as soon as possible.

Meeting participants should include all key project team members, including:

- Owner
- Architect
- Mechanical Engineer
- Electrical Engineer and/or Lighting Designer
- General Contractor (if selected)
- Utility Program Representative
- Leasing Agent (if speculative development)
- Facilities Manager
- End User Representative

0.2 DESIGN INTENT DOCUMENTATION

Criteria

The design team shall develop the following documents to communicate appropriate information to the various members of the design and construction team, as well as to owner, tenants and operations staff.

1. Operational Performance Requirements Narrative

(to be completed prior to bidding or commencement of construction)

This document describes the design and building features that support efficient building operation and the way the building is intended to operate. This narrative is intended to be included both in the construction documents to guide construction and commissioning, and in the operations manual completed at the end of the project. The narrative should include the following specific sections:

- A description of the design intent and building features incorporated to support efficient building performance. This description should include performance goals identified at project outset, and a list of specific features incorporated to meet the requirements of the Advanced Buildings program and any other efficiency goals.
- A description of the basis of design of the systems including all information necessary to prepare a design to accomplish operational performance. This description should include anticipated equipment types and capacities, ventilation system design flow rates and operational characteristics.
- A description of the sequence of operation of the systems and their interaction with other systems. Include descriptions of both HVAC and lighting control system types and capabilities.
- A table listing the operational and thermal efficiency of individual building components, including envelope insulation levels, window performance criteria, HVAC equipment efficiencies and lighting system energy performance standards.
- A set of guidelines requiring that substitutions proposed in the construction process identify how the proposed substitution affects the operational parameters described above.

Purpose

Ensure the design intent and design performance criteria are effectively documented and communicated through the design and construction process and to the owner and tenants to facilitate successful project operation, maintenance and occupancy.

Once this document is developed, it must be maintained through the design and construction process to reflect changes, modifications or additions to the project that impact the accuracy and completeness of the information described above.

2. Owner/User Guide

(to be completed prior to building occupancy)

This document provides information to the building owner and occupants that enables them to understand how to use and maintain the building. The document should include information that supports daily interaction with the building such as control locations and settings for lighting and HVAC, simple descriptions of the systems, and information about whom to contact for system repair and maintenance. Multiple copies of the Owner/User Guide should be produced for distribution to building occupants and owners The document should include the following information:

- A description of building design intent and performance features, including plain-language descriptions of the HVAC system components located in the building
- Description of how to operate key building control systems such as thermostats, lighting, security and alarm systems, etc., including basic information about appropriate thermostat and control setpoints.
- Information about building metering capabilities and energy use tracking systems.
- Purchasing guidelines for routine lighting and HVAC system maintenance (filters, lamps and ballasts, etc.).
- Purchasing guidelines for tenant equipment that focuses on performance criteria (i.e. Energy Star ratings, etc.)
- Basic description of maintenance procedures and contact information for maintenance and repair service providers. (This information will be edited through the course of building operation.)

3. Operations and Maintenance Manual

(to be provided prior to building occupancy)

This document provides information about building and system maintenance and operation. It includes maintenance schedules and information about equipment specifications to support repair and replacement when needed. This manual should be developed in electronic and printed form, and copies should be provided for reference at the building site. The document should include the following information:

- Operations manual, user guides and cut sheets for each piece of equipment installed in the building. Each significant piece of equipment should be permanently labeled, including all air handlers, pumps, boilers, valves, fans, adjustable dampers, hot water heaters, etc.
- Warranty information and date of installation for all significant equipment
- A copy of the Operational Performance Requirements Narrative developed by the design team(stated above).
- A description of the zones served by each piece of equipment, including sensor and control locations for each zone.
- A description of all building assemblies, including insulation levels and types, installed window thermal and solar performance characteristics, capacities and efficiencies of all HVAC equipment, and lamp and ballast replacement specifications for all fixture types.
- A description of how to operate building control systems and a description of default settings for all controls that aligns with original design parameters.
- A basic maintenance schedule for all major equipment describing the frequency at which filters should be changed, components cleaned or serviced, etc., with blank space to track ongoing maintenance and service calls.
- A form that lists maintenance staff or contractors and their contact information. Include blank forms that can be updated if contractors or strategies are modified over time.

Specific components of this document can serve as ‘ready-access’ information to building occupants and maintenance contractors. Such information should be laminated and mounted near the mechanical equipment or in an accessible maintenance space.

4. Acceptance Testing or Commissioning Plan

(to be completed prior to building construction)

An acceptance testing plan shall be prepared that specifies the process for meeting the owner’s project requirements and to describe how operation of various systems and equipment will be verified. This document shall describe the process to be implemented to meet the requirements of Criterion 2.16 Acceptance Testing. The plan should be developed in the construction documents phase and included in the bid documentation as a project requirement. The document shall describe:

- A process to verify proper coordination among systems and assemblies, and between all contractors, subcontractors, vendors and manufacturers of furnished equipment and assemblies.
- Construction and quality control procedures to be implemented to maintain and deliver envelope air tightness and thermal performance requirements.
- A description of the testing requirements and protocols and passing criteria to be used to ensure proper equipment calibration, operation and control.
- A list of test outcome documentation and forms necessary for review prior to final system acceptance.
- Equipment Start-Up protocols and handoff to building operations staff

Additional information about acceptance testing requirements can be found in Criterion 2.16 and in Appendix A. Note that acceptance testing is a form of commissioning that can be implemented by the construction team. The project owner may also consider the implementation of a full commissioning protocol using a third-party provider.

5. Integration into Construction Documents

In the course of developing the information above, the design team shall ensure that the construction documents contain sufficient information to completely describe the:

- envelope, including air barrier
- heating, ventilation and air conditioning (HVAC)
- hot water
- lighting
- electric power distribution systems
- on-system energy systems including operational features and controls

All HVAC, lighting and electric power distribution system plans shall contain sufficient information to identify the system and equipment arrangements, system and equipment sizing, systems specifications and systems sequence(s) of operation. The construction documents shall demonstrate that the tabulation of the building loads used assumptions consistent with Advanced Buildings or document why different assumptions were used.

Specifications shall include narrative descriptions in each subsection that includes systems and equipment related to building energy performance. The narrative shall identify performance requirements for the equipment and systems and shall include a list of performance parameters that must be submitted with any proposed substitution request in the construction process.

The construction documents shall require the submittal of operation manuals and maintenance manuals as a condition of final acceptance, and a description of their format and content. The operation manual shall provide all relevant information needed for day-to-day operation and management of each system. The maintenance manual shall describe equipment inventory and support the maintenance program. The submittal of record drawings and control documents are a condition of final acceptance.

6. Requirements for Bid Submittals

The bid submittals shall be reviewed to assure conformance with the Construction Documents. Changes shall be reviewed to assure they are consistent with the operational performance requirements and statement of goals and principles, if appropriate. Or-equal substitutions shall be shown to assure equal or better energy and indoor environmental performance when compared to the same element in the original construction document.

7. As-Built Construction Documents

Two sets of ‘as-built’ construction documents, including plans, specifications and the documentation described above, shall be provided to the owner at the time of project completion.

General

For buildings targeting a higher level of energy performance, successfully communicating design intent, performance requirements and operational characteristics is critical to a successful project outcome. The steps described above provide a framework for effective communication of building performance goals through the design process and into construction and building operation.

The construction documents represent the final product of the design process and are essential to guiding the overall construction process. This requirement places additional emphasis on elements of the construction documents that support improved building performance.

Some of these documents should be completed prior to bidding or the commencement of construction, as described below. The documents must be tailored to the facility's complexity and reflect the owner's plan for operations. The building owner should be engaged in this process to help determine the appropriate scope for these documents.

Performance goals for the project should be identified at the beginning of the project and documented for everyone involved to reference. As the design evolves, the level of detail supporting performance goals must also evolve so that subsequent design steps can refine and clarify how the building will achieve performance goals and how the systems will operate in this context. This information also provides a reference point for the construction team to understand how their efforts contribute to the outcome. Specifically, the design intent documentation should clearly address performance criteria by which proposed substitutions will be evaluated and performance testing requirements to insure that the final project meets the goals of the design process. This information should also be communicated to the building occupants and operators to guide day-to-day building operation and long- term maintenance practices.

The documentation of design intent should reflect the specific requirements of *Advanced Buildings New Construction Guide* so that these requirements are incorporated into the design and clearly communicated to the construction team.

0.3 BUILDING CONFIGURATION ALTERNATIVES

Criteria

During the conceptual and schematic design phases the design shall evaluate the impact of the following on the building configuration:

Climate and site characterization

The major climatic variables that impact the energy performance of buildings including temperature, wind, solar energy and moisture.

- Characterize the local climate using annual seasonal metrics such as annual solar radiation, cooling degree days (CDD), heating degree days (HDD), design dew-point temperature and design wet-bulb temperature. Identify promising design and construction strategies to respond to these local conditions.
- Assess local topography or adjacent properties that would impact access to sunlight and passive solar heating.
- Use the psychometric chart to provide a quick overview of the number of hours in which heating, cooling, humidification or dehumidification are likely to be needed. Use this information to prioritize mechanical system design response.
- Assess different building orientations and their solar heat gain implications.

HVAC System Selection

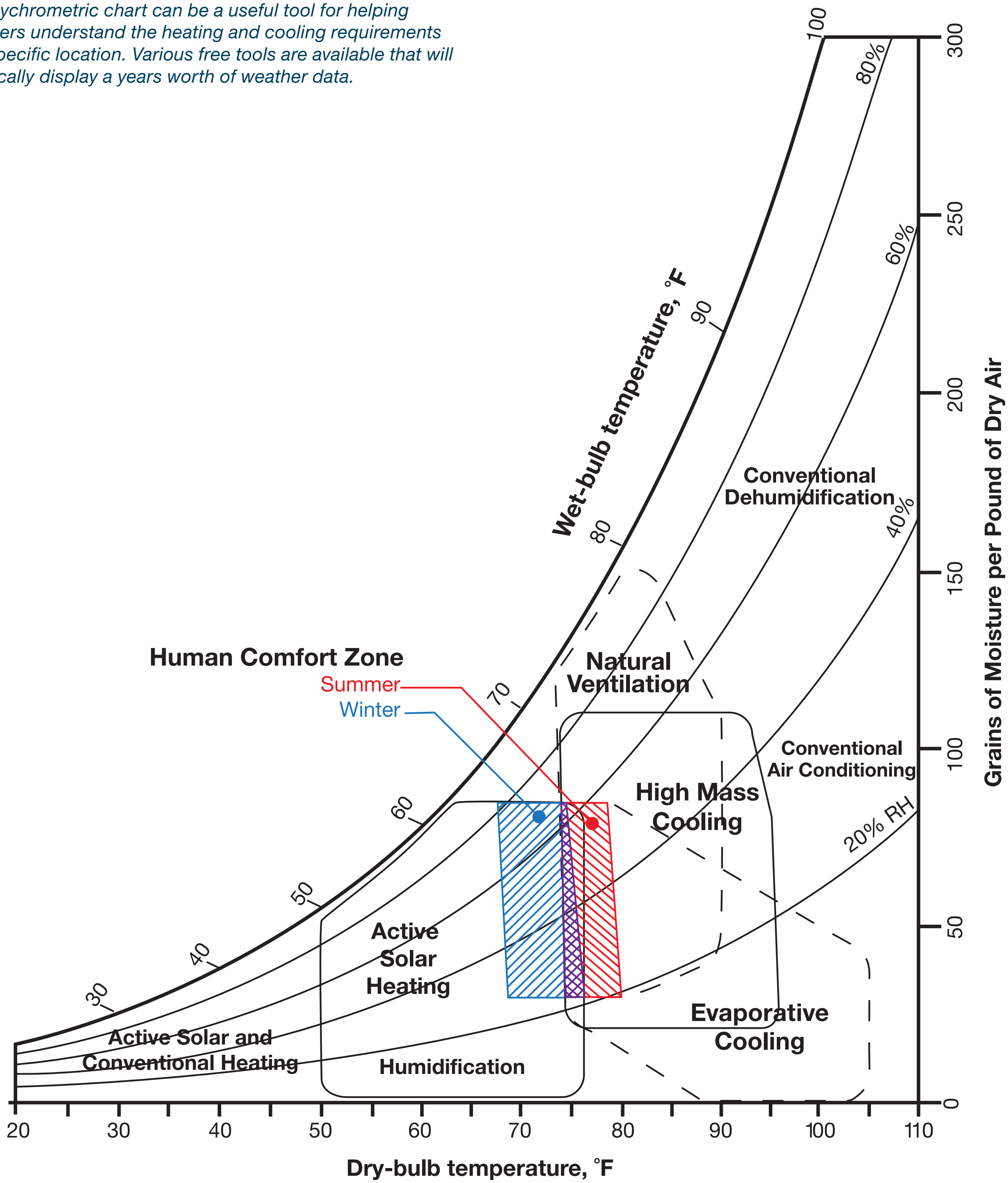
Assess the impact of different HVAC system types on the building configuration, including:

- The impact of ventilation-only duct systems on factors such as accommo-dating ducts in floor-to-floor heights and the building structure
- The impact of zoning and control considerations on the arrangement and grouping of spaces in the building program

Purpose

To ensure the design process addresses the impact of factors such as climate, siting, building orientation and shape, HVAC and lighting system selection, daylighting strategies on the building configura-tion alternatives.

The psychrometric chart can be a useful tool for helping designers understand the heating and cooling requirements for a specific location. Various free tools are available that will graphically display a years worth of weather data.



- The viability of different HVAC systems when taking into account technical limitations (such as evaporative cooling potential for the climate and geological considerations for ground-source heat pump wells) and practical limitations (such as programmatic requirements for zoning, controllability, responsiveness, etc.)
- The viability and impact of implementing natural ventilation strategies.

Daylighting

Assess the impact of different daylighting strategies including:

- The impact of alternative building shapes and configurations on potential sidelighting strategies (e.g., narrower floor plate layouts or increased ceiling heights).
- The potential benefits of glare reduction strategies such as minimizing east and west sidelighting in favor of north and south sidelighting or permanent shading, especially on orientation and façade design.
- The impact of toplighting on roof structure and HVAC system layouts.
- Daylighting control zone implications (e.g., the cost of small and/or numerous control zones).

Lighting System Selection

Assess the impact of different lighting systems and controls including:

- The impact of different lighting strategies on floor-to-floor height (e.g., suspended indirect vs. direct lighting) and ceiling configuration.
- Practical implications of occupancy sensor and lighting override switch locations.
- The zoning requirements of the building program.

Passive building features and load reduction alternatives

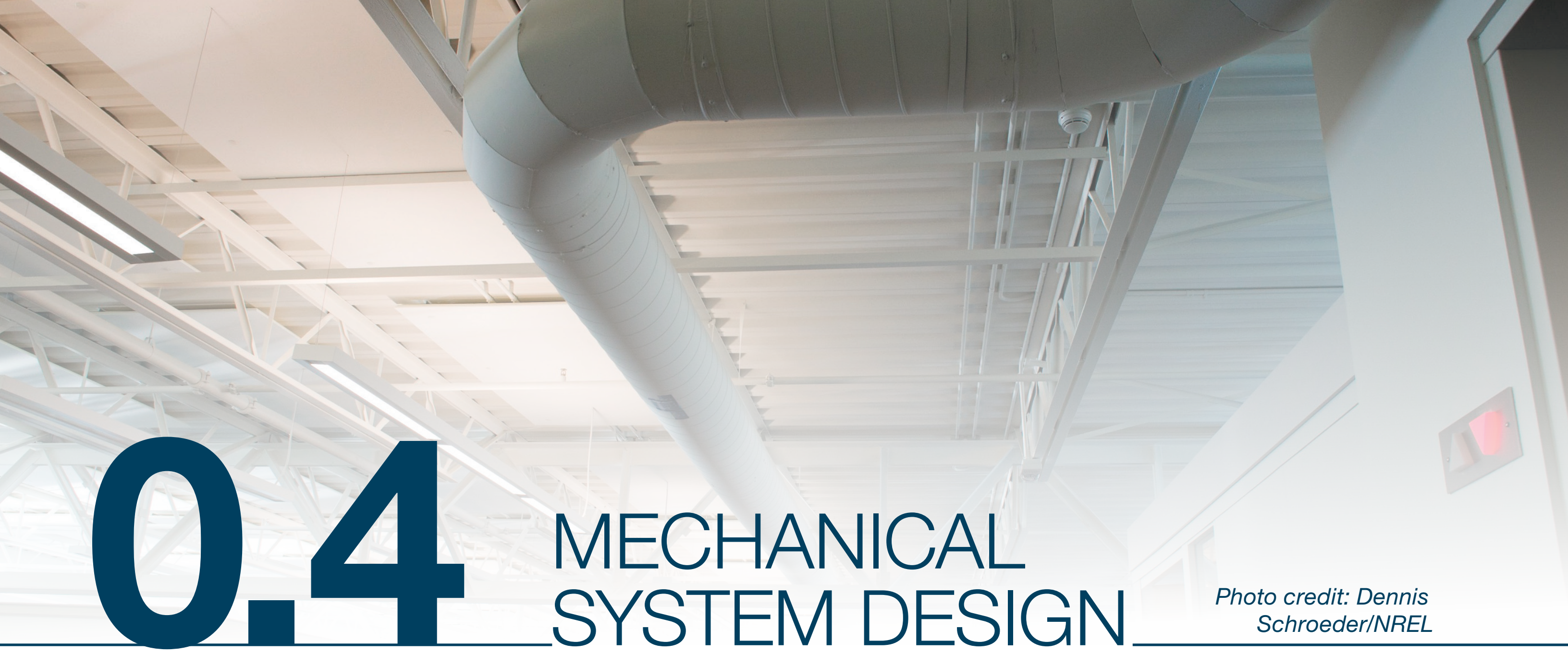
Consider building components and configurations that take advantage of climate conditions and reduce building thermal, solar and internal loads, including:

- The use of load calculation tools to compare the impact of alternate assemblies and systems on overall building performance.
- Fenestration performance and configuration alternatives to improve building energy performance; consider thermal and daylight harvesting tradeoffs to maximize overall building performance.
- Use of thermal mass with night ventilation strategies for load shifting.

General

Energy efficiency considerations often come rather late in the design process, after many building configuration decisions have already been made. This results in missed opportunities and often rules out many highly effective design strategies. By taking the building configuration impacts of energy decisions earlier in the design process, the design team can consider a broader array of options for achieving very high levels of energy performance in the design.

Many resources are available to designers to help analyze different climates and building configurations. Early-design analysis software and other evaluation tools can be used to analyze site characteristics and compare design alternatives without significant investment in full-scale energy modeling. Refer to the US Department of Energy's Building Energy Software Tools Directory (http://apps1.eere.energy.gov/buildings/tools_directory/subjects_sub.cfm) and the Decision Support Tools for Green Building (http://www.wbdg.org/tools/gbt.php) for a list of useful analysis tools.



0.4 MECHANICAL SYSTEM DESIGN

Photo credit: Dennis Schroeder/NREL

Purpose

Ensure the mechanical system is designed to minimize energy consumption and maximize occupant comfort throughout the range of operating conditions.

Criteria

Consider the selection of primary heating and cooling systems with higher inherent efficiencies than conventional rooftop package equipment, such as systems that utilize water or refrigerant instead of air as a primary heat transfer medium (e.g. radiant systems, variable refrigerant flow systems, or ground source heat pumps). Consider separating primary heating and cooling systems from ventilation systems using dedicated outside air systems (DOAS) for ventilation loads.

Employ best practices design techniques to improve system performance and meet ASHRAE Standard 55. The design engineer shall document the following actions in the design process:

- When sizing heating and cooling equipment, perform load calculations using building shell and interior load assumptions that are consistent with *Advanced Buildings New Construction Guide* requirements. Include accurate characterization of lighting, solar loads, glazing performance, occupancy and ventilation loads based on specific design characteristics of this project.
- When sizing the fan and air distribution systems, document fan-sizing calculations with zone-by-zone load calculations. Perform calculations to determine critical path supply duct pressure loss. Compare fitting selections for the critical branch to minimize fan horsepower requirements. Utilize best practices for duct construction and fan system design detailed in Criteria 2.12 – Fan Power Reduction to minimize pressure loss and meet the fan power requirements of Criterion 2.12. Use relief fans in lieu of return fans where possible, and provide automatic dampers on exhaust in lieu of barometric dampers to reduce fan power and increase barometric relief.
- Perform a second set of calculations using part-load conditions (maximum likely load and/or standard operating conditions). This includes using benchmark data, average daytime temperatures and non-peak solar gain, and other assumptions to define part-load conditions for the heating and cooling system. Include diversity factors for interior loads and other factors that will allow proper assessment of part-load operation.

- Describe the system operation at these conditions and describe features of the design that will facilitate efficient operation at these part-load conditions. Document in Criteria 0.2 how the system will deliver ventilation air, maintain comfort in accordance with ASHRAE Standard 55 and operate in an energy- efficient manner.

The design practices described above will lead to installed system capacities that more closely match actual building loads. This reduces installed excess system capacity, thereby reducing equipment first costs. By sizing the system more closely to the actual building loads, the system operating characteristics more closely match the efficiency curves and performance characteristics anticipated in manufacturer data. This increases operating efficiency, reduces operating costs, and extends equipment service life. Additional savings can be achieved by adopting the adaptive comfort standards described in ASHRAE Standard 55.

Core Performance Building: Brooks School, North Andover, MA. Photo credit: Architerra

0.5 OPERATOR TRAINING AND DOCUMENTATION

Purpose

Ensure the building operations team understands how the building is intended to operate and has the resources to monitor and understand building operational characteristics.

Criteria

Ensure that handoff of the building includes providing the operators and occupants with the resources, documentation and training necessary to efficiently operate the building by verifying that the following steps were taken before occupancy:

- A full copy of the Construction Documents and the other documents generated as a part of Criteria 0.2 was delivered to the building and accepted by the building operations team (if there was no building operations team or the building operations team is not located at the building, then a copy of these documents should be provided to the building owner and an additional copy of the documentation should be made readily available at the building)
- Operator training was performed by the building construction and design team, covering:
  - » Operation of all building systems and equipment
  - » Operation of all controls and their settings
  - » Maintenance schedules and any maintenance contracts or contacts for all systems and equipment
  - » Data collection equipment, interface and data protocols
- A simple and easy-to-understand written description of systems and controls intended to be operated directly by tenants should also be provided. Multiple copies of this document should be provided in the building for tenant use. Consider laminated or mounted copies to make tenant operation of the building more effective.

General

Energy efficiency requires both efficient design and efficient operation. The performance of many energy efficient buildings is compromised by a disconnect between the people responsible for designing the building and those responsible for operating the building. Therefore, the handoff to building operations staff and occupants is critical.

Criteria 0.2 creates a comprehensive set of documentation about the building design and intended operation. This documentation provides all the information needed to operate the building as efficiently as designed. This criterion ensures this documentation makes it into the hands of the people who will need to use it, is readily available at the building and is understood by the operations staff. This documentation is made much more valuable by in-person training and handoff. Operator training should include a formal walk-through and training session to give the building operations team hands-on experience with the topics discussed and allow the opportunity for operators to ask questions of the installation team.

Over time, the operations staff should add to and update the building documentation to ensure that building, system, equipment and control setting changes are documented and that information continues to be transmitted to new staff, new occupants and new owners. Efficient operation should not rely on information stored only in the staff person's head.

Ideally, an independent training session should be held specifically for building occupants. This training would focus on daily operation of the equipment, atypical (e.g., off hours) operation of the equipment, and contacts for the operations staff and/or service technicians.

Tier One

All of the Criteria listed in this section are required components of *Core Performance,* originally published as Version 1 of the *Advanced Buildings* Program. These requirements are applicable for projects comparing to an energy code baseline of 2010 or earlier (such as ASHRAE90.1-2010, or IECC 2009). Energy savings projections for this Tier of *Advanced Buildings* are predicted in comparison to these earlier versions of code and are based on the implementation of all applicable measures in this section.

Core Performance Building: Goodyear School, Woburn, MA. Photo Credit: Greg Premru photography

1.0 INTRODUCTION

Tier One

Tier One of this Guide represents a comprehensive approach to energy savings to achieve whole-building savings above energy codes in jurisdictions that have not adopted the most current versions of energy codes; i.e. versions previous to 2010. This includes the IECC 2009 or earlier, and ASHRAE 901.-2007 or earlier. For projects in jurisdictions enforcing these codes, all of the measures in this section should be followed (as well as the Design Process Strategies) to achieve Tier One. Projects should also check with local utilities to identify local program requirements to achieve incentives.

Tier One is based on the *Advanced Buildings: Core Performance Guide* and represents the basic requirements of that Guide and its *2012 Supplement.*

***AB:NC Tier One* requires the implementation of all of the Criteria in the Design Strategies Section (Criteria 0.1-0.5).**

Tier One and IECC-2012

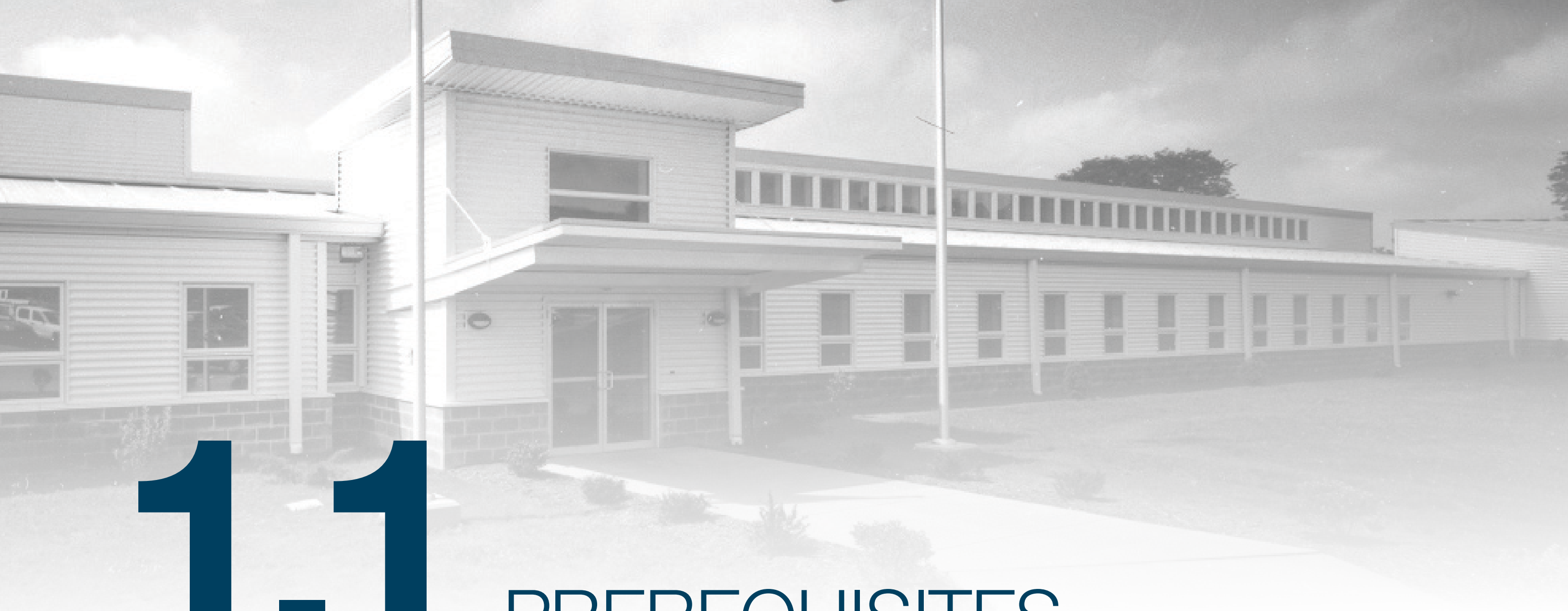
Tier One of the *Advanced Buildings New Construction Guide* can also directly support the adoption of stretch codes modeled on the IECC code. Entering into the 2012 code cycle, the International Code Council had aggressive goals for advancement of the IECC, seeking a 25-30% improvement over the 2006 version. During that time utility incentive programs implementing the *Core Performance Guide* were delivering savings in that range. A suite of proposals based directly on the *Advanced Buildings: Core Performance Guide* was proposed and adopted as code language, with some small revisions. After code adoption in 2012 IECC, small changes were made to the *Core Performance Guide* to align it with the final version of IECC 2012.

Advanced Buildings: New Construction Tier One can therefore be used to provide guidance in jurisdictions that have adopted IECC-2012 as either a base or stretch code. The guidance can help designers, engineers and contractors effectively meet the requirements of this substantially more stringent code. This guidance goes beyond the basic code requirements, offering more information about the requirements and how to meet them.

Table 1.0.1: Alignment of *Advanced Buildings: New Construction* Tier One strategies with IECC code requirements.

Criterion	2012 IECC CORRESPONDENCE	2012 IECC REQUIREMENT
1.2 – Air Barrier	SECTION C402.4	CLIMATE ZONES 4-8
1.3 – Opaque Wall	SECTION C402.2	ALL CLIMATE ZONES
1.4 – Fenestration	SECTION C402.3	ALL CLIMATE ZONES
1.5 – Minimum Interior Air Quality	NONE	NONE
1.6 – Lighting Controls	SECTION C405.2	ALL CLIMATE ZONES
1.7 – Lighting Power Density	SECTIONS C405.5 and C405.6	ALL CLIMATE ZONES
1.8 – Cool Roof	SECTION C402.2.2.1.1	CLIMATE ZONES 1-3
1.9 – Mechanical System Efficiency	SECTION C403.2.3	ALL CLIMATE ZONES
1.10 – Fundamental Economizer Performance	SECTION C403.3	CLIMATE ZONES 2-8
1.11 – Energy Recovery Ventilation	SECTION C403.2.6	Based on Outside Air Flow Rate
1.12 – Demand Control Ventilation	SECTION C403.2.5.1	High density occupancies without energy recovery
1.13 – Acceptance Testing	SECTION C408	Buildings with cooling capacity greater than 480,000 Btu/h or heating capacity greater than 600,000 Btu/h
1.14 – Additional Efficiency Option	SECTION C406	ONE PACKAGE OPTION, ALL CLIMATE ZONES

The *Advanced Buildings New Construction Guide* is meant to complement code books, not replace them. It is aligned with the IECC-2012, but it does not contain all of the code requirements. It focuses on those areas where the IECC has seen the greatest change in terms of stringency. Projects should still consult code books for code compliance.



1.1 PREREQUISITES

Photo credit: DOE/NREL

Criteria

- All projects shall implement the strategies in the Design Section of *Advanced Buildings New Construction Guide* (Criteria 0.1-0.5).
- All buildings shall meet or exceed applicable state and local energy codes. Where state and local codes are not as stringent as the 2007 version of ANSI/ASHRAE/IESNA Standard 90.1 (90.1-2007) or the 2009 version of the International Energy Conservation Code (IECC-2009) requirements, features of building elements not described in *AB:NC Tier One* shall meet or exceed IECC-2009.

Purpose

Define the minimum level of acceptable performance for measures not specified in Tier One of *Advanced Buildings New Construction Guide.*

1.2 AIR BARRIER PERFORMANCE

Photo credit: Dennis Schroeder / NREL

Purpose

Reduce uncontrolled air movement through the building envelope.

Criteria

The building envelope shall 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 shall also be provided for interior separations between conditioned space and space designed to maintain temperature or humidity levels which 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 shall have the following characteristics:

1. It must be continuous, with all joints made airtight.
2. Materials used for the air barrier system shall have an air permeability not to exceed 0.004 cfm/ft^2 under a pressure differential of 0.3 in. water (1.57psf) (0.02 L/s.m^2 @ 75 Pa) when tested in accordance with ASTME 2178. The following materials can be assumed to meet this standard when installed according to the manufacturer's instructions:
   - Plywood - minimum ⅜ in (10 mm)
   - Oriented strand board - minimum ⅜ in (10 mm)
   - Extruded polystyrene insulation board - minimum ½ in (12 mm) in thickness
   - Foil-back urethane insulation board - minimum ½ in (12 mm) in thickness
   - Exterior or interior gypsum board - minimum ½ in (12 mm) in thickness
   - Cement board - minimum ½ in (12 mm)
   - Built-up roofing membrane
   - Modified bituminous roof membrane
   - Fully adhered single-ply roof membrane
   - A Portland cement/sand parge, or gypsum plaster minimum ⅝ in (16 mm) thick
   - Cast-in-place and precast concrete
   - Fully grouted concrete block masonry

- Sheet steel or aluminum
- Closed-cell spray foam a minimum density of 1.5 pcf (2.4 kg/m^3) no less than 1½ inches (36 mm) in thickness.
- Open-cell spray foam with a density between 0.4 and 1.5 pcf (0.6 and 2.4 kg/m^3) no less than 4.5 inches (140 76mm) in thickness.

3. All prefabricated fenestration assemblies shall meet the air leakage requirements in Table 1.2.1.

Table 1.2.1 Fenestration Infiltration Rate Requirements

Fenestration Assembly	Maximum Rate (CFM/FT^2)	Test Procedure
Windows	0.20[a]	AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC 400
Sliding Doors	0.20[a]	
Swinging Doors	0.20[a]	
Skylights - with condensation weepage openings	0.30	
Skylights - all others	0.20[a]	
Curtain Walls	0.06	NFRC 400 or ASTME 283 at 1.57 psf (75 Pa)
Storefront Glazing	0.06	
Commercial Glazed Swinging Entrance Doors	1.00	
Revolving Doors	1.00	
Garage Doors	0.40	ANSI/DASMA 105, NFRC 400, or ASTME 283 at 1.57 psf (75 Pa)
Rolling Doors	1.00	

Include footer: For SI: 1 cubic foot per minute=0.47/s, 1 square foot=0.093 m^2.

a. The maximum rate for windows, sliding and swinging doors, and skylights is permitted to be 0.3 cfm per square foot of fenestration or door area when tested in accordance with AAMA/WDMA/CAS 101/I.S.2/A440 at 6.24 psf (300 Pa).

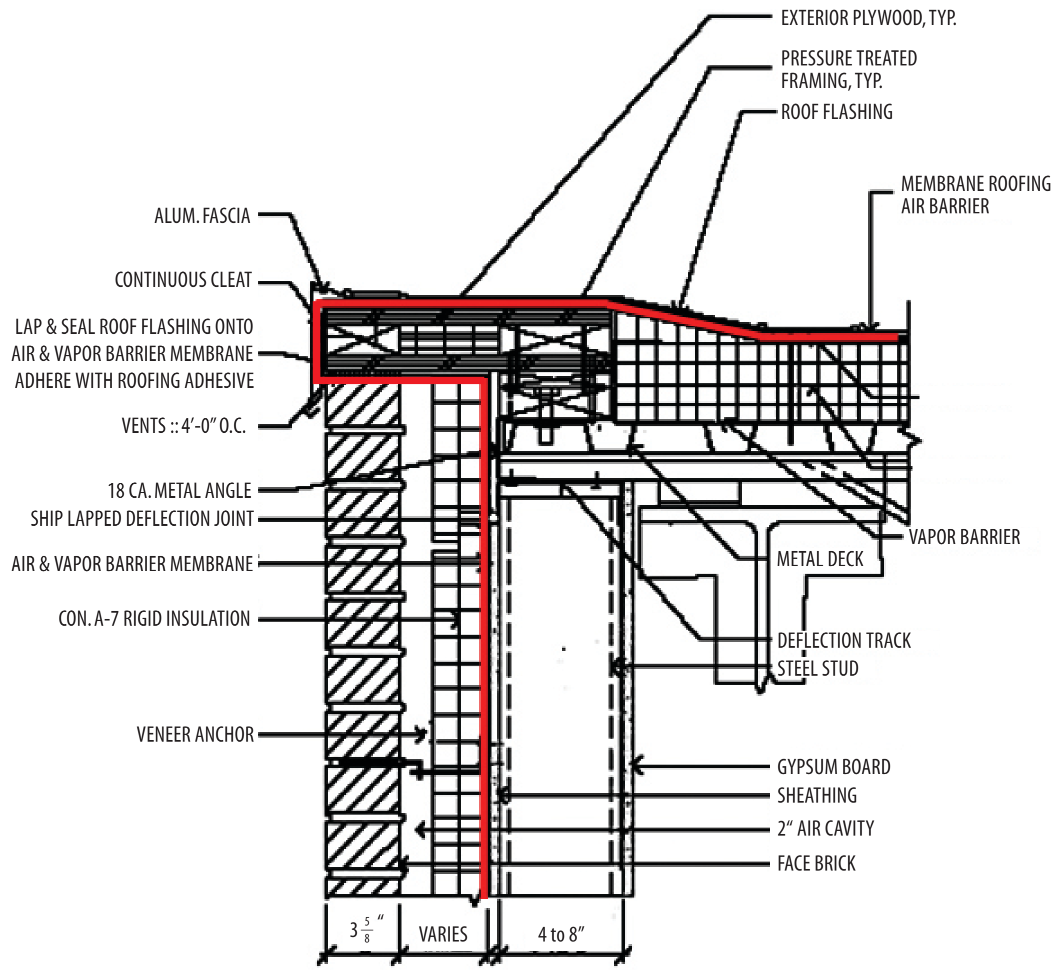
4. The air barrier shall be capable of withstanding positive and negative combined design wind, fan and stack pressures on the envelope without damage or displacement and shall transfer the load to the structure. It shall not displace adjacent materials under full load.
5. The air barrier shall be durable or maintainable.
6. All ducts in unconditioned spaces shall be sealed at joints with mastic.
7. All joints and seams shall be sealed, including sealing transitions in places and changes in materials. Penetrations of the air barrier and paths of air leakage shall be caulked, gasketed or otherwise sealed in a manner compatible with the construction materials and location. Joints and seals shall be sealed in the same manner or taped or covered with a moisture vapor-permeable wrapping material. Sealing materials shall be appropriate to the construction materials being sealed. Joints and seals shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation.
8. Connections between the following components shall be made with caulk, mastic, gaskets or other appropriate sealants:
   - Foundation and walls
   - Walls and windows or doors
   - Different wall systems
   - Wall and roof
   - Wall and roof over unconditioned space
   - Walls, floor and roof across construction, control and expansion joints
   - Walls, floors and roof to utility, pipe and duct pen-etrations

9. Recessed luminaires with air leakage to unconditioned spaces shall be labeled to have an air leakage rate of not more than 2.0 cfm and shall be sealed with a gasket and caulk.

10. Loading dock doors and cargo doors shall be weather sealed.

11. The sequence of construction shall allow for installation of a continuous air barrier and thorough sealing of all joints and penetrations.

Exception: Buildings that have demonstrated an air leakage rate of less than 2.0 L/s•m² @ 75 Pa (0.40 cfm/ft² at a pressure differential of 0.3" w.g. (1.57 psf)) in accordance with ASTME 779.



Attention to detail is critical at all joints and penetrations to assure a complete air barrier.

Detail credit: State of Massachusetts and Wagdy Anis, FAIA.

DETAIL AT ROOF EDGE

REFERENCE DETAIL: REGISTERED PROFESSIONAL TO REVIEW PRIOR TO USE

1.3 OPAQUE ENVELOPE PERFORMANCE

Photo credit: NREL

Criteria

- Walls, roof assemblies, floors and slabs-on-grade that are part of the building envelope shall meet the requirements shown in Table 1.3.1.
- Slab-on-grade floors and below-grade floors and walls shall be isolated from ground temperatures with a minimum layer of insulation according to Table 1.3.1. Where a heated slab is below grade, the below-grade walls shall comply with the exterior insulation requirements for the heated slab.
- Building spaces greater than 3,000 square feet, except for buildings in Climate Zones 1 and 2, shall be provided with a vestibule.

The U-factors within opaque wall categories (e.g. wall) can be calculated by an area-weighted average to achieve compliance with the values in Table 1.3.1. COMcheck and other software tools can be used for this averaging.

Purpose

Reduce environmental impacts and increased operational costs associated with thermal conductance through the building envelope.

Decoupling the temperature of slab-on-grade or below-grade masonry from the temperature of the ground reduces the potential for condensation on those surfaces.

Core Performance Building: Counseling Services of Addison County in Middlebury, VT. benefits from a focus on its thermal shell. Photo credit: Efficiency Vermont

Table 1.3.1 Opaque Envelope Requirements

Climate Zone	1	2	3	4 (except marine)	5 (and marine 4)	6	7	8
Roofs								
Insulation entirely above deck	R-20ci	R-20ci	R-20ci	R-25ci	R-25ci	R-30ci	R-35ci	R-35ci
Metal Buildings (with R-5 thermal blocks)[a, b]	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-25 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS
Attic and Other	R-38	R-38	R-38	R-38	R-38	R-49	R-49	R-49
Walls, Above Grade								
Mass	R-5.7ci	R-5.7ci	R-7.6ci	R-9.5ci	R-11.4ci	R-13.3ci	R-15.2ci	R-25ci
Metal Building	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci
Metal Framed	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci
Wood Framed and Other	R-13 + R-3.8 ci or R-20	R-13 + R-3.8 ci or R-20	R-13 + R-3.8 ci or R-20	R-13 + R-3.8 ci or R-20	R-13 + R-3.8 ci or R-20	R-13 + R-7.5ci or R-20 + R--3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-15.6ci or R-20 + R-10ci
Walls, Below Grade								
Below-grade wall[d]	NR	NR	NR	R-7.5ci	R-7.5ci	R-7.5ci	R-10ci	R-10ci
Floors								
Mass	NR	R-6.3ci	R-10ci	R-10ci	R-10ci	R-12.5ci	R-15ci	R-15ci
Joist/Framing	NR	R-30	R-30	R-30	R-30	R-30	R-30[e]	R-30[e]
Slab-on-Grade Floors								
Unheated Slabs	NR	NR	NR	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below	R-15 for 24" below	R-15 for 24" below
Heated Slabs[d]	R-7.5 for 12" below	R-7.5 for 12" below	R-10 for 24" below	R-15 for 24" below	R-15 for 36" below	R-15 for 36" below	R-20 for 24" below	R-20 for 48" below
Opaque Doors								
Swinging	U-0.61	U-0.61	U-0.61	U-0.61	U-0.37	U-0.37	U-0.37	U-0.37
Roll-up or Sliding	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75

For SI: 1 inch = 25.4 mm. | ci = Continuous insulation. | NR = No requirement. | LS = Linear System—A continuous membrane installed below the purlins and uninterrupted by framing members. Uncompressed, unfaced insulation rests on top of the membrane between the purlins.

a. Assembly descriptions can be found in ANSI/ASHRAE/IESNA Appendix A.

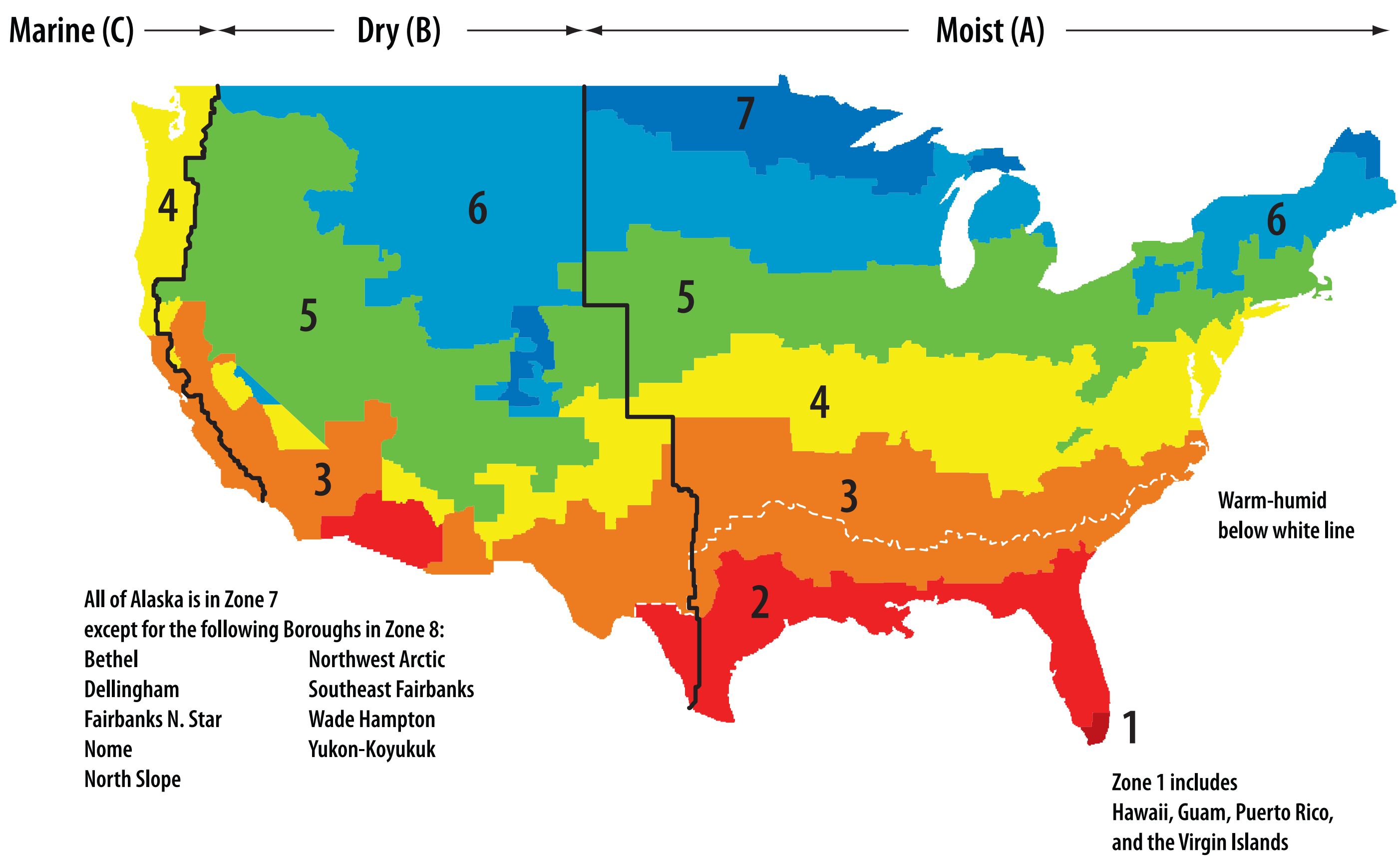
b. Where using R-value compliance method, a thermal spacer block shall be provided, otherwise use the U-factor compliance method in Table C402.1.2.

c. R-5.7ci is allowed to be substituted with concrete block walls complying with ASTM C 90, ungrouted or partially grouted at 32 inches or less on center vertically and 48 inches or less on center horizontally, with ungrouted cores filled with materials having a maximum thermal conductivity of 0.44 Btu-in/h-f² °F.

d. Where heated slabs are below grade, below-grade walls shall comply with the exterior insulation requirements for heated slabs.

e. Steel floor joist systems shall be insulated to R-38.

The climate map below indicates which zone designation should be used in determining envelope and fenestration performance requirements. A more detailed version of this map is located in Appendix B.



Core Performance Building: Tremont Yard Building, Lowell, MA. Photo credit: National Grid

1.4 FENESTRATION AREA AND PERFORMANCE

Purpose

Reduce environmental impacts and increased operational costs associated with thermal conductance through the building's fenestration.

Criteria

- Vertical glazing area shall be no greater than 30% of the gross above-grade wall area.

  Exception: Buildings in Climate Zones 1-6 where the vertical glazing area is no greater than 40% of the gross above-grade wall area, 50% of the conditioned floor area is within a daylight zones with automatic daylight controls in each daylight zone, and the fenestration VLT is no less than 1.1 times the SHGC.

- Skylight area shall be no greater than 3% of the roof area.

  Exception: Buildings where the skylight glazing area is not greater than 5% and automatic daylight controls are installed in the daylight zones under all skylights.

- Vertical glazed systems and skylights that are part of the envelope for buildings shall meet the criteria in Table 1.4.1. Each vertical fenestration system must meet the U-Factor and SHGC for the corresponding climate zone. The U-Factors within each fenestration category in Table 1.4.1 may be averaged based on the area-weighted average of all fenestration units within that category. SHGC may not be averaged.

For the purposes of calculating the area of daylight zones for *Advanced Buildings: New Construction Tier One*, a daylight zone adjacent to vertical fenestration shall be 15 feet deep and 2 feet on each side of a vertical window, a daylight zone under a skylight shall be the ceiling-to-floor height added in each dimension to the skylight dimension, and daylight zones shall stop when a ceiling height opaque partition is reached and may not overlap (be "double-counted").

Table 1.4.1
Fenestration Requirements

Climate Zone	1	2	3	4 (except marine)	5 (and marine 4)	6	7	8
Vertical fenestration								
U-Factor								
Fixed fenestration	0.50	0.50	0.46	0.38	0.38	0.36	0.29	0.29
Operable fenestration	0.65	0.65	0.60	0.45	0.45	0.43	0.37	0.37
Entrance doors	1.10	0.83	0.77	0.77	0.77	0.77	0.77	0.77
SHGC								
SHGC	0.25	0.25	0.25	0.40	0.40	0.40	0.45	0.45
Skylights								
U-Factor	0.75	0.65	0.55	0.50	0.50	0.50	0.50	0.50
SHGC	0.35	0.35	0.35	0.40	0.40	0.40	NR	NR

NR = No requirement.

The values in this table apply to the entire fenestration assembly.

1.5 MINIMUM IAQ PERFORMANCE

Clackamas High School, Clackamas, Oregon Photo credit: Michael Mathers

Purpose

Provide building occupants with acceptable indoor air quality.

Criteria

Design and operate the building to meet or exceed ASHRAE Standard 62.1, including:

- Design and implement an ASHRAE Standard 62.1-compliant outdoor air control technique.
- Develop and implement an IAQ Construction Management Plan to control contaminants and dust during construction.
- Flush the building with 100% of the scheduled quantity of outdoor air prior to occupancy and after the punch list is complete.
- Develop and implement an IAQ Operations Management Plan for building operation.

1.6 LIGHTING CONTROLS

Mount Angel Abbey, St. Benedict, OR.
Photo credit: Daylighting Pattern Guide

Criteria

- All areas of the building with manual lighting controls shall have bi-level controls. Bi-level switching should be achieved by one or more of the following:
  - » Step control of all lamps and luminaires
  - » Dual switching of alternate rows of luminaires, alternate luminaires or alternate lamps
  - » Switching the middle lamp luminaires independently of the outer lamps
  - » Switching each lamp or each luminaire

  Exceptions:
  - » Areas with only one luminaire
  - » Areas with rated power less than 100 watts
  - » Areas controlled by an occupant-sensing device
  - » Corridors, storerooms, restrooms, public lobbies, or electrical or mechanical rooms
  - » Sleeping units
  - » Spaces with installed lighting power density (LPD) less than 0.6 watts per square foot (6.5 W/m^2)
  - » Daylight zones equipped with Automatic Daylighting Controls
- Occupancy Sensors shall be installed to control lighting in all classrooms, conference/meeting rooms, employee lunch and break rooms, private offices, restrooms, storage rooms and janitorial closets, and other spaces 300 sf. or less enclosed by ceiling height partitions. The control device shall automatically turn off lights within 30 minutes of the last occupant leaving the space. The control device shall not automatically switch on more than 50% of the lighting power, except in corridors and other high-use areas or where safety or security is a concern.
- Where Automatic Daylight Controls are required by Criteria 1.6 or 1.14, or by the Special Condition below, they shall:

Purpose

To reduce lighting energy use through the installation of automatic lighting controls and adjustable lighting level strategies.

» Control the lights in the daylight areas separately from the non-daylight area

» Automatically and continuously reduce electrical lighting power of general lighting in the daylight zone to less than 35% of the maximum rated power in response to available daylight with daylight-sensing automatic controls and either continuous dimming ballasts

Exception: Warehouse and high bay spaces may utilize stepped dimming instead of continuous dimming ballasts provided at least one control step shall reduce power of general lighting in the daylight zone by 50-70% of rated power and another control step shall reduce lighting power by 65-100%, and general lighting in the daylight zone is reduced in a reasonably uniform and appropriate level of illuminance.

» Provide at least two control channels per zone

Special Conditions:

In Climate Zones 1-5, spaces greater than 10,000 square feet with a ceiling height of 15 feet or greater and directly under a roof shall be provided with skylights such that 50% or more of the floor area is within a daylight zone and controlled by multi-level automatic daylight controls.

- Automatic Time Switch Control Devices shall include an override switching device located in a readily accessible location. The lights controlled by the override switch shall be visible from the switch and be manually controlled by the override switch. Operation of the switch shall permit the controlled lights to remain on for no longer than 2 hours. Any individual override switch shall not control more than 5,000 square feet of floor space. In malls, arcades, auditoriums, single-tenant retail spaces, industrial facilities and arenas, the time limit on the override switch shall be permitted to exceed 2 hours provided the override switch is a captive key device; the area controlled by the override switch shall be permitted to control up to 20,000 square feet (1,860 m^2) of floor space.

Exceptions:

» Emergency egress lighting (the limit on emergency egress lighting is 15% of total connected lighting load)

» Lighting in spaces controlled by occupancy sensor

- Display lights, case lights and accent lights shall be controlled independently of all other dedicated general room controls.
- Sleeping units in hotels and motels shall have a master device at the room entry that controls all installed lights and switched receptacles.
- Supplemental task lighting and cabinet-mounted lighting shall have either a switch integral to the fixture or a readily accessible wall switch.

Exceptions from automatic lighting control requirements:

» Sleeping units not in hotels or motels

» Lighting in spaces where patient care is directly provided

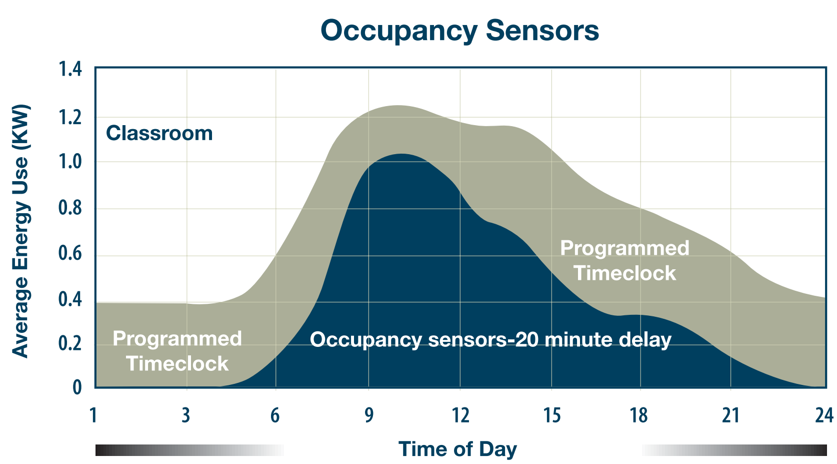
» Spaces where an automatic shutoff would endanger occupant safety or security

General

Occupancy sensors may be appropriate in additional space types and should be evaluated on a case-by-case basis. For instance, open office areas can be served by ceiling-mounted occupancy sensors in many cases.

Figure 1.6.1

Occupancy sensors can save substantial amounts of energy by turning lights off when a space is unoccupied. This graph shows the relative energy use of a pre-programmed timeclock vs. occupancy sensors with a 20 minute delay in a typical school classroom application.



1.7 LIGTHING POWER DENSITY–INTERIOR AND EXTERIOR

NREL's Research Support Facilities (RSF), Golden, CO. Photo Credit: Dennis Schroeder/NREL

Criteria

- Installed lighting power density (LPD) shall not exceed the lighting equipment power density (LPD) allowances as shown in either Table 1.7.1 or Table 1.7.2 in accordance with one of the following methods:
  - Using the Building Area Method, the LPD of each area of the building must be less than or equal to the LPD listed in Table 1.7.1. An "area" for this purpose is defined as all contiguous areas of a building associated with the types listed in the tables below.
  - Using the Space-by-Space Method, the total connected LPD for the whole building may not exceed the sum of the area of each space times the maximum LPD listed for that space in Table 1.7.2. A "space" for this purpose is defined as all contiguous areas of a building associated with the types listed in the Table 1.7.2. If the Space-by-Space Method is used for compliance, tradeoffs are permitted between spaces.

  Interior LPD Exceptions:
  - Lights in hotel/motel sleeping units
  - Task lighting for medical/dental purposes
  - Furniture-mounted task lighting controlled by an automatic shutoff
  - Displays for museums and galleries
  - Any other lighting exempted by local code

- The lighting power density of all exterior lighting supplied through the building's energy service shall not exceed the allowances in Table 1.7.3. The overall lighting power allowance is the sum of the base site allowance plus the area allowances for those areas that are illuminated. Tradeoffs are permitted as specified in the table.

  Exterior LPD Exceptions:
  - Low-voltage landscape lighting
  - Historical, safety, signage or emergency lighting that has been approved by a code official

Purpose

Reduce environmental impacts and increased operational costs associated with the energy consumption of lighting systems.

- » Advertising or directional signage controlled separately from general site lighting
- » Lighting for industrial production, material handling, transportation sites and associated storage areas

- All exterior luminaires on the building site that are supplied by the building's energy service shall include photocell controls that prevent daytime operation. Those exterior luminaires that operate at greater than 100 watts shall be controlled by a motion sensor or contain lamps with an efficacy of at least 60 lumens per watt.

The LPD of screw lamp holders shall be calculated at the **maximum labeled wattage**. Wattage for low-voltage lighting shall be calculated at the **rated wattage** of the supplying transformer.

Table 1.7.1 Building Area Method Allowances

Building Area Type	LPD (w/sf²)
Automotive Facility	0.9
Convention Center	1.2
Courthouse	1.2
Dining: bar lounge/leisure	1.3
Dining: cafeteria/fast food	1.4
Dining: family	1.6
Dormitory	1.0
Exercise center	1.0
Fire Station	0.8
Gymnasium	1.1
Health Care Clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing Facility	1.3
Motel	1.0
Motion picture theater	1.2
Multifamily	0.7
Museum	1.1
Office	0.9
Parking garage	0.3
Penetentiary	1.0
Performance Arts Theater	1.6
Police Station	1.0
Post office	1.1
Religious building	1.3
Retail	1.4
School/University	1.2
Sports Arena	1.1
Town Hall	1.1
Transportation	1.0
Warehouse	0.6
Workshop	1.4

Table 1.7.2 Space-By-Space Method Allowances

Common Space-By-Space Types	LPD (W/FT²)
Atrium - First 40 feet in height	0.03 per ft. ht.
Atrium - Above 40 feet in height	0.02 per ft. ht.
Audience/seating area - permanent	
For auditorium	0.90
For performing arts theater	2.60
For motion picture theater	1.20
Classroom/lecture/training	1.30
Conference/meeting/multipurpose	1.20
Corridor/transition	0.70
Dining area	
Bar/lounge/leisure dining	1.40
Family dining area	1.40
Dressing/fitting room performing arts theater	1.10
Electrical/mechanical	1.10
Food preparation	1.20
Laboratory for classrooms	1.30
Laboratory for medical/industrial/ research	1.80
Lobby	1.10
Lobby for performing arts theater	3.30
Lobby for motion picture theater	1.00
Locker room	0.80
Lounge recreation	0.80
Office - enclosed	1.10
Office - open plan	1.00
Restroom	1.00
Sales area	1.60[a]
Stairway	0.70
Storage	0.80
Workshop	1.60
Courthouse/police station/ penetentiary	
Courtroom	1.90
Confinement cells	1.10
Judge chambers	1.30
Penitentiary audience seating	0.50
Penitentiary classroom	1.30
Penitentiary dining	1.10

Common Space-By-Space Types	LPD (W/FT²)
Building specific space-by-space types	
Automotive - service/repair	0.70
Bank/office - banking activity area	1.50
Dormitory living quarters	1.10
Gymnasium/fitness center	
Fitness area	0.90
Gymnasium audience/seating	0.40
Playing area	1.40
Healthcare clinic/hospital	
Corridors/transition	1.00
Exam/treatment	1.70
Emergency	2.70
Public and staff lounge	0.80
Medical supplies	1.40
Nursery	0.90
Nurse station	1.00
Physical therapy	0.90
Patient room	0.70
Pharmacy	1.20
Radiology/imaging	1.30
Operating room	2.20
Recovery	1.20
Lounge/recreation	0.80
Laundry - washing	0.60
Hotel	
Dining area	1.30
Guest rooms	1.10
Hotel Lobby	2.10
Highway lodging dining	1.20
Highway lodging gues rooms	1.10
Library	
Stacks	1.70
Card file and cataloging	1.10
Reading area	1.20
Manufacturing	
Corridors/transition	0.40
Detailed manufacturing	1.30

Common Space-By-Space Types	LPD (W/FT²)
Equipment room	1.00
Extra high bay (>50-foot floor-ceiling height)	1.10
High bay (25- – 50-foot floor-ceiling height)	1.20
Low bay (<25-foot floor-ceiling height)	1.20
Museum	
General exhibition	1.00
Restoration	1.70
Parking garage - garage areas	0.20
Convention center	
Exhibit space	1.50
Audience/seating area	0.90
Fire stations	
Engine room	0.80
Sleeping quarters	0.30
Post office	
Sorting area	0.90
Religious building	
Fellowship hall	0.60
Audience seating	2.40
Worship pulpit/choir	2.40
Retail	
Dressing/fitting area	0.90
Mall concourse	1.60
Sales area	1.60[a]
Sports arena	
Audience seating	0.40
Court sports area - Class 4	0.70
Court sports area - Class 3	1.20
Court sports area - Class 2	1.90
Court sports area - Class 1	3.00
Ring sports area	2.70
Transportation	
Air/train/bus baggage area	1.00
Airport concourse	0.60
Terminal – ticket counter	1.50
Warehouse	
Fine material storage	1.40
Medium/bulky material	0.60

For SI: 1 foot = 304.8 mm, 1 watt per square foot = 11 W/m².

a. Where lighting equipment is specified to be installed to highlight specific merchandise in addition to lighting equipment specified for general lighting and is switched or dimmed on circuits different from the circuits for general lighting, the smaller of the actual wattage of the lighting equipment installed specifically for merchandise, or additional lighting power as determined below shall be added to the interior lighting power determined in accordance with this line item. Calculate the additional lighting power as follows:

Additional Interior Lighting Power Allowance = 500 watts + (Retail Area 1 x 0.6 W/ft²) + (Retail Area 2 x 0.6 W/ft²) + (Retail Area 3 x 1.4 W/ft²) + (Retail Area 4 x 2.5 W/ft²),

where:

Retail Area 1 = The floor area for all products not listed in Retail Area 2, 3 or 4.

Retail Area 2 = The floor area used for the sale of vehicles, sporting goods and small electronics.

Retail Area 3 = The floor area used for the sale of furniture, clothing, cosmetics and artwork.

Retail Area 4 = The floor area used for the sale of jewelry, crystal and china.

Exception: Other merchandise categories are permitted to be included in Retail Areas 2 through 4 above, provided that justification documenting the need for additional lighting power based on visual inspection, contrast, or other critical display is *approved* by the authority having jurisdiciton.

Table 1.7.3 Exterior Building Power Allowances

		Lighting Zones			
		Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.)		500 W	600 W	750 W	1300 W
Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas are tradable.)	**Uncovered Parking Areas**				
	Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2	0.13 W/ft^2
	Building Grounds				
	Walkways less than 10 feet wide	0.70 W/linear foot	0.70 W/linear foot	0.80 W/linear foot	1.00 W/linear foot
	Walkways 10 feet wide or greater, plaza areas, special feature areas	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2	0.20 W/ft^2
	Stairways	0.75 W/ft^2	1.00 W/ft^2	1.00 W/ft^2	1.00 W/ft^2
	Pedestrian tunnels	0.15 W/ft^2	0.15 W/ft^2	0.20 W/ft^2	0.30 W/ft^2
	Building Entrances and Exits				
	Main entries	20 W/linear foot of door width	20 W/linear foot of door width	30 W/linear foot of door width	30 W/linear foot of door width
	Other doors	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width
	Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.40 W/ft^2	0.40 W/ft^2
	Sales Canopies				
	Free-standing and attached	0.60 W/ft^2	0.60 W/ft^2	0.80 W/ft^2	1.00 W/ft^2
	Outdoor Sales				
	Open areas (including vehicle sales lots)	0.25 W/ft^2	0.25 W/ft^2	0.50 W/ft^2	0.70 W/ft^2
	Street frontage for vehicle sales lots in addition to “open area” allowance	No allowance	10 W/linear foot	10 W/linear foot	30 W/linear foot
Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the “Tradable Surfaces” section of this table.)	Building facades	No allowance	0.10 W/ft^2 for each illuminated wall or surface or 2.50 W/linear foot for each illuminated wall or surface length	0.15 W/ft^2 for each illuminated wall or surface or 3.75 W/linear foot for each illuminated wall or surface length	0.20 W/ft^2 for each illuminated wall or surface or 5.00 W/linear foot for each illuminated wall or surface length
	Automated teller machines and night depositories	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location
	Entrances and gatehouse inspection stations at guarded facilities	0.75 W/ft^2 of covered and uncovered area	0.75 W/ft^2 of covered and uncovered area	0.75 W/ft^2 of covered and uncovered area	0.75 W/ft^2 of covered and uncovered area
	Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.50 W/ft^2 of covered and uncovered area	0.50 W/ft^2 of covered and uncovered area	0.50 W/ft^2 of covered and uncovered area	0.50 W/ft^2 of covered and uncovered area
	Drive-up windows/doors	400 W per drive-through	400 W per drive-through	400 W per drive-through	400 W per drive-through
	Parking near 24-hour retail entrances	800 W per main entry	800 W per main entry	800 W per main entry	800 W per main entry

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m^2.

Core Performance Building: Brooks School, North Andover, MA. Photo credit: Architerra

1.8 COOL ROOFS

Purpose

Promote the installation of roof surfaces that reduce the urban heat island effect, reduce energy use and provide other environmental benefits.

Criteria

On low-slope roofs (2:12 or less) above cooled conditioned spaces, install a Cool Roof that meets one of four specification options below. The options may be applied on an area-weighted basis.

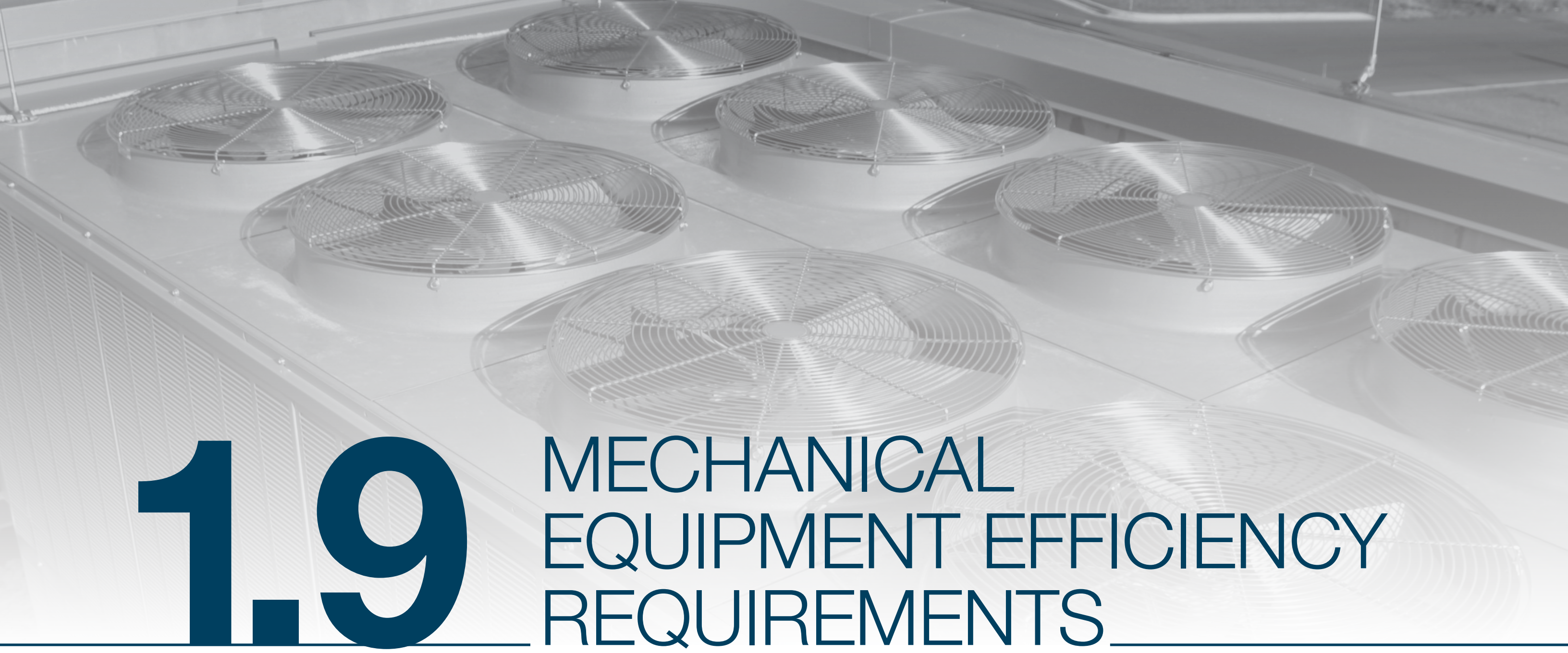
- Three-year aged solar reflectance of 0.55 and a three-year thermal emittance of 0.75
- An initial solar reflectance of 0.70 and initial thermal emittance of 0.75.
- A three-year solar reflectance index of 64.
- An initial solar reflectance index of 82.

Exceptions:

- » Areas that have roof gardens or landscaped roofs
- » Areas covered by solar electric or solar thermal systems
- » Areas covered by walkways, skylights, equipment or other building components
- » Portions of roofs that are ballasted
- » Portions of roofs shaded from the direct sun on the summer solstice by permanent features of the building or an adjacent building

General

Cool roofs not only have a positive effect by reducing building loads and the air temperature of roof-level air intake, they also reduce the "heat island" impact of the building on its surroundings.



1.9 MECHANICAL EQUIPMENT EFFICIENCY REQUIREMENTS

Criteria

Mechanical equipment shall meet the efficiency requirements of Tables 1.9.1 through 1.9.9.

General

The most important efficiency aspect of HVAC performance is the overall efficiency of the whole system for delivery of space conditioning, not just the efficiencies for components given in the tables below.

Using the design principles discussed in Criterion 0.4 Mechanical System Design will help assure the balance of system components (pipes, ducts, pumps, fans, etc.), enhance total system efficiency, and ensure the system is sized for more efficient performance.

Purpose

Reduce environmental impacts and operational costs associated with energy consumption of heating, ventilating and air conditioning equipment.

Table 1.9.1 Minimum efficiency requirements: electrically operated unitary air conditioners and condensing units

Equipment Type	Size Category	Heating Section Type	Subcategory Or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air Conditioners, Air Cooled	< 65,000 Btu/h[b]	All	Split System	13.0 SEER	AHRI 210/240
			Single Package	13.0 SEER	
Through-The-Wall (Air Cooled)	≤ 30,000 Btu/h[b]	All	Split System	12.0 SEER	
			Single package	12.0 SEER	
Small-Duct High-Velocity (Air Cooled)	< 65,000 Btu/h[b]	All	Split System	10.0 SEER	
Air Conditioners, Air Cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 11.4 IEER	AHRI 340/360
		All Other	Split System and Single Package	11.0 EER 11.2 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	
		All Other	Split System and Single Package	10.8 EER 11.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 10.1 IEER	
		All Other	Split System and Single Package	9.8 EER 9.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 9.8 IEER	
		All Other	Split System and Single Package	9.5 EER 9.6 IEER	
Air Conditioners, Water Cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	12.1 EER 12.3 IEER	AHRI 210-240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.1 EER 12.3 IEER	AHRI 340/360
		All	Split System and Single Package	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.5 EER 12.7 IEER	
		All	Split System and Single Package	12.3 EER 12.5 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.4 EER 12.6 IEER	
		All	Split System and Single Package	12.2 EER 12.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.0 EER 12.4 IEER	
		All	Split System and Single Package	12.0 EER 12.2 IEER	

Table 1.9.1 Minimum efficiency requirements: electrically operated unitary air conditioners and condensing units (continued)

Equipment Type	Size Category	Heating Section Type	Subcategory Or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air Conditioners, Evaporatively Cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.1 EER 12.3 IEER	AHRI 340/360
		All	Split System and Single Package	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.0 EER 12.2 IEER	
		All	Split System and Single Package	11.8 EER 12.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.9 EER 12.1 IEER	
		All	Split System and Single Package	12.2 EER 11.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.7 EER 11.9 IEER	
		All	Split System and Single Package	11.5 EER 11.7 IEER	
Condensing units, air cooled	≥ 135,000 Btu/h			10.5 EER 14.0 IEER	AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h			13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥ 135,000 Btu/h			13.5 EER 14.0 IEER	

For SI: 1 British thermal unit per hour = 0.2931 W.

a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

Table 1.9.2 Minimum efficiency requirements: electrically operated unitary and applied heat pumps

Equipment Type	Size Category	Heating Section Type	Subcategory Or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air Cooled (Cooling Mode)	< 65,000 Btu/hb	All	Split System	13.0 SEER	AHRI 210/240
			Single Package	13.0 SEER	
Through-The-Wall, Air Cooled	≤ 30,000 Btu/hb	All	Split System	13.0 SEER	
			Single package	13.0 SEER	
Single-Duct High-Velocity Air Cooled	< 65,000 Btu/hb	All	Split System	10.0 SEER	
Air Cooled (Cooling Mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	AHRI 340/360
		All Other	Split System and Single Package	10.8 EER 11.0 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 10.7 IEER	
		All Other	Split System and Single Package	10.4 EER 10.5 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.6 IEER	
		All Other	Split System and Single Package	9.3 EER 9.4 IEER	
Water Source (Cooling Mode)	< 17,000 Btu/h	All	86°F entering water	11.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	12.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	12.0 EER	
Ground Water Source (Cooling Mode)	< 135,000 Btu/h	All	59°F entering water	16.2 EER	
		All	77°F entering water	13.4 EER	
Water-Source Water To Water (Cooling Mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	ISO 13256-2
			59°F entering water	16.3 EER	
Ground Water Source Brine To Water (Cooling Mode)	< 135,000 Btu/h	All	77°F entering water	12.1 EER	
Air Cooled (Heating Mode)	< 65,000 Btu/hb	—	Split System	7.7 HSPF	AHRI 210/240
		—	Single Package	7.7 HSPF	
Through-The-Wall (Air Cooled, Heating Mode)	≤ 30,000 Btu/hb (cooling capacity)	—	Split System	7.4 HSPF	
		—	Single Package	7.4 HSPF	
Small-Duct High Velocity (Air Cooled, Heating Mode)	< 65,000 Btu/hb	—	Split System	6.8 HSPF	
Air Cooled (Heating Mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.3 COP	AHRI 340/360
			17°F db/15°F wb Outdoor Air	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.2 COP	
			17°F db/15°F wb Outdoor Air	2.05 COP	

Table 1.9.2 Minimum efficiency requirements: electrically operated unitary and applied heat pumps (continued)

Equipment Type	Size Category	Heating Section Type	Subcategory Or Rating Condition	Minimum Efficiency	Test Procedure[a]
Water Source (Heating Mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	4.2 COP	ISO 13256-1
Ground Water Source (Heating Mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.6 COP	
Ground Source (Heating Mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering water	3.1 COP	
Water Source Water To Water (Heating Mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	ISO 13256-2
		—	50°F entering water	3.1 COP	
Ground Source Brine To Water (Heating Mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	2.5 COP	

For SI: 1 British Thermal Unit Per Hour = 0.2931 W, °C = [(°F) - 32]/1.8.

A. Chapter 6 Of The Referenced Standard Contains A Complete Specification Of The Referenced Test Procedure, Including The Reference Year Version Of The Test Procedure.

B. Single-Phase, Air-Cooled Air Conditioners Less Than 65,000 Btu/H Are Regulated By NAECA. SEER Values Are Those Set By Naeca.

Table 1.9.3 Minimum efficiency requirements: electrically operated packaged terminal air conditioners, packaged terminal heat pumps, single-package vertical air conditioners, single vertical heat pumps, room air conditioners and room air-conditioner heat pumps

Equipment Type	Size Category (Input)	Subcategory Or Rating Condition	Minimum Efficiency	Test Procedure[a]
PTAC (Cooling Mode) New Construction	All Capacities	95°F db outdoor air	13.8 - (0.300 X Cap/1000) EER	AHRI 310/380
PTAC (Cooling Mode) Replacements[b]	All Capacities	95°F db outdoor air	10.9 - (0.213 X Cap/1000) EER	
PTHP (Cooling Mode) New Construction	All Capacities	95°F db outdoor air	14.0 - (0.300 X Cap/1000) EER	
PTHP (Cooling Mode) Replacements[b]	All Capacities	95°F db outdoor air	10.8 - (0.213 X Cap/1000) EER	
PTHP (Heating Mode) New Construction	All Capacities	—	3.2 - (0.26 X Cap/1000) COP	
PTHP (Heating Mode) Replacements[b]	All Capacities	—	2.9 - (0.26 X Cap/1000) COP	

Table 1.9.3 Minimum efficiency requirements: electrically operated packaged terminal air conditioners, packaged terminal heat pumps, single-package vertical air conditioners, single vertical heat pumps, room air conditioners and room air-conditioner heat pumps (continued)

Equipment Type	Size Category (Input)	Subcategory Or Rating Condition	Minimum Efficiency	Test Procedure[a]
SPVAC (Cooling Mode)	< 65,000 Btu/h	95°F db/75°F wb outdoor air	9.0 EER	AHRI 390
	≥ 65,000 Btu/h And < 135,000 Btu/h	95°F db/75°F wb outdoor air	8.9 EER	
	≥ 135,000 Btu/h And < 240,000 Btu/h	95°F db/75°F wb outdoor air	8.6 EER	
SPVHP (Cooling Mode)	< 65,000 Btu/h	95°F db/75°F wb outdoor air	9.0 EER	
	≥ 65,000 Btu/h And < 135,000 Btu/h	95°F db/75°F wb outdoor air	8.9 EER	
	≥ 135,000 Btu/h And < 240,000 Btu/h	95°F db/75°F wb outdoor air	8.6 EER	
SPVHP (Heating Mode)	< 65,000 Btu/h	47°F db/43°F wb outdoor air	3.0 COP	
	≥ 65,000 Btu/h And < 135,000 Btu/h	47°F db/43°F wb outdoor air	3.0 COP	
	≥ 135,000 Btu/h And < 240,000 Btu/h	47°F db/75°F wb outdoor air	2.9 COP	
Room Air Conditioners, With Louvered Slides	< 6,000 Btu/h	—	9.7 SEER	ANSI/AHA-MRAC-1
	≥ 6,000 Btu/h And < 8,000 Btu/h	—	9.7 SEER	
	≥ 8,000 Btu/h And < 14,000 Btu/h	—	9.8 SEER	
	≥ 14,000 Btu/h And < 20,000 Btu/h	—	9.7 SEER	
	≥ 20,000 Btu/h	—	8.5 EER	
Room Air Conditioners, With Louvered Slides	< 8,000 Btu/h	—	9.0 EER	
	≥ 8,000 Btu/h And < 20,000 Btu/h	—	8.5 EER	
	≥ 20,000 Btu/h	—	8.5 EER	
Room Air-Conditioner Heat Pumps With Louvered Sides	< 20,000 Btu/h	—	9.0 EER	
	≥ 20,000 Btu/h	—	8.5 EER	
Room Air-Conditioner Heat Pumps Without Louvered Sides	< 14,000 Btu/h	—	8.5 EER	
	≥ 14,000 Btu/h	—	8.0 EER	
Room Air Conditioner Casement Only	All Capacities	—	8.7 EER	
Room Air Conditioner Casement-Slider	All Capacities	—	9.5 EER	

For SI: 1 British Thermal Unit Per Hour = 0.2931 W, °C = [(°F) - 32]/1.8.
“Cap” = the rated cooling capacity of the project in Btu/H. If the unit’s capacity is less than 7000 Btu/H, use 7000 Btu/H in the calculation. If the unit’s capacity is greater than 15,000 Btu/H, use 15,000 Btu/H in the calculations.

A. Chapter 6 Of The Referenced Standard Contains A Complete Specification Of The Referenced Test Procedure, Including The Reference Year Version Of The Test Procedure.

B. Replacement Unit Shall Be Factory Labeled As Follows: "Manufactured For Replacement Applications Only: Not To Be Installed In New Construction Projects." Replacement Efficiencies Apply Only To Units With Existing Sleeves Less Than 16 Inches (406 Mm) In Height And Less Than 42 Inches (1067 Mm) In Width.

Table 1.9.4 Warm air furnaces and combination warm air furnaces/air-conditioning units, warm air duct furnaces and unit heaters, minimum efficiency requirements

Equipment Type	Size Category (Input)	Subcategory Or Rating Condition	Minimum Efficiency[d, E]	Test Procedure[a]
Warm Air Furnaces, Gas Fired	< 225,000 Btu/h	—	78% AFUE or 80% E_t^c	DOE 10 CFR Part 430 or ANSI Z21.47
	≥ 225,000 Btu/h	Maximum capacity[c]	80% E_t^f	ANSI Z21.47
Warm Air Furnaces, Oil Fired	< 225,000 Btu/h	—	78% AFUE or 80% E_t^c	DOE 10 CFR Part 430 or UL 727
	≥ 225,000 Btu/h	Maximum capacity[b]	81% E_t^g	UL 727
Warm Air Duct Furnaces, Gas Fired	All capacities	Maximum capacity[b]	80% E_c	ANSI Z83.8
Warm Air Unit Heaters, Gas Fired	All capacities	Maximum capacity[b]	80% E_c	ANSI Z83.8
Warm Air Unit Heaters, Oil Fired	All capacities	Maximum capacity[b]	80% E_c	UL 731

For SI: 1 British thermal unit per hour = 0.2931 W.

a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. Minimum and maximum ratings as provided for and allowed by the unit's controls.

c. Combination units not covered by the National Appliance Energy Conservation Act of 1987 (NAECA) (3-phase power or cooling capacity greater than or equal to 65,000 Btu/h [19 kW]) shall comply with either rating.

d. E_t = Thermal efficiency. See test procedure for detailed dicussion.

e. E_c = Combustion efficiency (100% less flue losses). See test procedure for detailed discussion.

f. E_c = Combustion efficiency. Units must also include an IID, have jackets not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.

g. E_t = Thermal efficiency. Units must also include an IID, have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.

Table 1.9.5 Minimum efficiency requirements: gas- and oil-fired boilers

Equipment Type[a]	Subcategory Or Rating Condition	Size Category (Input)	Minimum Efficiency	Test Procedure
Boilers, Hot Water	Gas-fired	< 300,000 Btu/h	80% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	80% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	82% E_c	
	Oil-fired[c]	< 300,000 Btu/h	80% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	82% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	84% E_c	
Boilers, Steam	Gas-fired	< 300,000 Btu/h	75% AFUE	10 CFR Part 430
	Gas-fired- all, except natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	79% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	79% E_t	
	Gas-fired-natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	77% E_t	
		> 2,500,000 Btu/h[a]	77% E_t	
	Oil-fired[c]	< 300,000 Btu/h	80% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	81% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	81% E_t	

For SI: 1 British thermal unit per hour = 0.2931 W.
E_c = Combustion efficiency (100% less flue losses). E_t = Thermal efficiency. See referenced standard document for detailed information.

a. These requirements apply to boilers with rated input of 8,000,000 Btu/h or less that are not packaged boilers and to all packaged boilers. Minimum efficiency requirements for boilers cover all capacities of packaged boilers.

b. Maximum capacity - minimum and maximum ratings as provided for and allowed by the unit's controls.

c. Includes oil-fired (residual).

Table 1.9.6 Minimum efficiency requirements: condensing units, electrically operated

Equipment Type	Size Category (Input)	Minimum Efficiency[b]	Test Procedure[a]
Condensing Units, Air Cooled	≥ 135,000 Btu/h	10.1 EER 11.2 IPLV	AHRI 365
Condensing Units, Water Or Evaporatively Cooled	≥ 135,000 Btu/h	13.1 EER 13.1 IPLV	

For SI: 1 British Thermal Unit Per Hour = 0.2931 W.

a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. IPLVs are only applicable to equipment with capacity modulation.

Table 1.9.7 Minimum efficiency requirements: water chilling packages[a]

Equipment Type	Size Category	Units	As Of 1/1/2010[B] Path A Full Load	Path A IPLV	Path B Full Load	Path B IPLV	Test Procedure[c]
Air-Cooled Chillers	< 150 Tons	EER	≥ 9.562	≥ 12.500	NA	NA	AHRI 550/590
	≥ 150 Tons	EER	≥ 9.562	≥ 12.750	NA	NA	
Air-Cooled Without Condenser, Electrically Operated	All Capacities	EER	Air-Cooled Chillers Without Condensers Shall Be Rated With Matching Condensers And Comply With The Air-Cooled Chiller Efficiency Requirements				
Water Cooled, Electrically Operated, Reciprocating	All Capacities	kW/ton	Reciprocating Units Shall Comply With Water Cooled Positive Displacement Efficiency Requirements				
Water Cooled, Electrically Operated, Positive Displacement	< 75 Tons	kW/ton	≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600	
	≥ 75 Tons And < 150 Tons	kW/ton	≤ 0.775	≤ 0.615	≤ 0.790	≤ 0.586	
	≥ 150 Tons And < 300 Tons	kW/ton	≤ 0.680	≤ 0.580	≤ 0.718	≤ 0.540	
	≥ 300 Tons	kW/ton	≤ 0.620	≤ 0.540	≤ 0.639	≤ 0.490	
Water Cooled, Electrically Operated, Centrifugal	< 150 Tons	kW/ton	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450	
	≥ 150 Tons And < 300 Tons	kW/ton					
	≥ 300 Tons And < 600 Tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.600	≤ 0.400	
	≥ 600 Tons	kW/ton	≤ 0.570	≤ 0.539	≤ 0.590	≤ 0.400	
Air Cooled, Absorption Single Effect	All Capacities	COP	≥ 0.600	NR	NA	NA	AHRI 560
Water Cooled, Absorption Single Effect	All Capacities	COP	≥ 0.700	NR	NA	NA	
Absorption Double Effect, Indirect Fired	All Capacities	COP	≥ 1.000	≥ 1.050	NA	NA	
Absorption Double Effect, Direct Fired	All Capacities	COP	≥ 1.000	≥ 1.000	NA	NA	

For SI: 1 Ton = 3517 W, 1 British Thermal Unit Per Hour = 0.2931 W, °C = [(°F) - 32]/1.8.
NA = Not Applicable, not to be used for compliance; NR = No Requirement.

a. The centrifugal chiller equipment requirements, after adjustment in accordance with section c403.2.3.1 Or section c403.2.3.2, Do not apply to chillers used in low-temperature applications where the design leaving fluid temperatures is less than 36°F. The requirements do not apply to positive displacement chillers with leaving fluid temperatures less than or equal to 32°F. The requirements do not apply to absorption chillers with design leaving fluid temperatures less than 40°F.

b. Compliance with this standard can be obtained by meeting the minimum requirements of path a or b. However, both the full load and IPLV shall be met to fulfill the requirements of Path A or B.

c. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

Table 1.9.8 Minimum efficiency requirements: heat rejection equipment

Equipment Type[a]	Total System Heat Rejection Capacity At Rated Conditions	Subcategory Or Rating Condition	Performance Required[b, c, d]	Test Procedure[e, f]
Propeller Or Axial Fan Open Circuit Cooling Towers	All	95°F Entering Water 85°F Leaving Water 75°F Entering wb	≥ 38.2 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal Fan Open Circuit Cooling Towers	All	95°F Entering Water 85°F Leaving Water 75°F Entering wb	≥ 20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller Or Axial Fan Closed Circuit Cooling Towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 14.0 gpm/hp	CTI ATC-105S and CTI STD-201
Centrifugal Closed Circuit Cooling Towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 7.0 gpm/hp	CTI ATC-105S and CTI STD-201
Air-Cooled Condensers	All	125°F Condensing Temperature R-22 Test Fluid 190°F Entering Gas Temperature 15°F Subcooling 95°F Entering db	≥ 176,000 Btu/h•hp	ARI 460

For SI: °C = [(°F) - 32]/1.8, L/s • kW = (gpm/hp)(11.83), COP = (Btu/h • hp)/(2550.7).
DB = dry bulb temperature, °F, wb = wet bulb temperature, °F.

a. The efficiencies and test procedured for both open and closed circuit cooling towers are not applicable to hybrid cooling towers that contain a combination of wet and dry heat exchange Sections.

b. For purposes of this table, open circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 403.2.3(8) divided by the fan nameplate rated motor power.

c. For purposes of this table, closed circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 403.2.3(8) divided by the sum of the fan nameplate rated motor power and the spray pump nameplate rated motor power.

d. For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan nameplate rated motor power.

e. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

f. If a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment efficiency ratings, then the product shall be listed in the certification program, or, if a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment efficiency ratings, but the product is not listed in the existing certification program, the ratings shall be verified by an independent laboratory test report.

Table 1.9.9 Heat transfer equipment

Equipment Type	Subcategory	Minimum Efficiency	Test Procedure[a]
Liquid-To-Liquid Heat Exchangers	Plate type	NR	AHRI 400

NR = No Requirement

a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

1.10 ECONOMIZER PERFORMANCE

Photo credit: New Buildings Institute

Criteria

Economizers shall be installed on all cooling systems larger than 33,000 Btu/h in all climate zones except 1A and 1B. All installed economizers shall include the following features (to be verified at project completion):

- **Fully-modulating damper motor.** A fully-modulating damper motor shall be installed on return air dampers capable of providing up to 100% of the design supply air quantity as outdoor air for cooling. Economizer dampers shall be capable of being sequenced with the mechanical cooling equipment
- **Damper drive mechanism.** The Damper drive mechanism shall be provided with a direct modulating actuator with gear-driven interconnections and a permanently lubricated bushing or bearing on the outside and return dampers
- **Primary Control Sensor Placement.** For direct-expansion (DX) cooling coils, the primary control sensor shall be located in the discharge air position, after the cooling coil. When chilled water coils are used, the primary control sensor shall be installed before the cooling coil in the mixed-air position
- **Coordinated Control.** The economizer shall be controlled so it is only active when there is a call for cooling
- **Economizer control.** Economizer control shall be selected in accordance with Table 1.10.1
- **High-limit control setpoint.** Economizer controller shall utilize a deadband between economizer enable/disable operation. High limit control type shall be selected in accordance with Table 1.10.1
- **Relief air and modulating return air damper.** Systems shall be capable of relieving excess outdoor air during economizer operation by providing relief air with either a barometric damper in the return air duct upstream of the return air damper, a motorized exhaust air damper or an exhaust fan with backdraft dampers. Return air relief and outside air intake hoods shall be installed so that relief dampers operate freely.

Purpose

Ensure that buildings served by unitary or packaged HVAC equipment optimize their energy savings from the proper performance of outside-air (OA) economizers.

- **Minimum outside ventilation air measurement by temperature.** The minimum OA setpoint shall be set by measuring the temperature of the mixed air, return air and outside air to calculate the percentage of outside air. This measurement is conducted during acceptance testing and should be considered an ongoing operational set point.

Exceptions:

» Cooling equipment in Climate Zone 2B with a 10% efficiency improvement above the requirements of Criteria 1.9

» Cooling equipment in Climate Zone 3B with a 15% efficiency improvement above the requirements of Criteria 1.9

» Cooling equipment in Climate Zone 4B with a 20% efficiency improvement above the requirements of Criteria 1.9

General

See Criteria 2.10 for more information and more advanced economizer approaches.

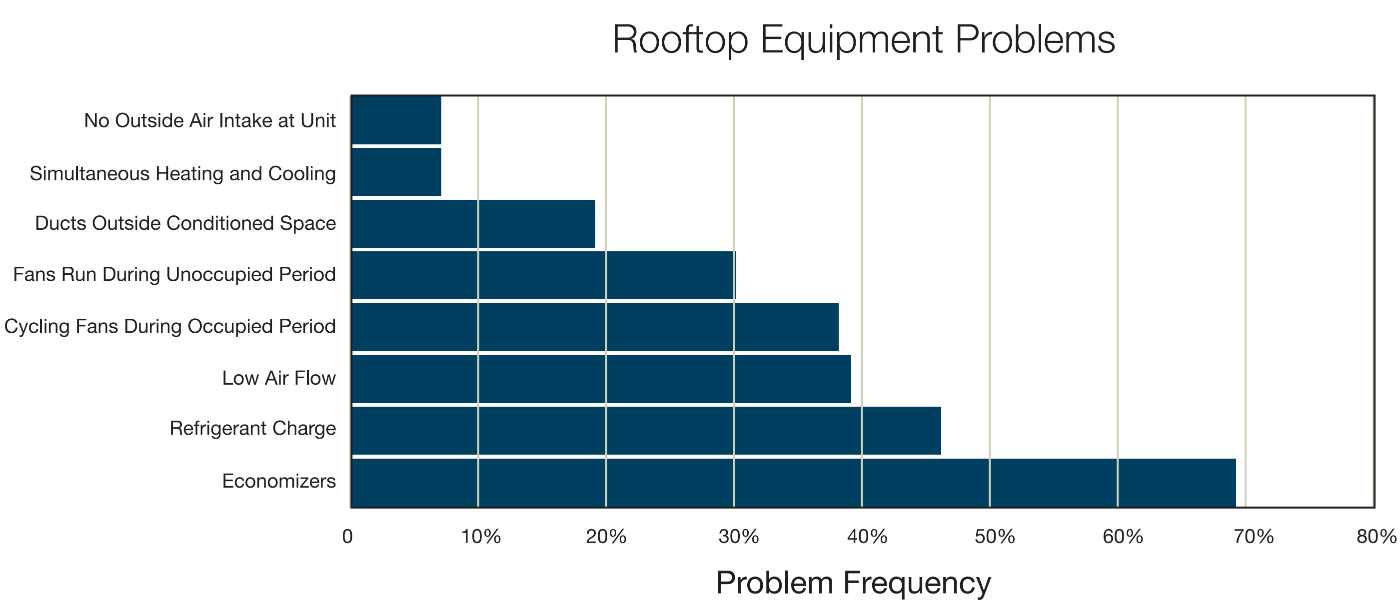
Table 1.10.1 Economizer control

Device Type	Acceptable in Climate Zone at listed Set point	High Limit Logic (Economizer Off When)	Not Recommended in Climate Zone
Fixed Enthalpy + Fixed Drybulb	All	Outdoor air enthalpy exceeds 28 Btu/lb of dry air or Outdoor air dry bulb exceeds 75°F	All
Differential enthalpy + fixed (or differential) drybulb	All	Outdoor air enthalpy exceeds return air enthalpy or Outdoor air dry bulb exceeds 75°F (or return air temperature)	All

Note: IECC-2012 allows for a wider array of less optimal control types and control logics

Figure 1.10.1

This graph, compiled from a number of field studies, shows how frequently performance aspects of newly installed rooftop HVAC equipment was found to be defective. Note that the economizers on an astonishing 70% of rooftop units less than five years old are either missing or inoperative.



1.11 ENERGY RECOVERY VENTILATION

Photo credit: National Grid

Criteria

- When design airflow rates meet the thresholds of Table 1.11.1, the ventilation system shall be provided with an energy recovery ventilation (ERV) system capable of recovering waste heat from air exhaust into the incoming fresh air stream
- When installed, energy recovery systems shall have the capability to provide a change in the enthalpy of the outdoor air supply of not less than 50%.
- Where an air economizer is installed, the energy recovery system shall include a bypass or controls that permit operation of the economizer in accordance with Criteria 1.10.

Exceptions:

- » Where Energy Recovery Ventilation is prohibited by the International Mechanical Code
- » Where more than 60% of the heating energy for outdoor air is site-recovered energy or from solar energy
- » Systems serving non-cooled spaces heated to less than 60°F.
- » Heating systems in Climate Zones 1 and 2
- » Cooling systems in Climate Zones 3c, 4c, 5b, 5c, 6b, 7 and 8
- » Systems expected to operate fewer than 20 hours per week at the outdoor air percentage listed in Table 1.11.1.

Purpose

Reduce energy use associated with ventilation requirements by recapturing waste heat and cooling in exhaust air flow.

Table 1.11.1 Design airflow rate thresholds

	Percent (%) Outdoor Air at Full Design Airflow Rate					
	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80%
Climate Zone	**Design Supply Fan Airflow Rate (cfm)**					
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	≥ 5000	≥ 5000
1B, 2B, 5C	NR	NR	≥ 26000	≥ 12000	≥ 5000	≥ 4000
6B	≥ 11000	≥ 55000	≥ 4500	≥ 3500	≥ 2500	≥ 1500
1A, 2A, 3A, 4A, 5A, 6A	≥ 5500	≥ 4500	≥ 3500	≥ 2000	≥ 1000	> 0
7, 8	≥ 2500	≥ 1000	> 0	> 0	> 0	> 0

General

See Criteria 2.18 for more information and more advanced Energy Recovery System approaches.

1.12 DEMAND CONTROL VENTILATION

USD 422 Greensburg K-12 School, Greensburg, KS. Photo Credit: McCownGordon Construction

Criteria

DCV shall be provided for spaces larger than 500 sf when the average occupant load is 25 people per 1,000 sf or greater on systems meeting one or more of the following conditions:

- Contains an air-side economizer
- Automatically modulates control of the damper
- A design outdoor airflow rate greater than 3000 cfm

Exceptions:

» Systems with ERV

» Multiple-zone systems without direct digital control of individual zones communicating with a central control panel

» Systems with a design outdoor airflow less than 1200 cfm

» Systems where the supply airflow rate minus any makeup air requirements is less than 1200 cfm

» Ventilation provided exclusively for process loads

General

See Criteria 2.19 for more information and more advanced DCV approaches.

Purpose

Reduce the energy use associated with heating and cooling outside air in excess of ventilation flow rates required by building occupancy, while maintaining high indoor air quality for the building occupants.

1.13 ACCEPTANCE TESTING

Genzyme Center, Cambridge, MA. Photo credit: Daylighting Pattern Guide

Purpose

Ensure that equipment is installed, configured and operating as intended by the construction documents through testing and verifying system performance.

Criteria

The construction process shall be conducted to deliver a building that meets or exceeds the requirements of the owner (as identified in the Operational Performance Requirements), the construction documents and the acceptance testing plan developed under Criteria 0.2. This process shall include the following:

- Where the following equipment is installed, acceptance testing shall be performed by the installing contractor(s), engineer of record or owner's agent in accordance with Appendix A, when applicable:
  - » Outdoor Air Systems
  - » Package Rooftop Units
  - » Air Distribution Systems
  - » Economizers
  - » Demand Control Ventilation Systems
  - » Variable Air Volume Systems with Variable Frequency Drives
  - » Heat or Energy Recovery Ventilation Systems
  - » Hydronic System Controls
  - » Chilled Water Systems
  - » Automatic Daylighting Controls
  - » Occupancy Sensors
  - » Automatic Time-of-Day Controls
  - » Building Control Systems
  - » Fans and circulating pumps
- Change orders shall be reviewed to assure they are consistent with the operational performance requirements and statement of goals and principles. Or-equal substitutions shall be shown to assure equal or better energy and indoor environmental performance when compared to the original certified design.

- The installing contractor(s), engineer of record or owner's agent shall certify that the procedures listed in Appendix A were carried out and the equipment performed as specified, with any deficiencies being reported for correction. For equipment not listed above, the design team shall provide acceptable test results, and the contractor shall certify that the tests were completed and the equipment performed as specified.
- An acceptance testing report shall be prepared documenting the results of the construction process including:
  - Deficiencies found during testing required by this section that have not been corrected at the time of report preparation and the anticipated date of correction
  - Deferred tests that cannot be performed at the time of report preparation due to climatic conditions
  - Climatic conditions required for performance of the deferred tests and the anticipated date of each such test
  - Complete the Construction Certification prior to requesting a final occupancy permit (but not necessarily before temporary occupancy)

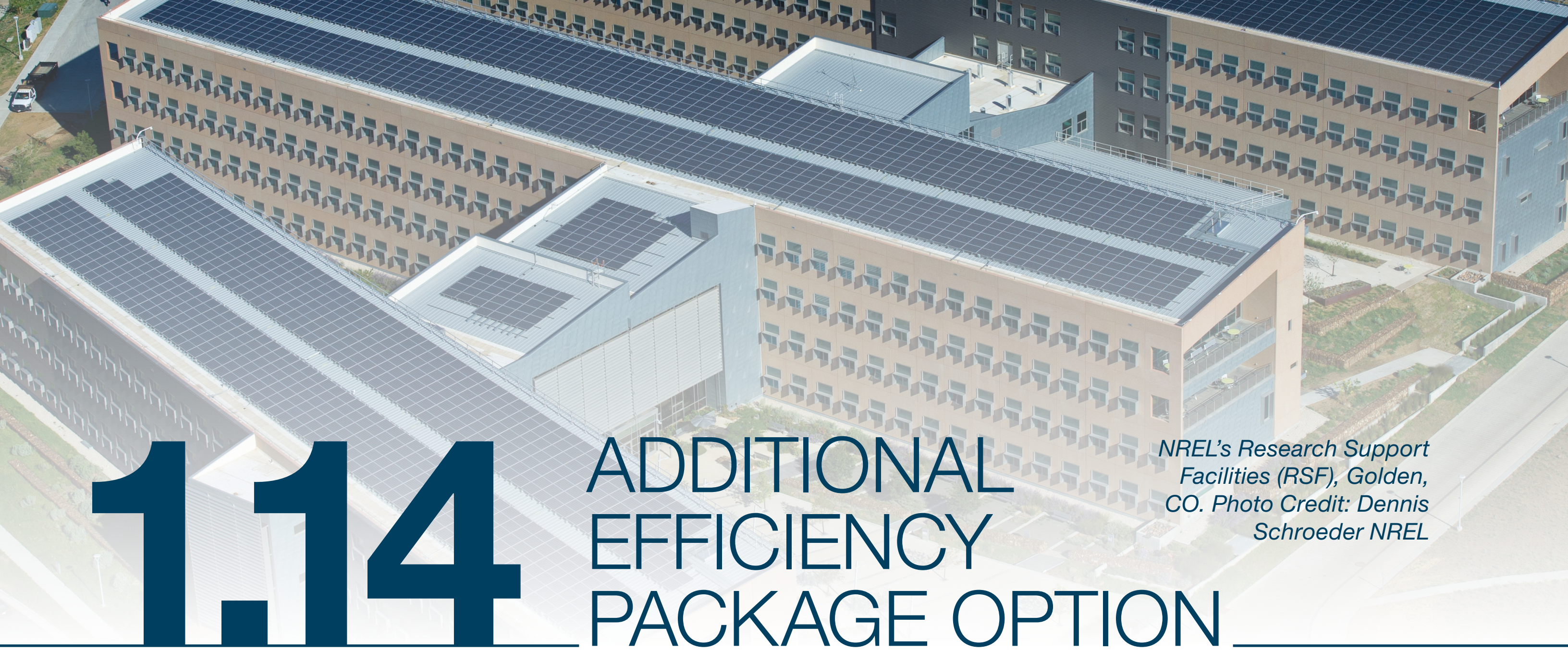
General

The acceptance testing reports demonstrate that the installing contractor, engineer of record or owner's agent:

- Reviewed the installation
- Performed acceptance tests and documented results
- Documented the operating and maintenance information and test results

The building owner may decide to use a third-party commissioning agent to conduct this work.

In addition to Appendix A, ICC Guideline G4 from the International Code Council provides guidance for commissioning a wide range of systems, including non-energy systems.



NREL's Research Support Facilities (RSF), Golden, CO. Photo Credit: Dennis Schroeder NREL

1.14 ADDITIONAL EFFICIENCY PACKAGE OPTION

Purpose

Achieve an approximately 3% reduction in the building's fossil fuel energy use through the implementation of one of three "Additional Efficiency Package Options."

Criteria

Implement no less than one of the following three energy efficiency strategies:

- **Efficient HVAC performance:** All HVAC systems serving the building shall meet the efficiency requirements of Tables 1.14.1 – 1.14.7. Buildings with equipment that is not listed in these Tables are not eligible for the Efficient HVAC Performance Package option.
- **Efficient lighting system:** Installed lighting power density (LPD) shall not exceed the LPD allowances in Table 1.14.8. Only the Building Area Method is available for this Additional Efficiency Package Option. An "area" for this purpose is defined as all contiguous areas of a building, which in total must meet the LPD requirements listed in the tables below based on the primary building space type. Three building types have additional specifications in this Efficiency Package. These building types shall meet the following additional requirements, when applicable:
  - In warehouse building area types, a minimum of 70% of the floor space shall be in daylight zones provided with automatic daylight controls meeting the requirements of Criteria 1.7.
  - In office area types, either the LPD shall not exceed 0.85 W/sf or 30% of the conditioned floor area shall be in daylight zones provided with installed automatic daylighting controls meeting the requirements of Criteria 1.7.
  - In retail area types, either the LPD shall not exceed 1.30 W/sf or 30% of the conditioned floor space shall be in daylight zones provided with installed automatic daylighting controls meeting the requirements of Criteria 1.7.
- **On-site renewable energy:** The building shall be provided an on-site renewable energy system that derives energy from solar radiation, wind, waves, biomass or the internal heat of the earth (ground-source heat pumps are not qualified as renewable energy systems) that exceeds one of the following thresholds:
  - For solar hot water systems, 1.75 Btu per square foot of conditioned floor area in the building.

- For photovoltaic systems, 0.50 watts per square foot of conditioned floor area in the building.
- A calculation showing that the capacity of all of the on-site installed renewable systems will provide at least 3% of the energy used by the lighting, mechanical and service hot water systems.

Table 1.14.1 Electrically operated unitary air conditioners and condensing units

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency	
			Climate Zones 1-5	Climate Zones 6-8
Air conditioners, air cooled	< 65,000 Btu/h	Split system	15.0 SEER 12.5 EER	14 SEER 12 EER
		Single package	15.0 SEER 12.0 EER	14.0 SEER 11.6 EER
	≥ 65,000 Btu/h and < 240,000 Btu/h	Split system and single package	12.0 EER[b] 12.54 IEER[b]	11.5 EER[b] 12.0 IEER[b]
	≥ 240,000 Btu/h and < 760,000 Btu/h	Split system and single package	10.8 EER[b] 11.3 IEER[b]	10.5 EER[b] 11.0 IEER[b]
	≥ 760,000 Btuh/h	—	10.2 EER[b] 10.7 IEER[b]	9.7 EER[b] 10.2 IEER[b]
Air conditioners, water and evaporatively cooled	—	Split system and single package	14.0 EER	14.0 EER

For SI: 1 British thermal unit per hour = 0.2931 W.

a. IEERs are only applicable to equipment with capacity modulation.

b. Deduct 0.2 from the required EERs and IPLVs for units with a heating section other than electrical resistance heat.

Table 1.14.2 Electrically operated unitary and applied heat pumps

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency Climate Zones 1-5	Minimum Efficiency Climate Zones 6-8
Air cooled (Cooling mode)	< 65,000 Btu/h	Split system	15.0 SEER 12.5 EER	14.0 SEER 12.0 EER
		Single package	15.0 SEER 12.0 EER	14.0 SEER 11.6 EER
	≥ 65,000 Btu/h and < 240,000 Btu/h	Split system and single package	12.0 SEER 12.4 EER	11.5 EER[b] 12.0 IEER[b]
	≥ 240,000 Btu/h	Split system and single package	12.0 SEER 12.4 EER	10.5 EER[b] 10.5 IEER[b]
Water sources (Cooling mode)	< 135,000 Btu/h	85°F entering water	14.0 EER	14.0 EER
Air cooled (Heating mode)	< 65,000 Btu/h (Cooling capacity)	Split system	9.0 HSPF	8.5 HSPF
		Single package	8.5 HSPF	8.0 HSPF
	≥ 65,000 Btu/h and < 135,000 Btu/h (Cooling capacity)	47°F db/43°F wb outdoor air	3.4 COP	3.4 COP
		17°F db/15°F wb outdoor air	2.4 COP	2.4 COP
	≥ 135,000 Btu/h (Cooling capacity)	47°F db/43°F wb outdoor air	3.2 COP	3.2 COP
		77°F db/15°F wb outdoor air	2.1 COP	2.1 COP
Water sources (Heating mode)	< 135,000 Btu/h (Cooling capacity)	70°F entering water	4.6 COP	4.6 COP

For SI: °C = [(°F) - 32] / 1.8, 1 British thermal unit per hour = 0.2931 W.

db = dry-bulb temperature, °F; wb = wet-bulb temperature, °F.

a. IEERs and Part load rating conditions are only applicable to equipment with capacity modulation.

b. Deduct 0.2 from the required EERs and IPLVs for units with a heating section other than electric resistance heat.

Table 1.14.3 Packaged terminal air conditioners and packaged terminal heat pumps

Equipment Type	Size Category	Minimum Efficiency
Air conditioners and heat pumps (cooling mode)	< 7,000 Btu/h	11.9 EER
	7,000 Btu/h and < 10,000 Btu/h	11.3 EER
	10,000 Btu/h and ≤ 13,000 Btu/h	10.7 EER
	> 13,000 Btu/h	9.5 EER

Table 1.14.4 Warm air furnaces and combination warm air furnaces/air-conditioning units, warm air duct furnaces and unit heaters, minimum efficiency requirements

Equipment Type	Size Category	Subcategory or rating condition	Minimum Efficiency	Test Procedure
Warm air furnaces, gas fired[a]	< 225,000 Btu/h	—	For Climate Zones 1 and 2 NR	DOE 10 CFR Part 430 or ANSI Z21.47
			For Climate Zones 3 and 4 90 AFUE or 90 E_t^c	
			For Climate Zones 4 – 8 92 AFUE or 92 E_t^c	
	≥ 225,000 Btu/h	Maximum capacity	90% E_c^b	ANSI Z21.47
Warm air furnaces, oil fired[a]	< 225,000 Btu/h	—	For Climate Zones 1 and 2 NR	DOE 10 CFR Part 430 or UL 727
			For Climate Zones 3 – 8 85 AFUE or 85 E_t^c	
	≥ 225,000 Btu/h	Maximum capacity	85% E_t^b	UL 727
Warm air duct furnaces, gas fired[a]	All capacities	Maximum capacity	90% E_c	ANSI Z83.8
Warm air unit heaters, gas fired	All capacities	Maximum capacity	90% E_c	ANSI Z83.8
Warm air unit heaters, oil fired	All capacities	Maximum capacity	90% E_c	UL 731

For SI: 1 British thermal unit per hour = 0.2931 W.

E_t = Thermal efficiency. E_c = Combustion efficiency (100% less flue losses).

a. Efficient furnace fan: Fossil fuel furnaces in climate zones 3 to 8 shall have a furnace electricity ratio not greater than 2% and shall include a manufacturer's designation of the furnace electricity ratio.

b. Units shall also include an IID (intermittent ignition device), have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.

c. Where there are two ratings for units not covered by NAECA (3-phase power or cooling capacity greater than or equal to 65,000 Btu/h [19kW]), units shall be permitted to comply with either rating.

Table 1.14.5 Gas- and oil-fired boilers

Equipment Type	Fuel	Size Category	Test Proceedure	Minimum Efficiency
Steam	Gas	< 300,000 Btu/h	DOE 10 CFR Part 430	83% AFUE
		> 300,000 Btu/h and > 2.5 m Btu/h	DOE 10 CFR Part 431	81% E_t
		> 2.5 m Btu/h		82% E_c
	Oil	< 300,000 Btu/h	DOE 10 CFR Part 430	85% AFUE
		> 300,000 Btu/h and > 2.5 m Btu/h	DOE 10 CFR Part 431	83% E_t
		> 2.5 m Btu/h		84% E_c
Hot water	Gas	< 300,000 Btu/h	DOE 10 CFR Part 430	97% AFUE
		> 300,000 Btu/h and > 2.5 m Btu/h	DOE 10 CFR Part 431	97% E_t
		> 2.5 m Btu/h		94% E_c
	Oil	< 300,000 Btu/h	DOE 10 CFR Part 430	90% AFUE
		> 300,000 Btu/h and > 2.5 m Btu/h	DOE 10 CFR Part 431	88% E_t
		> 2.5 m Btu/h		87% E_c

For SI: 1 British thermal unit per hour = 0.2931 W.

E_t = Thermal efficiency. E_c = Combustion efficiency (100% less flue losses).

Table 1.14.6 Chillers

			Minimum Efficiency[a] (I-P)				
			Path A		Path B[c]		
Equipment Type	Size Category	Units	Full Load	IPLV	Full Load	IPLV	Test Procedure[b]
Air-cooled chillers with condenser, electrically operated	< 150 tons	EER	10.000	12.500	NA	NA	AHRI 550/590[f]
	≥ 150 tons	EER	10.000	12.750	NA	NA	
Air-cooled without condenser, electrical operated	All capacities	EER	Condenserless units shall be rated with matched condensers				AHRI 550/590
Water-cooled, electrically operated, positive displacement (reciprocating)	All capacities	kW/ton	Reciprocating units required to comply with water cooled positive displacement requirements				AHRI 550/590[f]
Water-cooled electrically operated, positive displacement	< 75 tons	kW/ton	0.780	0.630	0.800	0.600	AHRI 550/590[f]
	≥ 75 tons and < 150 tons	kW/ton	0.775	0.615	0.790	0.586	
	≥ 150 tons and < 300 tons	kW/ton	0.680	0.580	0.718	0.540	
	≥ 300 tons	kW/ton	0.620	0.540	0.639	0.490	
Water-cooled electrically operated, centrifugal[d]	< 150 tons	kW/ton	0.634	0.596	0.639	0.450	AHRI 550/590[f]
	≥ 150 tons and < 300 tons	kW/ton	0.634	0.596	0.639	0.450	
	≥ 300 tons and < 600 tons	kW/ton	0.576	0.549	0.600	0.400	
	≥ 600 tons	kW/ton	0.570	0.539	0.590	0.400	

Table 1.14.6 Chillers (continued)

Equipment Type	Size Category	Units	Minimum Efficiency[a] (I-P)				Test Procedure[b]
			Path A		Path B[c]		
			Full Load	IPLV	Full Load	IPLV	
Air-cooled absorption single effect[e]	All capacities	COP	0.600	NR	NA	NA	AHRI 560
Water-cooled absorption single effect[e]	All capacities	COP	0.700	NR	NA	NA	AHRI 560
Absorption double effect indirect-fired	All capacities	COP	1.000	1.050	NA	NA	AHRI 560
Absorption double effect direct fired	All capacities	COP	1.000	1.000	NA	NA	AHRI 560

For SI: 1 Ton = 3516 W.

NA = Not applicable and cannot be used for compliance. NR = No minimum requirements.

a. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or Path B. However both the full load and IPLV shall be met to fulfill the requirements of Path A and Path B.

b. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

c. Path B is intended for applications with significant operating time at part load. All Path B machines shall be equipped with demand limiting capable controls.

d. The chiller equipment requirements do not apply for chillers used in low-temperature applications where the design leaving fluid temperature is greater than 40°F.

e. Only allowed to be used in heat recovery applications.

f. Packages that are not designed for operations at ARI Standard 550/590 test conditions (and, thus, cannot be tested to meet the requirements of Table C-3) of 44°F leaving chilled-water temperature and 85°F entering condenser-water temperature with 3 gpm/ton condenser-water flow shall have maximum full-load kW/ton and *NPLV* ratings adjusted using the following equation:

Adjusted maximum full load kW/ton rating = (full load kW/ton from Table C-3)/K_{adj}

Adjusted maximum *NPLV* rating = (IPLV from Table C-3)/K_{adj}

where:

K_{adj} = 6.174722 - 0.303668(X) + 0.00629466$(X)^2$ - 0.000045780$(X)^3$

X = DT_{std} + LIFT (°F)

DT_{std} =[(24 + (full load kW/ton from Table C-3) x 6.83)]/flow (°F)

Flow = condenser-water flow (gpm) / cooling full load capacity (tons)

LIFT = CEWT - CLWT (°F)

CEWT = full load entering condenser-water temperature (°F)

CLWT = full load leaving chilled-water temperature (°F)

The adjusted full load and *NPLV* values are only applicable over the following full-load design ranges:

Minimum leaving chilled-water temperature: 38°F

Maximum condenser entering water temperature: 102°F

Condenser-water flow: 1 to 6 gpm/ton

$X \geq 39$°F and ≤ 60°F

Table 1.14.7 Absorption Chillers

Equipment Type	Minimum Efficiency Full Load COP (IPLV)
Air cooled, single effect	0.60, allowed only in heat recovery applications
Water cooled, single effect	0.70, allowed only in heat recovery applications
Double effect – direct fired	1.00 (1.05)
Double effect – indirect fired	1.20

Table 1.14.8 LPD Additional Efficiency Package

Building Area Type[a]	LPD (w/ft^2)
Automotive Facility	0.82
Convention Center	1.08
Courthouse	1.05
Dining: bar lounge/leisure	0.99
Dining: cafeteria/fast food	0.90
Dining: family	0.89
Dormitory	0.61
Exercise center	0.88
Fire Station	0.71
Gymnasium	1.00
Health Care Clinic	0.87
Hospital	1.10
Library	1.18
Manufacturing Facility	1.11
Hotel/motel	0.88
Motion picture theater	0.83
Multifamily	0.60
Museum	1.06
Office	0.90/0.85[b]
Performance Arts Theater	1.39
Police Station	0.96
Post office	0.87
Religious building	1.05
Retail	1.4/1.3[b]
School/university	0.99
Sports arena	0.78
Town hall	0.92
Transportation	0.77
Warehouse[c]	0.60
Workshop	1.20

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m^2.

a. In cases where both a general building area type and a more specific building area type are listed, the more specific building area type shall apply.

b. First LPD value applies if no less than 30% of conditioned floor area is in daylight zones. Automatic daylighting controls shall be installed in daylight zones and shall meet the requirements of Section C405.2.2.3. In all other cases, second LPD value applies.

c. No less than 70% of the floor area shall be in daylight zone. Automatic daylighting controls shall be installed in daylight zones and shall meet the requirements of Section C405.2.2.3.

Tier Two

Section Two of the Guide incorporates strategies designed to provide a pathway for whole-building performance that exceeds the more recent code versions, such as IECC 2012 and ASHRAE 90.1-2010. Projects in jurisdictions that have adopted and enforce these codes must follow the requirements of this section to achieve significant savings beyond code. The measures in Section Two supersede the strategies listed in Section One.

This section is divided into two parts; the basic requirements of the program (for advanced code jurisdictions) and some optional additional enhanced strategies which may be adopted by individual projects. All of the measures up to and including measure 2.17 (and including the measures in Section Zero–Design Process Strategies) are basic requirements of the program. Measures in this section numbered 2.18 and above are considered enhanced measures.

Core Performance Building: Child and Family of Newport County Middletown, Rhode Island. Photo credit: National Grid

2.0 INTRODUCTION

Tier Two

Tier Two of the *Advanced Buildings New Construction Guide* is a comprehensive set of energy conservation measures designed to achieve significant savings over current energy code baselines, such as the 2012 *International Energy Conservation Code* and ASHRAE 90.1-2010. The criteria in this section address all aspects of building construction, from the envelope to mechanical equipment to controls, and are intended to be implemented as a unified whole.

Tier Two represents the next level of efficiency for whole-building energy performance, beyond the requirements in Tier One. The measures in Tier Two supersede the strategies listed in Tier One above. Tier Two also requires that the prerequisites in the Design Process Strategies section of the Guide be followed.

This section is divided into two parts: the basic requirements of the Tier (for advanced code jurisdictions) and some optional additional enhanced strategies that may be adopted by individual projects. All of the measures up to and including measure 2.17 (and including the prerequisites in the Design Process Strategies section) are basic requirements of Tier Two. Measures in this section numbered 2.18 and above are considered enhanced measures. Note that some of these enhanced measures may be required by individual utility incentive programs and/or may qualify for additional incentives.

For projects that are following the requirements of Tier 1, the measures in this section can be used individually or in combination to achieve additional savings above Tier 1. Additional incentives may be available for projects exceeding basic requirements; check with the local utility.

***Advanced Buildings: New Construction Tier Two* requires the implementation of all of the Criteria in the Design Strategies Section (Criteria 0.1-0.5).**

2.1 ENERGY CODE COMPLIANCE

Photo credit: Dennis Schroeder / NREL

Purpose

Define the minimum level of acceptable energy performance for measures not specified in *Advanced Buildings New Construction Guide.*

Criteria

All buildings shall meet or exceed applicable state and local energy codes. Where state and local codes are not as stringent as the 2012 International Energy Conservation Code (IECC) or the requirements of ASHRAE Standard 90.1-2010, features of those building elements not described in *Advanced Buildings New Construction Guide* shall meet or exceed ANSI/ASHRAE/IESNA Standard 90.1-2010 or the 2012 IECC.

Core Performance Building: Counseling Service of Addison County, Middlebury, VT. Photo credit: Robert Thorn / CSAC

2.2 AIR BARRIER PERFORMANCE

Criteria

All buildings less than 20,000 sf shall conduct a whole-building blower door test to determine that the infiltration rate does not exceed 0.4 cfm/sf of envelope area when tested at 75 Pa. In jurisdictions with more stringent air leakage requirements, local infiltration rates shall be used. (In Massachusetts, the requirement is for a leakage rate of 0.25 cfm/sf of **conditioned floor area** at 75 Pa.) Testing shall follow the protocol identified in ASTM Standard E779-10. Leakage rates may be extrapolated using lower testing pressures in accordance with this standard.

Buildings over 20,000 sf shall verify air barrier performance by one of the following:

- A whole-building blower door test verifying an infiltration rate no greater than 0.4 cfm/sf of envelope area at 75 Pa, or equivalent. (Use local requirements when more stringent.)
- A floor isolation blower door test verifying an infiltration rate no greater than 0.4 cfm/sf of envelope area at 75 Pa or equivalent. (Use local requirements when more stringent.)
- A continuous air barrier commissioning program conducted by a third-party entity responsible to the owner. The commissioning program shall include:
  - » Documentation of the continuous air barrier components included in the design.
  - » Third-party review of details to ensure continuity of the air barrier over building envelope components and penetrations including, but not limited to, air barrier elements in the compliance checklist in Section 602 of ICC G4-2012 Guideline for Commissioning.
  - » A field inspection checklist clearly showing all requirements necessary for maintaining air barrier continuity and durability.
  - » A final commissioning report showing compliance with the continuous air barrier requirements shall be provided to the building owner and code official.

Purpose

Reduce energy losses through the building's thermal envelope due to infiltration through verification of the code-required air barrier.

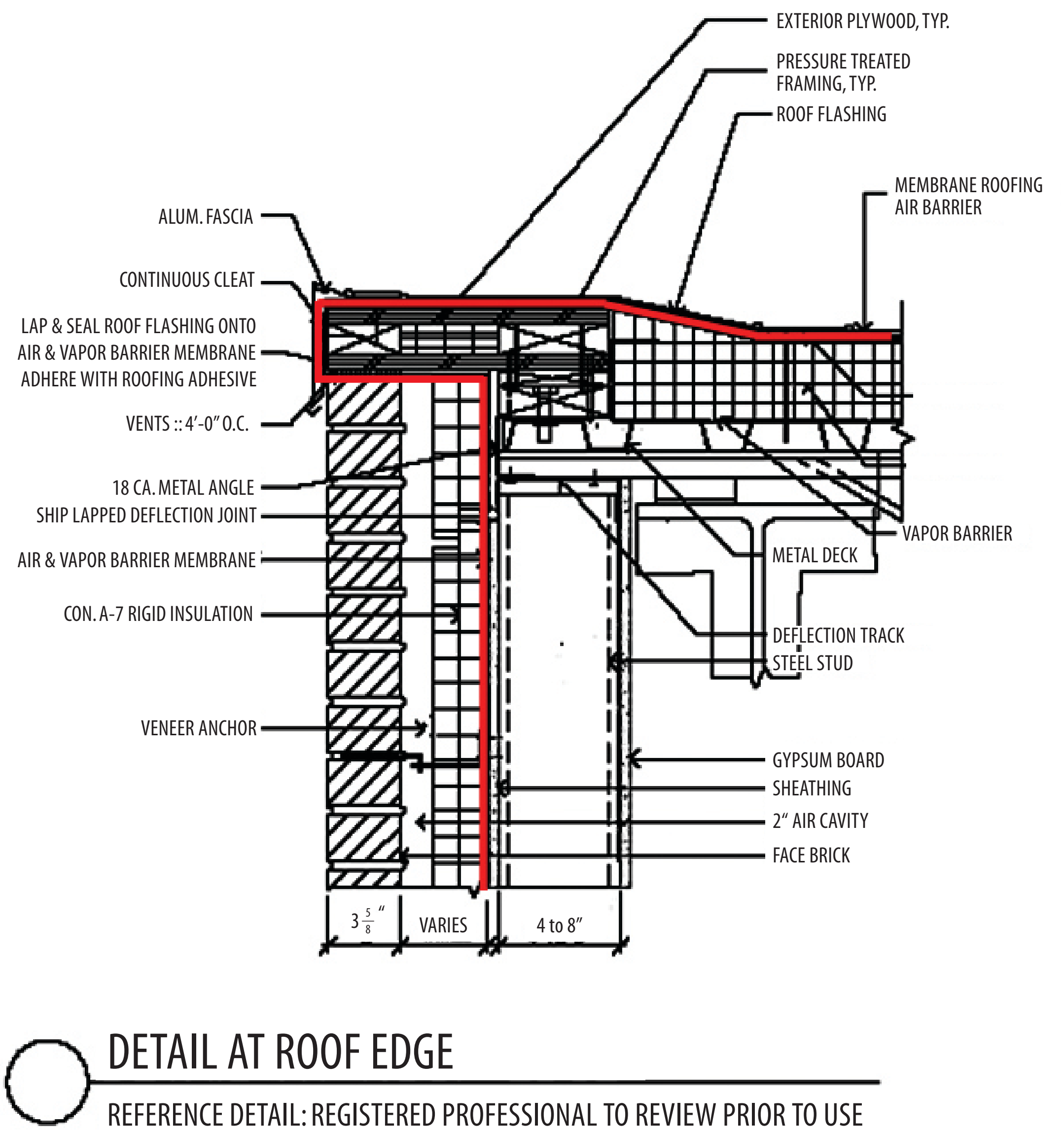
General

The most recent round of national model codes requires the inclusion of an air barrier in building envelope systems. Blower door testing helps insure these requirements are met and helps projects identify leakage areas for potential remediation to improve infiltration performance.

Generally, the following material characteristics and construction practices will result in an air barrier that will meet the verification criteria of this measure:

- The air barrier must be continuous, with all joints made airtight.
- Materials used for the air barrier system must have an air permeability not to exceed 0.004 cfm/sf under a pressure differential of 0.3 in. water (1.57psf) (0.02 L/s. m^2 @ 75 Pa) when tested in accordance with ASTM E 2178. The following materials are generally assumed to meet this standard:
  - » Plywood - minimum 3/8 in (10 mm)
  - » Oriented strand board - minimum 3/8 in (10 mm)

Attention to detail is critical at all joints and penetrations to assure a complete air barrier. **Detail:** *Courtesy of the state of Massachusetts and Wagdy Anis, FAIA.*



- Extruded polystyrene insulation board - minimum ¾ in (19 mm)
- Foil-back urethane insulation board - minimum ¾ in (19 mm)
- Exterior or interior gypsum board - minimum ½ in (12 mm)
- Cement board - minimum ½ in (12 mm)
- Built-up roofing membrane
- Modified bituminous roof membrane
- Fully adhered single-ply roof membrane
- A Portland cement/sand parge, or gypsum plaster minimum ⅝ in (16 mm) thick
- Cast-in-place and precast concrete
- Fully grouted concrete block masonry
- Sheet steel or aluminum

- The air barrier must be capable of withstanding positive and negative combined design wind, fan and stack pressures on the envelope without damage or displacement, and shall transfer the load to the structure.
- The air barrier material must be durable or maintainable.
- The air barrier material of an envelope assembly must be joined in an air-tight 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.
- The sequence of construction must allow for the installation of a continuous air barrier.
- Connections must be made between:
  - Foundation and walls
  - Walls and windows or doors
  - Different wall systems
  - Wall and roof
  - Wall and roof over unconditioned space
  - Walls, floor and roof across construction, control and expansion joints
  - Walls, floors and roof to utility, pipe and duct penetrations
- All penetrations of the air barrier system and paths of air infiltration/exfiltration must be made airtight.

2.3 OPAQUE ASSEMBLIES AND BELOW GRADE ASSEMBLIES

Photo credit: Pat Corkery / NREL

Purpose

Reduce energy losses due to thermal conductance through the building thermal envelope, including loss through below-grade floors and walls to the ground.

Criteria

All wall, roof and floor assemblies that are part of the building thermal envelope shall meet the requirements shown in Table 2.3.1.

U-Factors for above grade assemblies shall be calculated on a area weighted average basis for the whole assembly and calculated in accordance with ASHRAE Standard 90.1 Appendix A.

General

Historically, prescriptive codes and standards have specified opaque envelope requirements in two ways: the R-value of wall cavity insulation required in certain assembly types, and the total U-factor of a wall assembly. As requirements have become more stringent and continuous insulation has become a necessary component of more efficient thermal envelope assemblies, cavity insulation R-values have become a less effective way to specify envelope requirements. U-value requirements give designers many options for choosing a wall assembly that will best match the design requirements, local market of material and skill availability, and budget of the project.

ASHRAE Standard 90.1 Appendix A provides U-values of many standard construction assemblies. Projects using a custom or unusual envelope assembly must calculate the assembly U-value per the guidelines in ASHRAE 90.1 Appendix A, Section A9.

Designers should take note of their local insurance market. Many insurance companies will not insure a roof that has over a certain thickness of insulation on top of the roof deck. Some insurers may not accept roof assemblies with insulation used to create drainage slope or with insulation entirely above the roof deck.

Cool Roof

With the high levels of insulation required in this Guide, a Cool Roof would have only a negligible impact on the thermal performance of a building thermal envelope. However, Cool Roofs can provide other benefits such as reducing urban heat island effect and reducing the intake air temperature of outside air intakes located on or near the roof, thus reducing cooling loads. Since Cool Roofs can typically be specified at minimal to no incremental cost, they are still highly recommended on commercial buildings. Cool Roofs should meet one of the following requirements:

- Three-year aged solar reflectance of 0.55 and three-year aged thermal emittance of 0.75.
- Initial solar reflectance of 0.70 and initial thermal emittance of 0.75.
- Three-year aged solar reflectance index of 64.
- Initial solar reflectance index of 82.

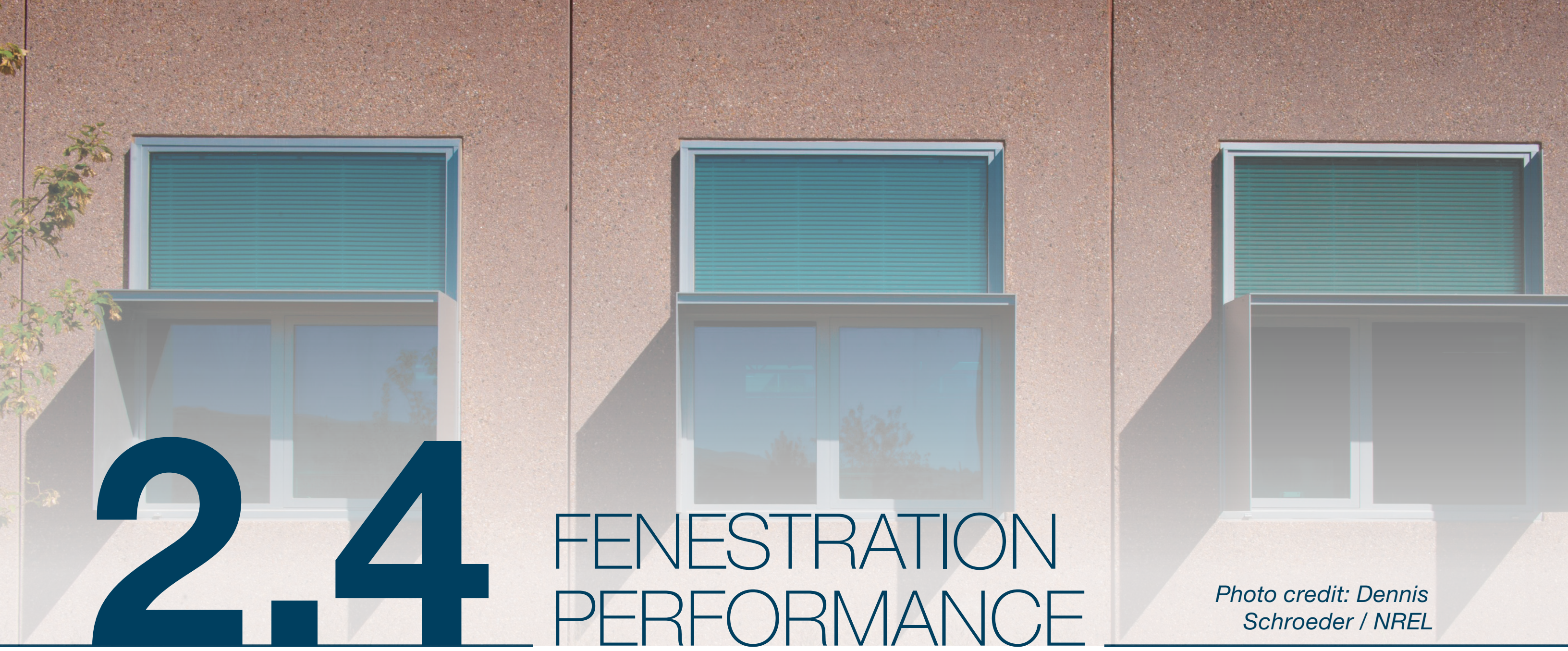
BEST PRACTICES

Table 2.3.1 Insulation Requirements for Above- and Below-Grade Assemblies, Slab Edge and Below-Grade Slabs[1]

Climate Zone	1	2	3	4	5	6	7	8
Roof, Flat	U-0.032	U-0.032	U-0.032	U-0.028	U-0.028	U-0.028	U-0.023	U-0.023
Roof, Sloped	U-0.021	U-0.021	U-0.021	U-0.021	U-0.021	U-0.017	U-0.017	U-0.017
Walls, Above Grade	U-0.051	U-0.051	U-0.051	U-0.051	U-0.051	U-0.036	U-0.036	U-0.024
Walls, Below Grade[2]	C-0.119	C-0.119	C-0.119	C-0.119	C-0.092	C-0.092	C-0.076	C-0.076
Floors	U-0.066	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033
Slab-on-Grade Floors (unheated)								
- Underslab	R-5	R-5	R-5	R-5	R-5	R-5	R-5	R-5
- Edge*	F-0.73	F-0.73	F-0.73	F-0.54	F-0.54	F-0.54	F-0.40	F-0.40
Slab-on-Grade Floors (heated)								
- Underslab	R-10	R-10	R-10	R-10	R-10	R-10	R-10	R-10
- Edge*	F-0.70	F-0.70	F-0.70	F-0.65	F-0.58	F-0.58	F-0.55	F-0.55

1 U-factors, C-Factors, and F-Factors are maximum values. R-Values for underslab insulation at Below-Grade Slab Floors are minimum values.

2 C-Factor and F-Factor are not the same as U-Factor. C-Factor is calculated similarly to U-Factor, but accounts for the assembly being in direct contact with the earth. F-Factor is in different units than U- and C-Factor; it denotes the heat loss of the edge of a slab per linear foot of perimeter rather than square foot of area.



2.4 FENESTRATION PERFORMANCE

Photo credit: Dennis Schroeder / NREL

Purpose

Reduce energy losses via the building's envelope through the installation of high-performance fenestration systems and the use of a consistent performance rating standard for these products.

Criteria

The weighted average of all fenestration assemblies shall meet the U-Factor and SHGC requirements shown in Table 2.4.1.

All vertical fenestration assemblies shall have a VLT (Visible Light Transmission) rating of no less than 1.5 times the SHGC rating of the assembly.

All fenestration assemblies shall be rated according to the requirements of the National Fenestration Rating Council (NFRC) with respect to the performance of the fenestration in the categories of U-Factor, Solar Heat Gain Coefficient and Visible Light Transmittance, and air leakage rate.

General

The 2012 International Energy Conservation Code (IECC-2012) limits the window-to-wall ratio (WWR) for commercial buildings to 30%. To allow greater flexibility in building design, the IECC allows a WWR of up to 40% for buildings in Climate Zones 1-6 if 50% of the conditioned floor area is within a daylit zone with automatic daylighting controls. Since the *Advanced Buildings New Construction Guide* already requires the incorporation of daylighting in the building, buildings that make use of the alternate code path for up to 40% WWR must incorporate a more efficient fenestration system.

Table 2.4.1

Climate Zone	1	2	3	4	5	6	7	8
Vertical Fenestration (0-30% window-to-wall ratio)	U-0.46	U-0.46	U-0.40	U-0.37	U-0.37	U-0.29	U-0.22	U-0.22
Vertical Fenestration (30-40% window-to-wall ratio)	U-0.36	U-0.36	U-0.30	U-0.29	U-0.29	U-0.22	U-0.17	U-0.17
Vertical SHGC	0.25	0.25	0.25	0.35	0.35	0.35	0.40	0.40
Skylight	U-0.65	U-0.55	U-0.50	U-0.50	U-0.50	U-0.50	U-0.50	U-0.50
Skylight SHGC	0.35	0.35	0.35	0.40	0.40	0.40	NR	NR

The values in this table apply to the entire fenestration assembly.

Notes: In order to meet these requirements, fenestration performance may be averaged for the entire building on a weighted average basis. For buildings with 30-40% WWR, the weighted average performance of all fenestration must meet the 30-40% U-value requirement.

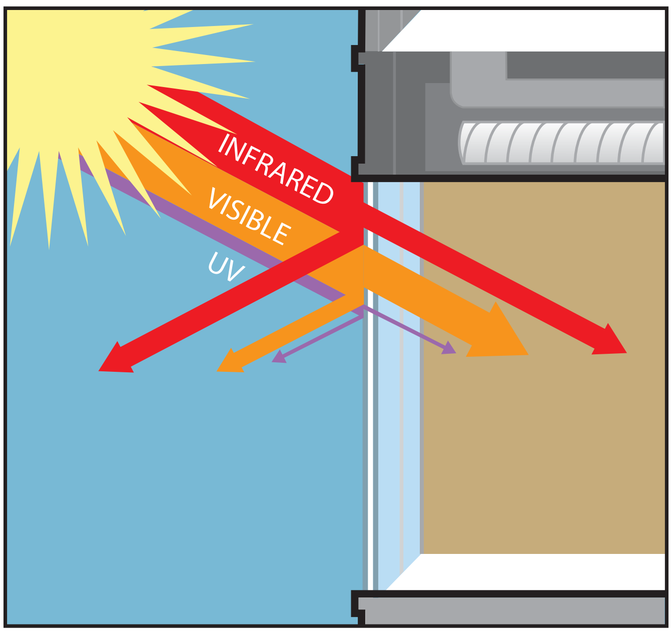
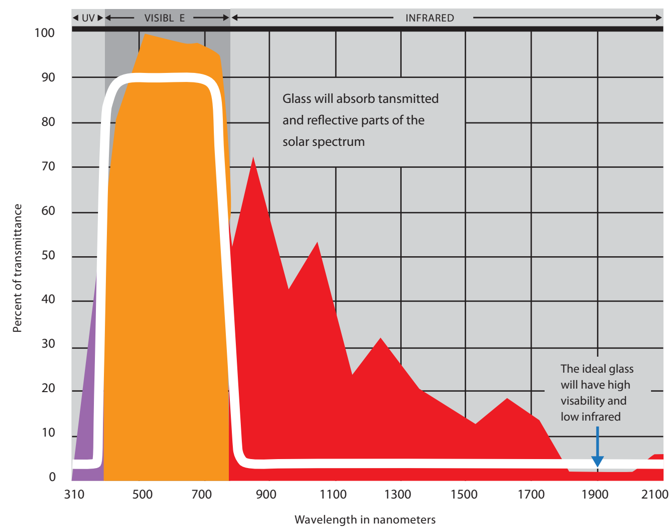


Diagram showing the advantage of using low-e glass to reduce solar gains.



Core Performance Building: Fidelity Bank Leominster, MA. Photo credit: Maugel Architects

2.5 DAYLIGHTING

Purpose

The incorporation of daylighting strategies and controls to reduce lighting energy use while maintaining the desired illumination level within the daylight zone.

Criteria

The building shall have no less than 35% of its conditioned net floor area within a daylit zone meeting the following requirements:

- The daylit zone area shall be determined using the area definitions of the current versions of one of the following: the International Energy Conservation Code, ASHRAE Standard 90.1, the International Green Construction Code or the Massachusetts Stretch Code.
- Surface finishes in the daylit zone shall have a minimum reflectance of 80% for ceilings, 65% for walls and 50% for floors.
- All lighting power in the daylit zone shall be controlled by automatic daylighting controls with the following capabilities:
  - » Continuous dimming from 100% power down to no more than 10% before turning off
  - » A 15-minute delay or other means to avoid cycling due to rapidly changing sky conditions
- The lighting in each daylight zone shall be separately controlled unless it is an adjacent zone associated with one building façade.
- All lighting controls in the daylit zone shall be installed and configured in accordance with manufacturer's instructions and commissioned in accordance with the Acceptance Testing Protocol in Appendix A.

Exception: Buildings in which more than 50% of the walls in the envelope are shared with other buildings are exempt from this Criterion provided the window-to-wall ratio for all non-shared walls does not exceed 30%.

General

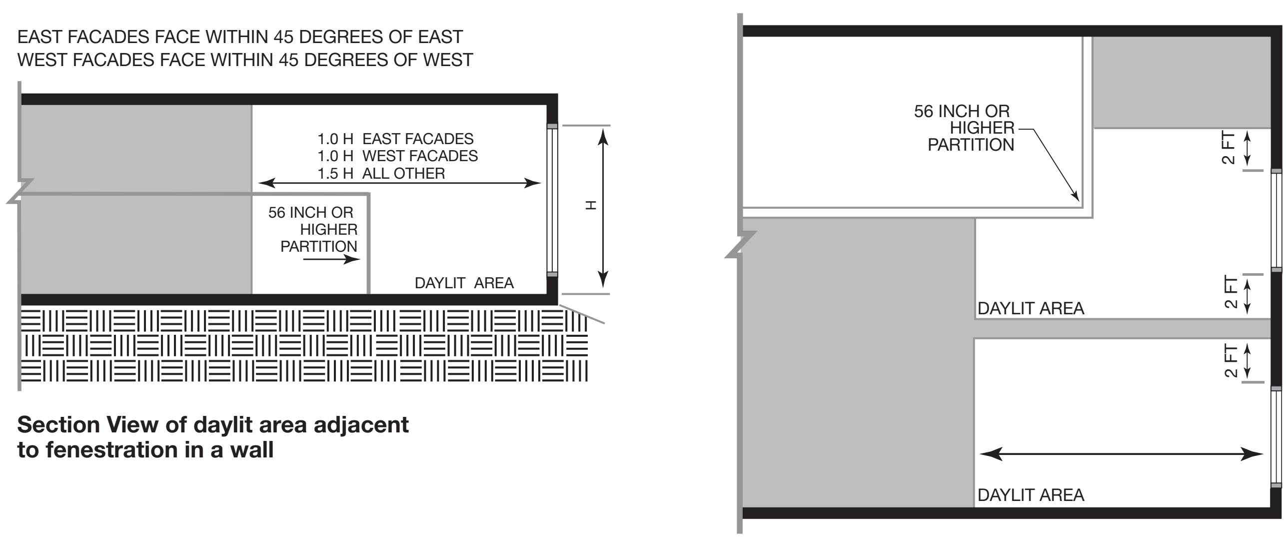
Many decisions made early in the design phase have a significant impact on a building's potential for daylight. Design focus should be put on maximizing the amount of continuously occupied space that has access to daylighting. Wherever possible a narrow floor plate with an elongated East to West orientation should be considered providing optimal North and South daylighting exposure. The volume-to-surface-area requirements of different building types vary dramatically and can have a significant impact on which daylighting strategy should be pursued. Multi-floor office buildings typically have greater sidelighting potential, while single-story buildings, such as high-bay retail and storage, should focus on a combination of sidelighting and toplighting to meet the requirements of this measure. Due to the variety of space use types in schools it is important to provide easy-to-use shading systems and lighting controls in classrooms that require audiovisual activities.

Any design team implementing a daylighting design must consider and account for the impacts of glare and solar heat gain associated with their approach. Buildings should limit their East-West direct sun exposure and ensure all sidelighting approaches include adequate glare and heat gain control strategies. Separating view and daylight glazing can be an effective strategy in helping to maintain visual and thermal comfort.

Advanced Buildings' *Daylighting Pattern Guide* (http://patternguide.advancedbuildings.net/) provides guidance for optimizing daylighting design. It illustrates a variety of prototypical space designs and their implications for daylighting.

BEST PRACTICES

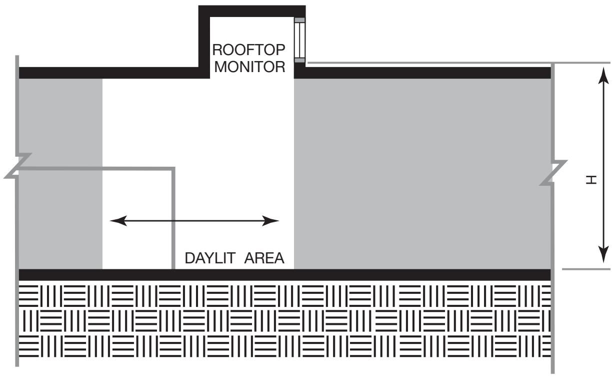
Small control zones increase the complexity and cost of automatic daylight controls. For this reason many base codes, including the IECC, exempt small daylit zones from automatic daylight control requirements (e.g. below 250 sf, check the base code in effect for your project). Designing so that control zones are larger, (usually larger than about 2,500 sf), will help ensure the control system remains cost effective. It will also help keep the system simpler and therefore easier to keep properly calibrated. If exempted by the base code, small daylit zones are not required to have automatic daylighting controls to meet this criterion unless their area is being used to meet the 35% threshold.



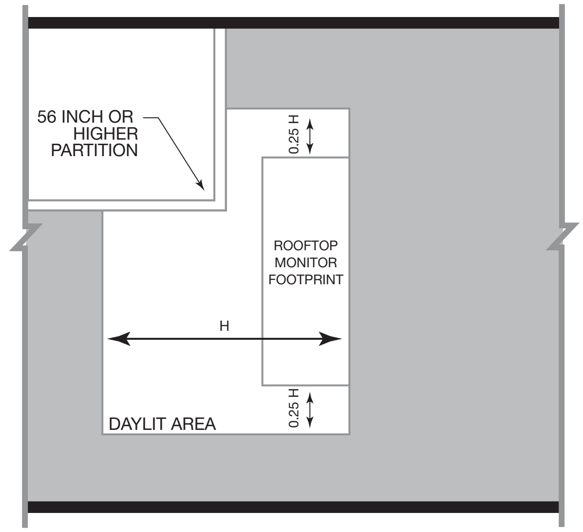
Section View of daylit area adjacent to fenestration in a wall

Plan view of daylit area adjacent to fenestration in a wall

Daylight Zone Adjacent to Fenestration in a Wall

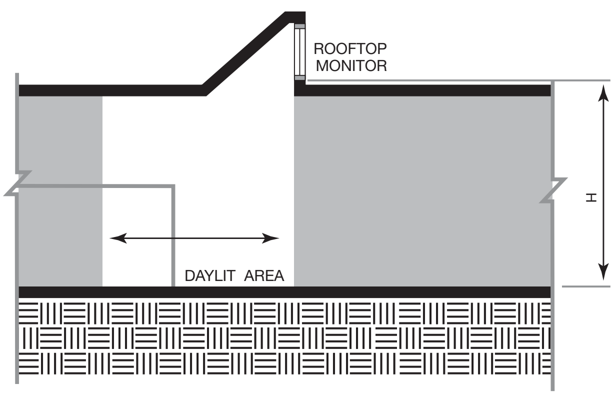


Section view of daylit area under a rooftop monitor

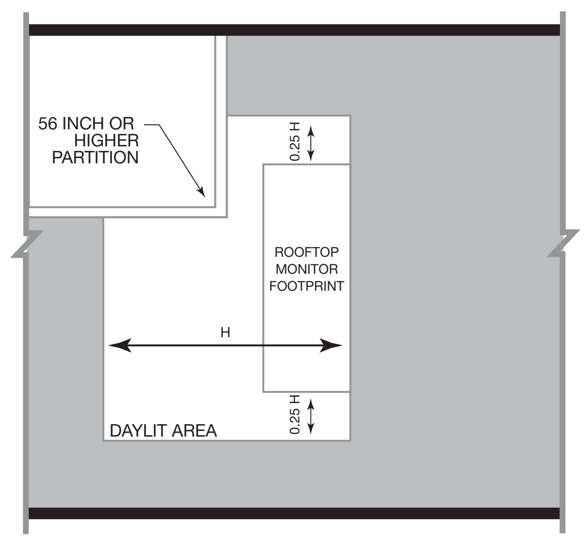


Plan view of daylit area under a rooftop monitor

Daylight Zone Under a Rooftop Monitor

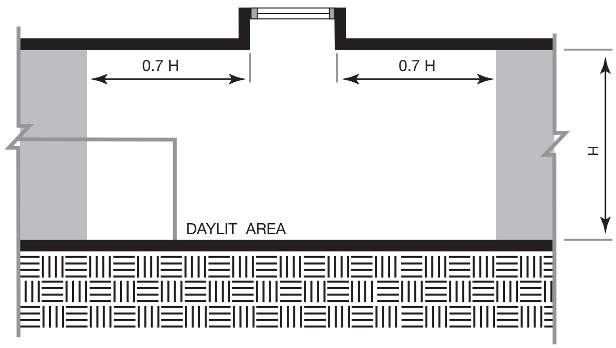


Section view of daylit area under a rooftop monitor

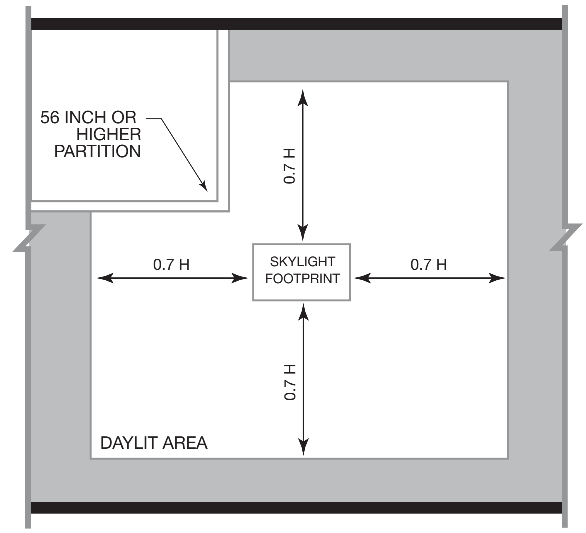


Plan view of daylit area under a rooftop monitor

Daylight Zone Under a Rooftop Monitor



Section view of a daylit area under a skylight



Plan view of daylit area under a skylight

Daylight Zone Under a Skylight

Photo credit: Pat Corkery / NREL

2.6 LIGHTING CONTROLS

Purpose

Reduce lighting energy use through the installation of automatic lighting controls and adjustable lighting level strategies

Criteria

Bi-Level Switching: Control devices shall be installed in occupied areas, that allow the occupants to reduce the connected lighting load in a reasonably uniform illumination pattern by at least 50% (or at least 40% for HID luminaries).

Vacancy Controls: Controls shall be installed to control the lighting of at least 85% of the connected interior lighting power of the building. Vacancy Controls shall be manual on/off, and shall shut off automatically after a period of inactivity of not more than 30 minutes. Where permitted by code, vacancy controls shall be used to control egress and emergency lighting during non-emergency conditions.

Exceptions: The following uses are exempted from the vacancy control requirements and may be excluded from the calculation determining 85% of the connected lighting load:

- All lighting exempted from automatic control requirements by code
- Lighting for theatrical purposes, including performances, stage, film production and video production
- Lighting intended for 24-hour operation
- 50% of the luminaires in corridors enclosed by floor-to-ceiling height partitions, provided the uncontrolled luminaires are reasonably distributed
- Public lobbies
- Health care patient rooms
- Lighting for industrial production that is provided with controls capable of automatically turning off lights during non-business hours
- Lodging guest rooms
- Retail display space that is provided with controls capable of automatically turning off lights during non-business hours

Daylighting Controls: Meet daylighting control requirements in Criterion 2.5.

2.7 LIGHTING POWER DENSITY

Core Performance Building: Brooks School North Andover, MA. Photo credit: Architerra

Criteria

Installed lighting power density (LPD) shall not exceed the values in Table 2.7.1. These LPD's shall be calculated based on luminaire efficiency, including lamps and ballasts.

All LED lighting installed shall be listed on the most recent version of either the EnergyStar Qualified Bulbs list or the DesignLights Consortium's Qualified Products List.

Purpose

Reduce the energy consumption of lighting systems through the installation of efficient lamps, ballasts and luminaires.

Table 2.7.1 Interior Lighting Power[1]

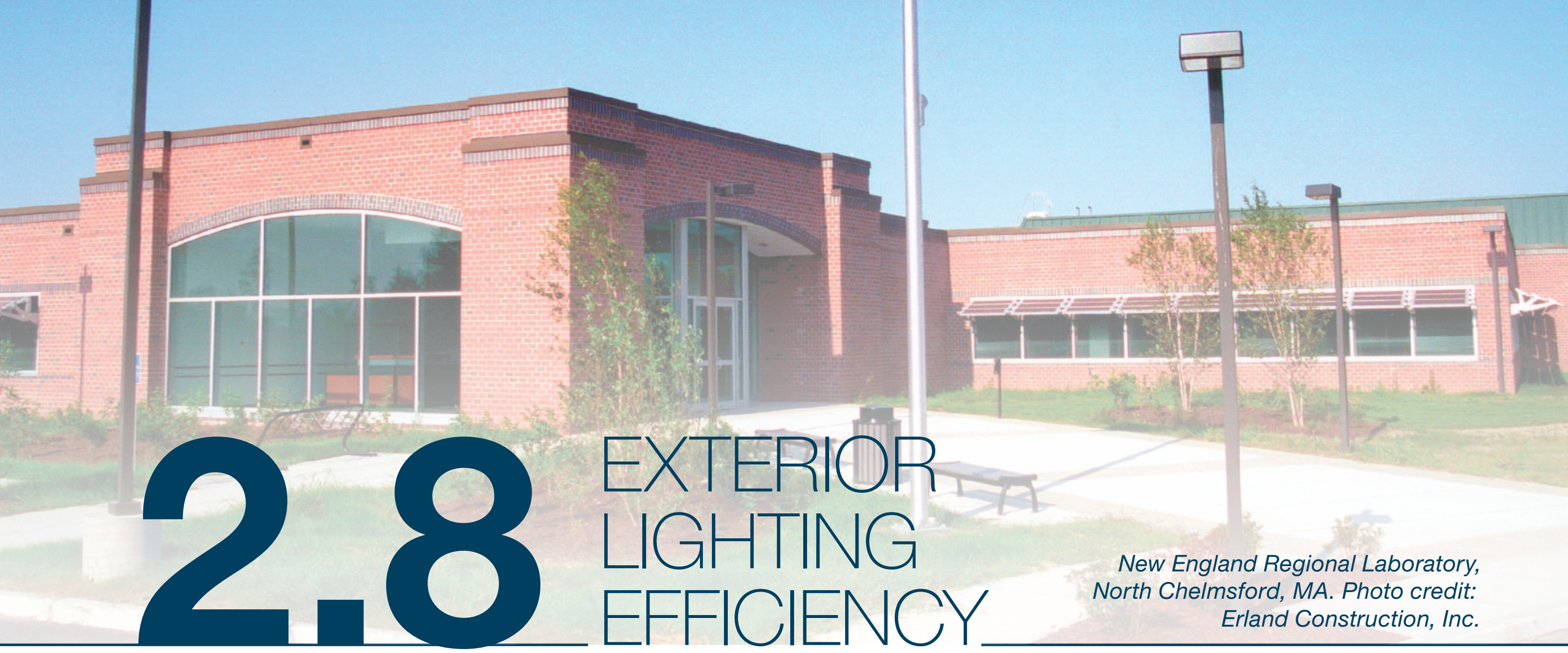
Building Area Type[a]	Lpd (W/Ft^2)
Automotive facility	0.80
Convention center	1.01
Courthouse	1.01
Dining: bar lounge/leisure	0.99
Dining: cafeteria/fast food	0.90
Dining: family	0.89
Dormitory	0.57
Exercise center	0.84
Fire station	0.67
Gymnasium	0.94
Health care clinic	0.87
Hospital	1.05
Library	1.18
Manufacturing facility	1.11
Hotel/Motel	0.56
Motion picture theater	0.76
Multifamily	0.51

Core Performance Building: Brooks School North Andover, MA. Photo credit: Architerra

Table 2.7.1 Interior Lighting Power[1] *continued*

Building Area Type[a]	Lpd (W/Ft²)
Museum	1.02
Office	0.81
Performing arts theater	1.39
Police station	0.87
Post office	0.87
Religious building	1.00
Retail	1.26
School/university	0.87
Sports arena	0.78
Town hall	0.89
Transportation	0.70
Warehousec	0.6
Workshop	1.19

1 Published 6/1/13. This table is subject to continuous maintenance. Check http://newbuildings.org/resource/new-construction-guide-errata for updates.



2.8 EXTERIOR LIGHTING EFFICIENCY

New England Regional Laboratory, North Chelmsford, MA. Photo credit: Erland Construction, Inc.

Criteria

All lamps over 75W used for exterior lighting shall meet the following requirements:

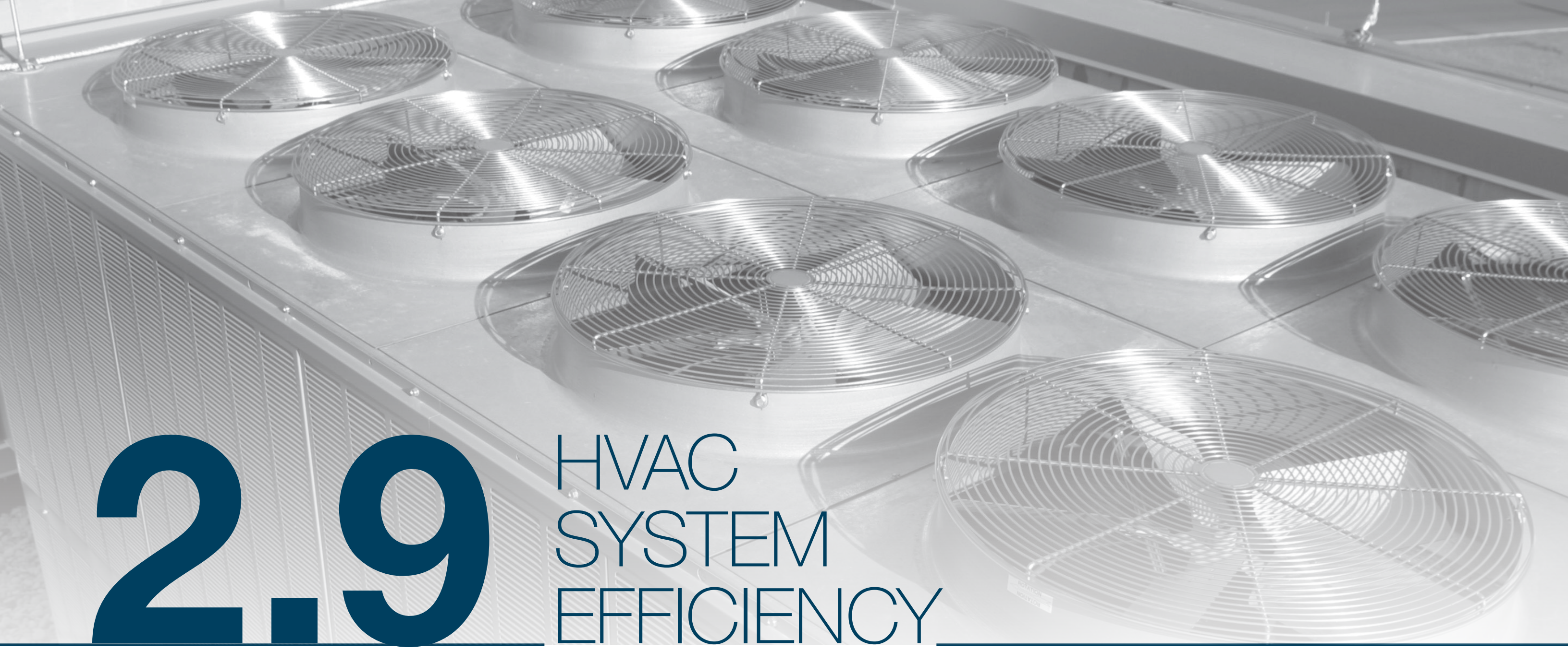
- Lamp efficacy of no less than 80 lumens/Watt
- Color Rendering Index (CRI) of no less than 22
- All LED lighting shall be listed on either the EnergyStar Qualified Bulbs list or the DesignLights Consortium’s Qualified Product List
  Exception: solar-powered lamps not connected to any electrical service

For building sites with a connected exterior lighting load greater than 5 kVA, site lighting shall be provided with controls meeting the following requirements:

- For parking structure and parking canopy lighting: occupancy sensing controls capable of reducing lighting power by no less than 30% after 30 minutes of inactivity. Each control zone shall be no larger than the area covered by a single luminaire or 1,000 sf, whichever is larger.
- For all other site lighting: astronomical time clock, photosensor controls or occupancy controls capable of reducing input power by 30%.
  Exceptions:
  - Luminaires within 30' of building entrances
  - Luminaires within 50' of site entrances
  - Luminaires within 30' of parking structure entrances

Purpose

Reduce energy associated with site lighting by improving lamp efficacy and the use of automatic controls that can reduce lighting power during unoccupied periods on large sites.



2.9 HVAC SYSTEM EFFICIENCY

Purpose

Reduce the energy consumption associated with heating and air conditioning through the installation of efficient equipment.

Criteria

- All HVAC equipment shall meet the minimum efficiency requirements in Tables 2.9.1 through 2.9.7.
- Gas Unit Heaters shall include an intermittent ignition device and have either power venting or a flue damper.
- Gas Furnaces <225,000 Btu/hr should have an AFUE rating of 94 or higher. Gas furnaces that are part of rooftop package equipment shall have an AFUE of at least 80.
- Boilers shall be provided with an intermittent ignition device, an air positive shut-off device (such as a flue or vent damper) and variable speed drives for all combustion fans.
- Equipment not listed in Tables 2.9.1 through 2.9.7 shall meet ENERGY STAR Criteria where available.

General

The most important aspect of HVAC performance is the overall efficiency of the whole system for delivery of space conditioning, not just the efficiencies for components given in the tables in this section. Using the design principles discussed in Criteria 0.4 Mechanical System Design will help assure that the balance of system components (pipes, ducts, pumps, fans, etc.) enhance total system efficiency and that the system is sized for more efficient performance.

Table 2.9.1 Unitary Air Conditioners and Condensing Units, Electrically Operated

Equipment Type	Size	Heating Type	Subcategory	Minimum Efficiency	Test Procedure
Air Conditioners, Air Cooled (Cooling Mode)	<65,000 Btu/h	All	Split System	15.0 SEER 12.5 EER	AHRI 210/240
			Single Package	15.0 SEER 12.0 EER	
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	12.2 EER 14.0 IEER	AHRI 340/360
		All Other	Split System and Single Package	12.0 EER 13.8 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	12.2 EER 13.2 IEER	
		All Other	Split System and Single Package	12.0 EER 13.0 IEER	
	≥240,000 Btu/h and <760,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	10.8 EER 12.3 IEER	
		All Other	Split System and Single Package	10.6 EER 12.1 IEER	
	≥760,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	10.4 EER 11.6 IEER	
		All Other	Split System and Single Package	10.2 EER 11.4 IEER	
Air Conditioners, Water Cooled	<65,000 Btu/h	All	Split System and Single Package	14.0 EER	AHRI 210/240
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	14.0 EER 15.3 IEER	AHRI 340/360
		All Other	Split System and Single Package	13.8 EER 15.1 IEER	
	≥135,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	14.0 EER 14.8 IEER	
		All Other	Split System and Single Package	13.8 EER 14.6 IEER	

Table 2.9.1 Unitary Air Conditioners and Condensing Units, Electrically Operated *continued*

Equipment Type	Size	Heating Type	Subcategory	Minimum Efficiency	Test Procedure
Air Conditioners, Evaporatively Cooled	<65,000 Btu/h	All	Split System and Single Package	14.0 EER	AHRI 210/240
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	14.0 EER 15.3 IEER	AHRI 340/360
		All Other	Split System and Single Package	13.8 EER 15.1 IEER	
	≥135,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	13.5 EER 14.3 IEER	
		All Other	Split System and Single Package	13.3 EER 14.1 IEER	

Table 2.9.2 Unitary and Applied Heat Pumps, Electrically Operated

Equipment Type	Size Category	Heating Section	Subcategory	Minimum Efficiency	Test Procedure
Air Cooled (Cooling Mode)	<65,000 Btu/h	All	Split System	15.0 SEER 12.5 EER	AHRI 210/240
			Single Package	15.0 SEER 12.0 EER	
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	11.3 EER 12.3 IEER	AHRI 340/360
		All Other	Split System and Single Package	11.1 EER 12.1 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	10.9 EER 11.9 IEER	
		All Other	Split System and Single Package	10.7 EER 11.7 IEER	
	≥240,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	10.3 EER 10.9 IEER	
		All Other	Split System and Single Package	10.1 EER 10.7 IEER	

Table 2.9.2 Unitary and Applied Heat Pumps, Electrically Operated *continued*

Equipment Type	Size Category	Heating Section	Subcategory	Minimum Efficiency	Test Procedure
Air Cooled (Heating Mode)	<65,000 Btu/h		Split System	9.0 HSPF	AHRI 210/240
			Single Package	8.5 HSPF	
	≥65,000 Btu/h and <135,000 Btu/h		47 F db/43 F wb Outdoor Air	3.4 COP	AHRI 340/360
			17 F db/15 F wb Outdoor Air	2.4 COP	
	≥135,000 Btu/h		47 F db/43 F wb Outdoor Air	3.2 COP	
			17 F db/15 F wb Outdoor Air	2.1 COP	
Water Source (Cooling Mode)	<135,000 Btu/h	All	86 Entering Water	14.0 EER	ISO 13256-1
Water Source (Heating Mode	<135,000 Btu/h		68 Entering Water	4.6 COP	ISO 13256-1

Table 2.9.3 Package Terminal Air Conditioners and Heat Pumps, Electrically Operated

Equipment Type	Size Category (Input)	Subcategory Or Rating Condition	Minimum Efficiency	Test Procedure
PTAC (cooling mode)	All Capacities	95°F db outdoor air	14.1 - (0.300 × Cap/1000) EER	AHRI 310/380
PTHP (cooling mode)	All Capacities	95°F db outdoor air	14.1 - (0.300 × Cap/1000) EER	
PTHP (heating mode)	All Capacities	—	3.3 - (0.26 × Cap/1000) COP	
SPVAC (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	9.1 EER	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	9.0 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	8.7 EER	
SPVHP (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	9.1 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	9.0 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	8.7 EER	

Table 2.9.3 Package Terminal Air Conditioners and Heat Pumps, Electrically Operated *continued*

Equipment Type	Size Category (Input)	Subcategory Or Rating Condition	Minimum Efficiency	Test Procedure
SPVHP (heating mode)	< 65,000 Btu/h	47°F db/ 43°F wb outdoor air	3.1 COP	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	47°F db/ 43°F wb outdoor air	3.1 COP	
	≥ 135,000 Btu/h and < 240,000 Btu/h	47°F db/ 75°F wb outdoor air	3.0 COP	

Table 2.9.4 Boilers

Type	Fuel	Size Category	Minimum Efficiency Requirements	Test Procedure
Hot Water	Gas	< 300,000 Btu/hr	97.3% AFUE	DOE 10 CFR Part 430
		300,000 - 2,500,000 Btu/hr	94.5% Et	DOE 10 CFR Part 431
		> 2,500,000 Btu/hr	94.5% Ec	
	Oil	< 300,000 Btu/hr	88.6% AFUE	DOE 10 CFR Part 430
		300,000 - 2,500,000 Btu/hr	85.3% Et	DOE 10 CFR Part 431
		> 2,500,000 Btu/hr	86.2% Ec	
	Cordwood	All	72.8% Et	ASME PTC 4.1
	Wood Pellet	All	86.0% Et	
Steam	Gas	< 300,000 Btu/hr	83.4% AFUE	DOE 10 CFR Part 430
		300,000 - 2,500,000 Btu/hr	80.6% Et	DOE 10 CFR Part 431
		> 2,500,000 Btu/hr	80.5% Ec	
	Oil	< 300,000 Btu/hr	85.6% AFUE	DOE 10 CFR Part 430
		300,000 - 2,500,000 Btu/hr	83.0% Et	DOE 10 CFR Part 431
		> 2,500,000 Btu/hr	83.5% Ec	

Et = thermal efficiency, Ec = Combustion Efficiency

Table 2.9.5 Chillers

Equipment Type	Size Category	Minimum Efficiency Requirements: Path A	Minimum Efficiency Requirements: Path B	Test Procedure c
Air-Cooled Chillers	< 150 Tons	≥10.100 EER	≥9.700 EER	AHRI 550/590
		≥13.700 IPLV	≥15.800 IPLV	
	≥150 Tons	≥10.100 EER	≥9.700 EER	
		≥14.000 IPLV	≥16.100 IPLV	
Air-Cooled without Condenser, Electrically Operated	All Capacities	Air-cooled chillers without condenser must be rated with matching condensers and comply with air-cooled chiller efficiency requirements		
Water-Cooled, Electrically Operated Positive Displacement	< 75 Tons	≤0.750 kW/ton	≤0.780 kW/ton	
		≤0.600 IPLV	≤0.500 IPLV	
	≥ 75 tons and <150 tons	≤0.720 kW/ton	≤0.750 kW/ton	
		≤0.560 IPLV	≤0.490 IPLV	
	≥ 150 tons and < 300 tons	≤0.660 kW/ton	≤0.680 kW/ton	
		≤0.540 IPLV	≤0.440 IPLV	
	≥ 300 tons and < 600 tons	≤0.610 kW/ton	≤0.625 kW/ton	
		≤0.520 IPLV	≤0.410 IPLV	
	≥ 600 tons	≤0.560 kW/ton	≤0.585 kW/ton	
		≤0.500 IPLV	≤0.380 IPLV	
Water Cooled, Electrically Operated Centrifugal	< 150 Tons	≤0.610 kW/ton	≤0.695 kW/ton	
		≤0.550 IPLV	≤0.440 IPLV	
	≥ 150 tons and <300 tons	≤0.610 kW/ton	≤0.635 kW/ton	
		≤0.550 IPLV	≤0.400 IPLV	
	≥ 300 tons and <400 tons	≤0.560 kW/ton	≤0.595 kW/ton	
		≤0.520 IPLV	≤0.390 IPLV	
	≥ 400 tons and <600 tons	≤0.560 kW/ton	≤0.585 kW/ton	
		≤0.500 IPLV	≤0.380 IPLV	
	≥ 600 tons	≤0.560 kW/ton	≤0.585 kW/ton	
		≤0.500 IPLV	≤0.380 IPLV	

Table 2.9.5 Chillers *continued*

Equipment Type	Size Category	Minimum Efficiency Requirements		Test Procedure c
		Path A	Path B	
Air-Cooled Absorption, Single Effect	All Capacities	≥0.600 COP	NA	AHRI 560
Water-Cooled Absorption, Single Effect	All Capacities	≥0.700 COP	NA	
Double-Effect, Indirect-Fired	All Capacities	≥1.000 COP ≥1.050 IPLV	NA	
Absorption Double-Effect, Direct-Fired	All Capacities	≥1.000 COP ≥1.000 IPLV	NA	

1. FL is the full load performance requirements and IPLV is for the part load performance requirements
2. Both the full load and IPLV requirements must be met or exceeded to comply with this standard. When there is a Path B, compliance can be with either Path A or Path B for any application.
3. The requirements for centrifugal chiller shall be adjusted for non-standard rating conditions per C403.2.3.1 of the IECC and are only applicable for the range of conditions listed in C403.2.3.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

Table 2.9.6 Variable Refrigerant Flow Air Conditioner

Equipment Type	Size Category	Heating Section Type	Minimum Efficiency Requirements	Test Procedure
VRF Air Cooled (Cooling Mode)	< 65,000 Btu/h	All	15.0 SEER 12.5 EER	AHRI 1230
	> 65,000 Bth/h and < 135,000 Btu/h	Resistance or None	11.7 EER 14.9 IEER	
	> 135,000 Btu/h and < 240,000 Btu/h	Resistance or None	11.7 EER 14.4 IEER	
	> 240,000 Btu/h	Resistance or None	10.5 EER 13.0 IEER	

Table 2.9.7 Variable Refrigerant Flow Air Multisplit Heat Pump

Equipment Type	Size Category	Heating Section Type	Subcategory	Minimum Efficiency Requirements	Test Procedure
VRF Air Cooled (Cooling Mode)	< 65,000 Btu/h	All	Multisplit	15.0 SEER	AHRI 1230
				12.5 EER	
	> 65,000 Bth/h and < 135,000 Btu/h	Resistance or None	Multisplit	11.3 EER	
				14.2 IEER	
			Multisplit with Heat Recovery	11.1 EER	
				14.0 IEER	
	> 135,000 Btu/h and < 240,000 Btu/h	Resistance or None	Multisplit	10.9 EER	
				13.7 IEER	
			Multisplit with Heat Recovery	10.7 EER	
				13.5	
	> 240,000 Btu/h	Resistance or None	Multisplit	10.3 EER	
				12.5 IEER	
			Multisplit with Heat Recovery	10.1 EER	
				12.3 IEER	
VRF Air Cooled (Heating Mode)	< 65,000 Btu/h	-	Multisplit	9.0 HSPF	
	> 65,000 Bth/h and < 135,000 Btu/h	-	47°F db/43°F wb Outdoor Air	3.4 COP	
		-	17°F db/15°F wb Outdoor Air	2.4 COP	
	≥ 135,000 Btu/h	-	47°F db/43°F wb Outdoor Air	3.2 COP	
		-	17°F db/15°F wb Outdoor Air	2.1 COP	
VRF Water Source (Cooling Mode)	< 135,000 Btu/h	All	Multisplit System with Heat Recovery 86° Entering Water	14.0 EER	
			Multisplit System 86° Entering Water	13.8 EER	
	≥ 135,000 Btu/h	All	Multisplit System with heat recovery, 86° Entering Water	13.4 EER	
			Multisplit System, 86° Entering Water	12.1 EER	
VRF Water Source (Heating Mode)	< 135,000 Btu/h		68° Entering Water	4.6 COP	
	≥ 135,000 Btu/h	All	Multisplit System, 68° Entering Water	4.6 COP	

For additional information on VRF systems refer to Tier 3.6 in the *Advanced Buildings New Construction Guide.*

High levels of HVAC performance depend not only on selecting high efficiency components, but also upon proper sizing and system matching to loads.

Core Performance Building: Gibney Family Vision Center So. Burlington, VT. Photo Credit: Neagley & Chase Construction Co.

2.10 ECONOMIZER

Criteria

When economizers are required/installed, they shall incorporate the following features:

- Outside air and return air dampers shall have a motorized actuator with full modulation, gear-driven interconnections, and permanently lubricated bushings or bearings.
- Sensors that provide feedback for economizer control shall be located downstream of DX cooling coils and upstream of hydronic cooling coils.
- Sensors controlling economizer operation shall be placed in a location where the return and outside air streams have adequately mixed.
- Controls that ensure that the economizer is only active when there is a call for cooling.
- An economizer controller that utilizes a deadband between economizer enable/disable operation of no greater than 2°F in a dry-bulb temperature application and 2 Btu/lb in an enthalpy application.
- A differential dry-bulb, fixed dry-bulb, differential enthalpy or dewpoint/dry-bulb temperature economizer control. Specific climatic conditions should help determine the most appropriate type of control/sensor strategy.
- Relief air provided by either a barometric damper in the return air duct upstream of the return air damper, a motorized exhaust air damper, or an exhaust fan with backdraft dampers. Return air relief and outside air intake hoods shall be installed so that relief dampers operate freely.
- Verification of the minimum OA setpoint by measuring the temperature of the mixed air, return air and outside air to calculate the percentage of outside air. (This measurement is conducted during acceptance testing and may also be an ongoing operational control point.)

Purpose

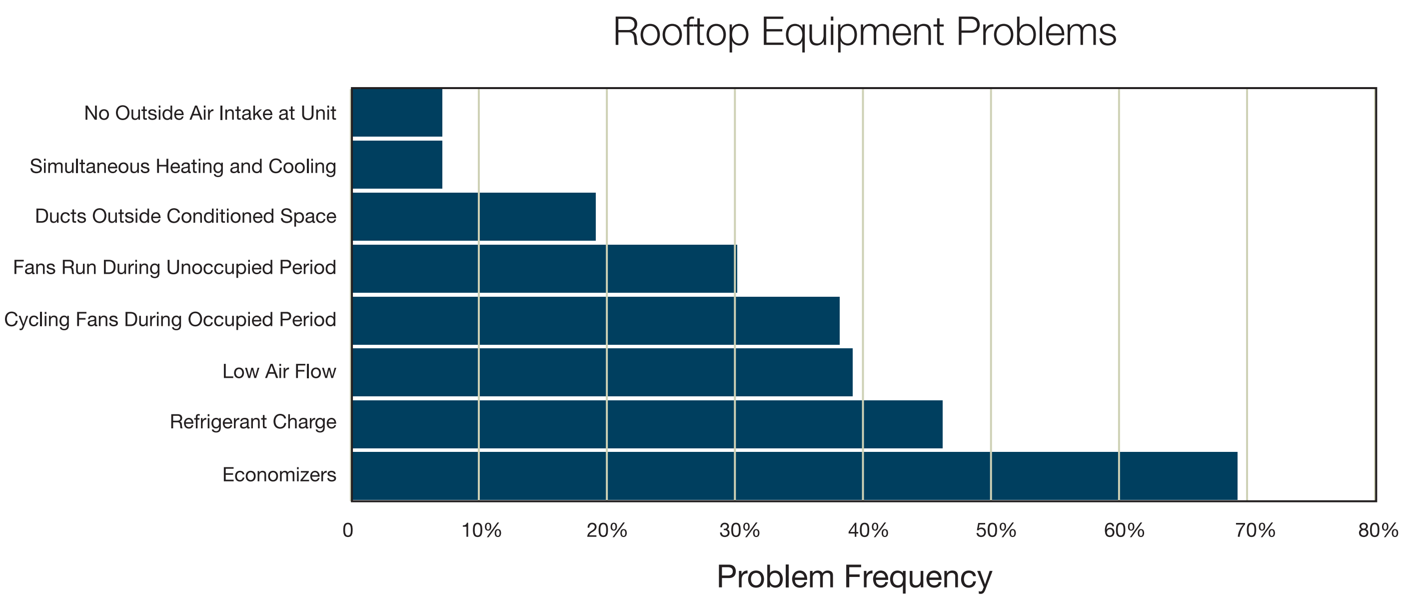
Ensure optimal energy savings from the proper performance of outside air (OA) economizers.

General

Economizer control can reduce cooling loads when outside air conditions are cooler and/or dryer than return air conditions. In some climates, economizer use reduces the amount of energy used for mechanical cooling by 20-60%. There are a number of design conditions that, in combination, determine economizer performance: the economizer must coordinate or interlock with mechanical cooling so that it is only used when there is a call for cooling; a changeover control must return outside air dampers to the minimum ventilation position when outside air is too warm to provide cooling; and the level of economizer control integration determines the ability to make full use of outside air to eliminate or minimize mechanical cooling loads.

Factory-installed economizers are generally more reliable than field-installed economizers and should be selected when possible; however, there are conditions that call for field installation of economizers.

Conventional design and installation of economizers has been demonstrated to result in high failure rates and significant performance problems such that they do not meet anticipated performance guidelines. The strategies in this criterion have been demonstrated to significantly improve economizer performance and reliability.



The graph above, compiled from a number of field studies, shows how frequently performance aspects of newly installed rooftop HVAC equipment was found to be defective. Note that the economizers on an astonishing 70% of rooftop units less than five years old are either missing or inoperative!

2.11 DUCT CONSTRUCTION

Core Performance Building: Gibney Family Vision Center, So. Burlington, VT. Photo credit: Efficiency Vermont

Criteria

The following requirements apply to all heating and cooling distribution ductwork, and to ventilation air intake ductwork:

- No more than 5% of the ductwork may be located outside the building thermal envelope.
- Install a minimum of R-10 Insulation on all ducts located outside of conditioned spaces.
- Install a minimum of R-6 Insulation on all supply ducts located within conditioned space not directly served by that ductwork.
- All duct insulation shall be on the exterior of the duct
- Outside air ventilation intake ducts located in conditioned space shall be insulated with R-10 between the outside air intake and the primary equipment supplied by the duct.
- Outside air intakes shall be fitted with automatic dampers located near the envelope penetration; dampers shall close completely when ventilation is not required.
- All duct joints and field connections in ductwork shall be secured with mechanical fasteners and shall be sealed with a duct sealing mastic with a UL labeling of 181A-M or 181B-M. Pressure-sensitive tape shall not be used as a duct sealing mechanism.
- For ducts designed to operate at pressures greater than 2 inches water gauge (500 Pa), a minimum of 25% of the duct area shall be leak-tested in accordance with the SMACNA *HVAC Air Duct Leakage Test Manual* to meet a rate of air leakage (CL) less than or equal to 4.0 as determined in accordance with the following equation:

  CL = F/P0.65

  where:

  F = The measured leakage rate in cfm per 100 square feet of duct surface

  P = The static pressure of the test

  (See Criterion 2.12 – Fan Power Reduction for further requirements for higher pressure duct systems.)

Purpose

Reduce energy losses associated with HVAC loads by reducing losses from ducts due to thermal conductance and air leakage.

Well insulated ductwork used in the Fidelity Bank in Leominster, MA. Photo credit: National Grid

2.12 FAN POWER REDUCTION

Core Performance Building: UMASS Memorial Health Center Worcester, MA. Photo credit: National Grid

Criteria

Design all air distribution systems to meet the following criteria:

- Limit the fan energy used to meet design heating, cooling and ventilation requirements. Specify no more than 0.8 watts of fan power per cfm delivered for variable volume systems. For constant volume systems, limit fan power to 0.65 watts/cfm delivered. For packaged equipment with pre-installed integral fans, the total capacity of the system shall not exceed one nominal ton of cooling capacity (12,000 Btu) for each 800sf of conditioned building floor area. (See below for duct design best practices that can reduce the required fan energy.) Buildings that need to exceed these guidelines must complete full load calculations to demonstrate higher-than-average load conditions justifying additional fan power or system capacity. Additional system sizing criteria are provided in section 0.4.
- Fans that aren't integrated directly into packaged equipment shall have:
  - Electronic commutation for single-phase motors (brushless motors)
  - For fans attached to motors over 1hp, an FEG (Fan Efficiency Grade) of 71 or higher. Total efficiency of the fan at the point of operation should be within 10% points of the fan's maximum total efficiency.
- Duct systems shall be designed to operate at a static pressure of 2.0 inches water gauge (w.g.) (500 Pa) or less. 'High' pressure duct systems shall not be used. Specific building use areas with concentrated loads (i.e. lab areas) may include 'Medium' pressure duct systems (up to 3.0" w.g) if specific calculations of the need for increased airflow are provided.
- All fans shall be designed to be controlled based on actual loads or occupancy schedule rather than for continuous uncontrolled operation. (Fans are permitted to operate continuously if they meet the control requirements and the load or occupancy schedule requires such operation.)

Purpose

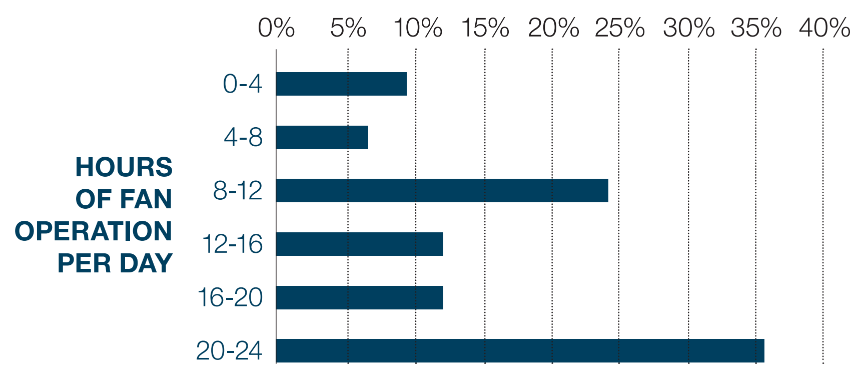
Reduce energy consumption associated with fans by increasing the efficiency of the duct and distribution systems and by increasing the efficiency of fan motors.

Figure 2.12.1

Survey of Fan Operation of 149 RTUs in Pacific Northwest

This graph indicates that almost half of the sampled units were wasting energy by running their fans more than 16 hours a day.

% OF BPA SAMPLE



General

The performance of fans used for ventilation can be improved in three primary ways:

- Improving the efficiency of the fan motor.
- Reducing static pressure drops so as to reduce the required fan size.
- Select a fan whose peak performance level matches the design conditions.

Improving fan efficiency

- Improve single-phase fan motor efficiency by using electronically commutated motors. ECMs, or brushless motors, are more efficient and have a longer service life.
- Choose fans with higher Fan Efficiency Grades. 67 represents the state of the market; 71 is required by this Criterion, but larger fans with an FEG in the 80s are available.

Reducing static pressure drop

Fan systems are designed to ensure that adequate airflow can be delivered given the aggregate static pressure drops of the distribution system and central equipment components. Duct design decisions can reduce static pressure losses arising from friction(due to duct sizing and directional changes) and turbulence (due to duct size transitions). Equipment selection choices can reduce losses associated with filters, coils, dampers, diffuser, and energy recovery systems.

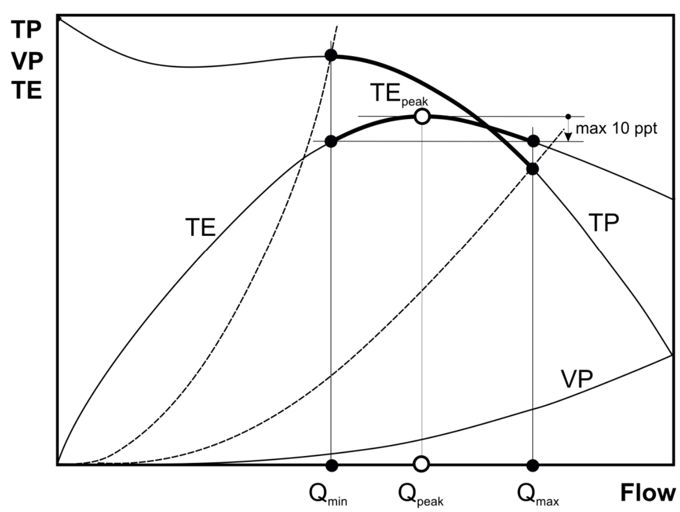
Because there are so many ways to create static pressure drops, there are also many ways to reduce them. The following strategies can help minimize pressure drops:

- Minimize duct turns and intersections.
- Replace 90-degree turns with smooth radius sweep turns, combination 45-degree turns, or turning vanes.
- Replace tee intersections with wye intersections.
- Eliminate flex duct and other duct constructions with uneven surface profiles
- Minimize duct size transitions.
- Choose diffusers designed to minimize pressure drop.
- Increase the cross-sectional area of air filters and coils.
- Increase duct size so as to decrease airflow velocity.
- Use motorized relief dampers instead of barometric/ gravity dampers
- Locate air handlers centrally to the zones they serve so as to minimize duct run length.
- Use coil and energy recovery bypass dampers.

Matching fan efficiency curve to system load

For a fan to achieve high peak efficiency it is critical that it be selected so that its peak efficiency aligns with system load characteristics. Fans operated above or below ideal load characteristics are significantly less efficient than those that are well matched to the peak load characteristics of the system. For this reason it is important to select a fan whose peak efficiency fan curve characteristics are well matched to the most common load conditions and air flow rates expected in the system. The diagram below demonstrates that the fan should be sized so that peak operating efficiency coincides with the most typical range of expected operating conditions. Over- or under-sizing fans beyond typical system performance boundaries results in substantial energy performance penalties. Variable speed fans can also be used to more closely align fan operating characteristics with system loads.

A typical fan performance curve, efficiency curve, and two system curves are shown. The system operating point should fall within a range around the peak efficiency. This figure shows an efficiency range on either side of the peak efficiency, the corresponding point on the fan curve, and the two associated system curves. They system should be designed to operate between these two system curves.



TP = fan total pressure
VP = fan velocity pressure
TE = fan total (energy) efficiency
Q = flow
Qmin, Qmax = flow range for the allowable fan efficiency range

References: International Mechanical Code; ASHRAE 90.1-2010; IGCC 2012; IECC 2012; SMACNA

2.13 HVAC CONTROLS

Core Performance Building: Tremont Yard Building Lowell, MA. Photo credit: National Grid

Criteria

Provide all HVAC systems with controls that meet the following requirements:

- The capability of all HVAC controls in the building to be accessed and configured either from a single location in the building, or remotely (i.e. wireless interface to laptop or smartphone).
- Control system settings automatically return to program defaults no more than two hours after a program override by building occupants.
- The controls for Package Terminal Air Conditioners (PTACs) used in hotel and motel guest rooms shall incorporate captive key controls, occupancy sensing controls or other automatic controls such that, no more than 30 minutes after the room has been vacated, setpoints are set up at least +5° F in cooling mode and set down at least -5° F in heating mode.

Purpose

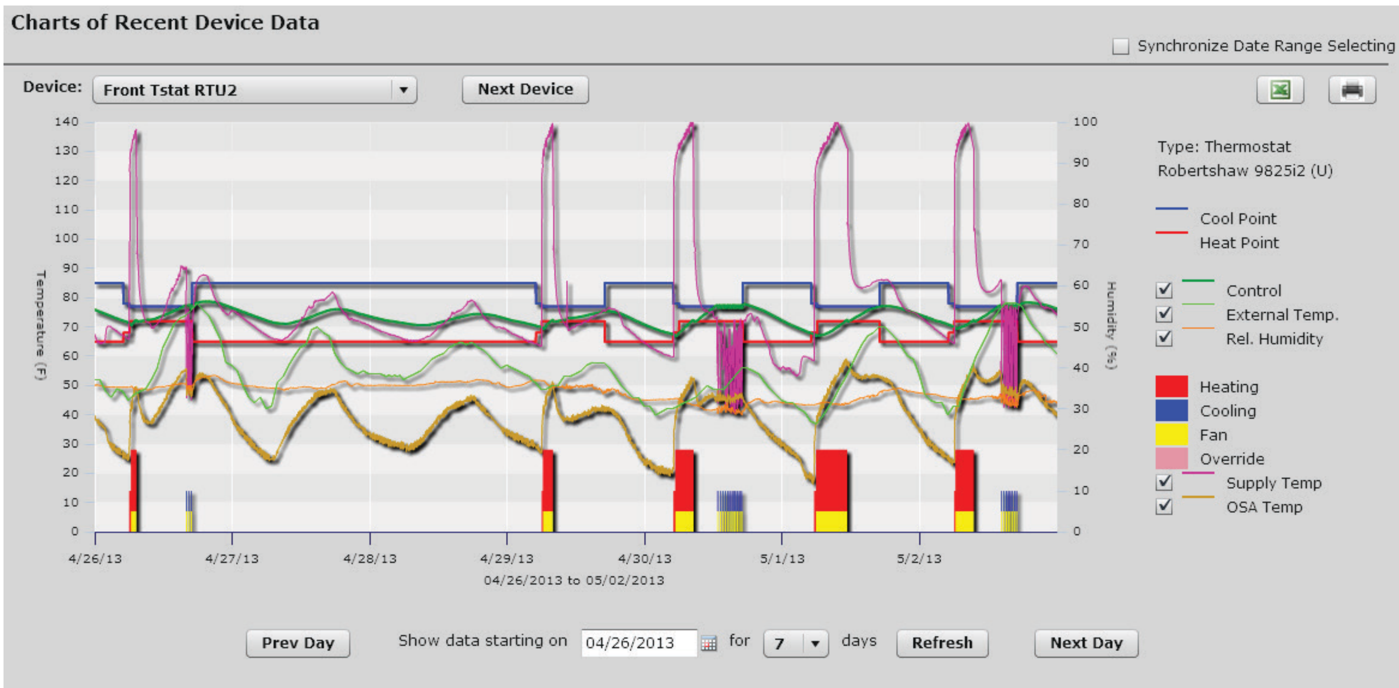
Reduce energy associated with HVAC loads through the use of effective controls that offer a greater level of control and improved ease of use.

General

One obstacle to the efficient operation of HVAC systems can be the HVAC controls themselves. Even a very efficient system is wasting energy if it runs when not needed. Controls can't be so basic that they don't provide a level of programming sufficiently granular to fulfill the scheduling needs of the space. But controls must also be understandable and easy to use for the occupants. Controls that don't meet the needs of the occupants or are too difficult to use are more likely to be overridden and disabled, making the systems they control more likely to be left on when not needed. The distribution of multiple control points around a building can lead to zone conflicts that only multiply the pitfalls of poor controls.

Programmable controls that respond to typical occupancy patterns of occupied and unoccupied hours are a good start toward better building control. The 2012 IECC requires programmable controls that allow schedules for all seven days of the week to be programmed independently. This new base code requirement is a big improvement over the “5 + 2” controls frequently found in small commercial buildings that use one schedule for weekdays and another for weekends. To prevent overrides and disabling, controls must also respond to temporary occupant needs. By automatically returning to programed operation after an occupant event, long-term HVAC system performance is maintained. By centralizing control operation capabilities, it becomes easier for building managers to validate and maintain appropriate system and control operation. Many modern HVAC controls now have web-style interfaces that can be accessed from computers and other devices inside, and even outside, the building.

More sophisticated controls with longer programming cycles and better user interfaces are also available and can significantly improve the effectiveness of control systems in aligning more directly with user needs and maintaining off-hour performance options.



The DreamWatts Energy Manager by Makad Energy is an example of a service that meets all the Tier 2.13 functionality requirements.

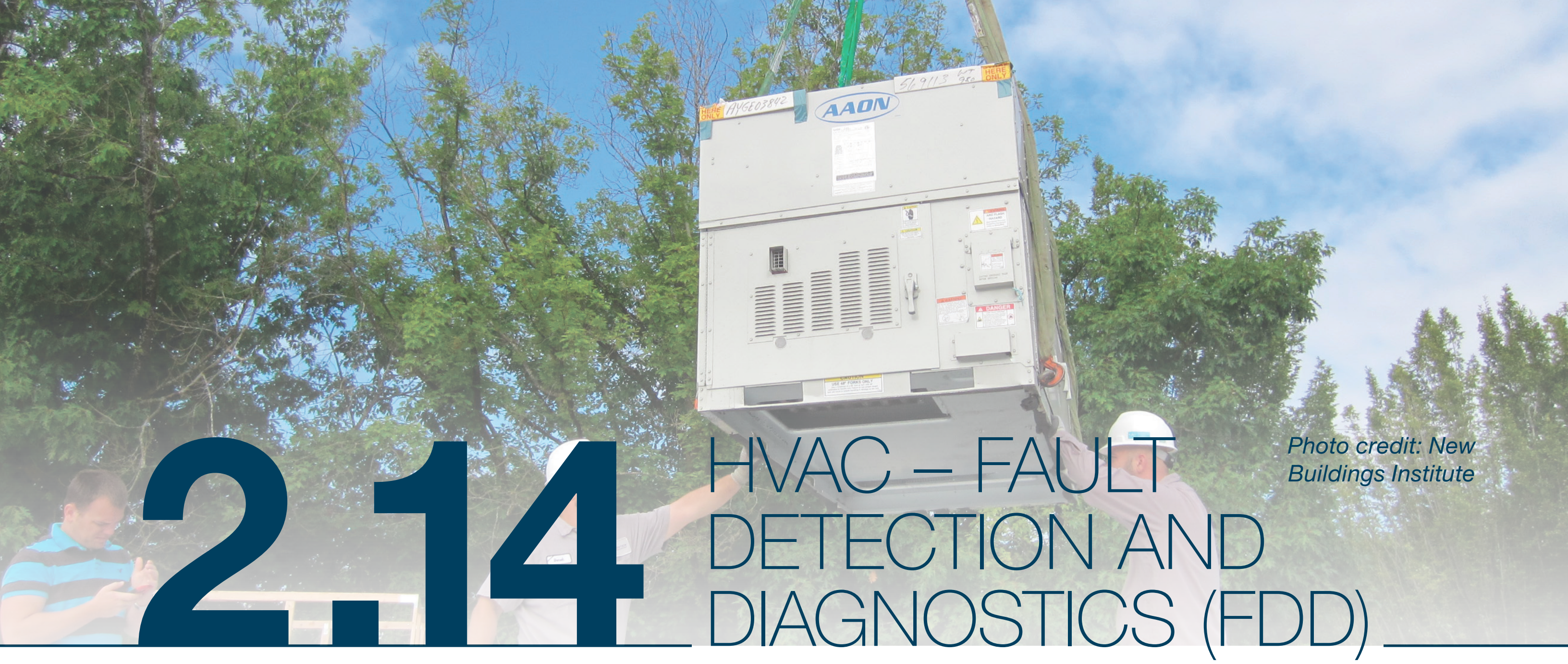


Photo credit: New Buildings Institute

2.14 HVAC – FAULT DETECTION AND DIAGNOSTICS (FDD)

Criteria

All HVAC systems shall be provided with built-in or add-on FDD equipment capable of detecting the following conditions (when applicable to the HVAC equipment):

- Failed compressor
- Failed evaporator fan motor
- Failed evaporator fan belt
- Failed condenser fan motor
- Sensor failure (all OEM products that are microprocessor-controlled have a sensor alarm(s)
- Failed relief damper
- Low refrigerant charge
- Dirty air filter
- Dirty evaporator coil
- Dirty condenser coil
- Reduced airflow
- Excessive airflow

FDD equipment must be capable of communicating faults via one of the following:

- Accessible onsite storage of a minimum of six months of faults
- Transmission of faults to a remote location

Purpose

Reduce HVAC energy consumption through supporting effective equipment maintenance with integrated fault detection and diagnostics (FDD).

General

Achieving energy efficiency in HVAC systems cannot stop at design or specification. Once an energy efficient HVAC system is installed, it must be maintained. In all HVAC systems, potential operating faults may occur at any time. There is no ‘grace’ period during which one can assume flawless operation providing optimal efficiency and performance. Severe faults are often quickly detected by the occupants before any warning light or alarm is noticed. However, most faults cause degradation in operating performance and efficiency over time. The system continues to run while wasting energy, potentially shortening equipment life, and potentially compromising occupant comfort and indoor air quality.

Fault Detection and Diagnostic functionality allows maintenance and other performance issues to be quickly identified and remedied. FDD functionality can be either active or passive. Active FDD functionality alerts building occupants or maintenance staff when a fault is detected. Passive FDD functionality records faults as they occur, which can then be accessed by HVAC maintenance staff doing repairs or regular maintenance. Increasing numbers of HVAC systems are available with integrated FDD functionality, but for systems without integrated FDD, there are several add-on FDD devices available on the market.

At present, there are no national FDD standards or guidelines. However, for rooftop units specifically, work on the test methods and establishing fault thresholds is underway in California to meet 2013 Title 24 rooftop unit mandatory economizer FDD requirements. Work on rooftop unit-related national standards for test methods is underway through ASHRAE Special Project Committee 207.

Non-Energy Benefits of FDD

Lower Operational Costs. By maintaining optimal performance of the system, energy cost savings will occur over the life of the system.

Lower Maintenance Costs. Early detection of maintenance issues can prevent them from progressing to the point of requiring more costly remedies or repairs.

Equipment Life. By maintaining operational peak efficiency, the life of the system and key components such as compressors, heat exchangers and pumps will be extended

Indoor Air Quality and Occupant Comfort. The ability to maintain proper outside airflow to meet air quality and thermal comfort requirements is directly tied to the operating condition of the system and a number of fault conditions that may arise

Property Management. Organizations that manage multiple properties will perceive a significant benefit of having FDD embedded and automated within the overall building energy management and maintenance system.

2.15 WATER HEATING

Photo credit: Dennis Schroeder / NREL

Criteria

- All service and domestic water heating equipment shall be Energy Star listed where available.
- All boilers used for service and domestic water heating shall meet the equipment standards of Table 2.9.4.
- All hot water storage tanks shall be provided with R-14 insulation and heat traps to prevent thermo-siphoning.
- All non-sealed-combustion water heaters shall include automatic flue control dampers.
- All commercial lavatory faucets shall have a flow rate no greater than 0.5 gallons per minute (gpm) at 80 psi.
- All commercial showerheads shall have a flow rate no greater than 2.0 gpm at 60 psi.
- All hot water supply piping shall meet the following requirements:
  - If the source of the hot water is a water heater, storage tank or boiler, the total length of pipe from source to fixture shall not exceed 32 ft.
  - If the hot water is from a recirculation loop or heat traced pipe, the total length of pipe from the recirculation loop to the fixture shall not exceed 12 ft.
  - If the source of the hot water is an instantaneous water heater, the length of the pipe from the water heater to the fixture shall not exceed 20 ft.
  - All hot water supply piping shall be thermally insulated to a minimum of R4 per inch of the nominal diameter of the pipe.
  - Hot water circulation loops shall include controls capable of turning off the pump automatically based on a time clock and when there is limited hot water demand.

Buildings with high service hot water loads (>75,000 Btu/h peak demand) or showing a service hot water load of 10% or more of total building energy load shall have one or more of the following, sized to provide at least 40% of peak hot water demand:

Purpose

Reduce energy consumption from hot water loads by improving equipment efficiency, reducing standby losses and heat losses from distribution, and offsetting loads in high hot water usage applications.

- Instantaneous fuel-fired water heating systems
- Waste water heat recovery system that has the capability to preheat water by not less than 10°F.
- Heat pump water heaters set up to recover waste heat from building exhaust ventilation.
- Solar water heating systems.

General

The best way to reduce hot water energy consumption is to reduce hot water demand. Specify efficient, low-flow fixtures and automatic shutoff controls to maximize savings. These strategies will also reduce overall water use on the cold water side. Also be sure to consider the efficiency of water circulation pumps and controls to minimize energy associated with water heating loads.

2.16 ACCEPTANCE TESTING

Core Performance Building: UMASS Memorial Health Center Worcester, MA. Photo credit: National Grid

Criteria

The construction process shall be conducted to deliver a building that meets or exceeds the requirements of the owner (as identified in the Operational Performance Requirements), the construction documents and the acceptance testing plan developed under Criteria 0.2. This process shall include the following:

- Where the following equipment is installed, acceptance testing shall be performed by the installing contractor(s), engineer of record or owner's agent in accordance with Appendix A, when applicable:
  - » Outdoor Air Systems
  - » Package Rooftop Units
  - » Air Distribution Systems
  - » Economizers
  - » Demand Control Ventilation Systems
  - » Variable Air Volume Systems with Variable Frequency Drives
  - » Heat Recovery Ventilation Systems
  - » Hydronic System Controls
  - » Chilled Water Systems
  - » Automatic Daylighting Controls
  - » Occupancy Controls
  - » Automatic Time-of-Day Controls
  - » Building Control Systems
  - » Fans and circulating pumps
- Change-orders shall be reviewed to assure they are consistent with the operational performance requirements and statement of goals and principles. Or-equal substitutions shall be shown to assure equal or better energy and indoor environmental performance when compared to the original certified design.

Purpose

Ensure that equipment is installed, configured and operating as intended by the construction documents through testing and verifying system performance.

- The installing contractor(s), engineer of record or owner's agent shall certify that the procedures listed in Appendix A were carried out and the equipment performed as specified; any deficiencies were reported for correction. For equipment not listed above, the design team shall provide acceptable test results, and the contractor shall certify that the tests were completed and the equipment performs as specified.
- An acceptance testing report shall be prepared documenting the results of the construction process including:
  - » Deficiencies found during testing required by this section that have not been corrected at the time of report preparation and the anticipated date of correction.
  - » Deferred tests that cannot be performed at the time of report preparation due to climatic conditions.
  - » Climatic conditions required for performance of the deferred tests and the anticipated date of each such test.
  - » Complete the Construction Certification prior to requesting a final occupancy permit (but not necessarily before temporary occupancy).

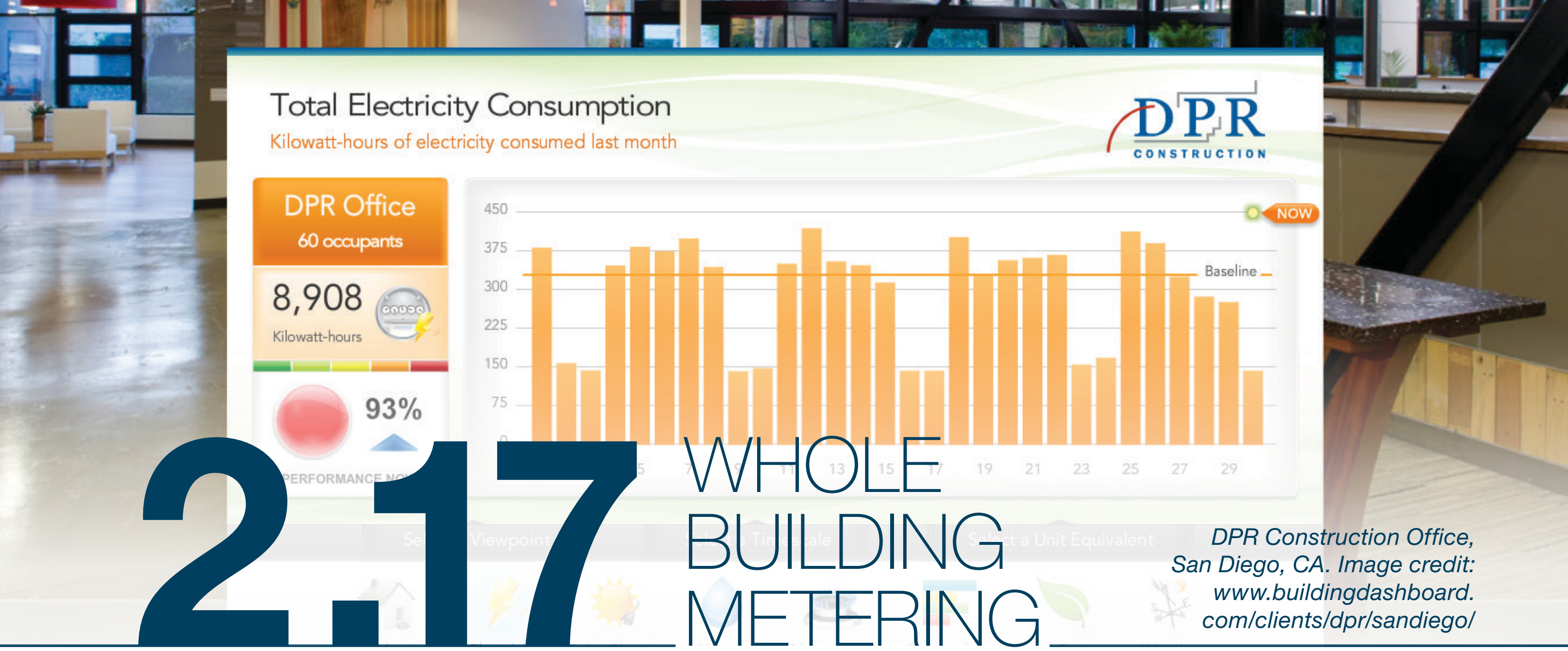
General

The acceptance testing reports demonstrate that the installing contractor, engineer of record or owner's agent:

- Reviewed the installation
- Performed acceptance tests and documents results
- Documented the operating and maintenance information and test

The building owner may decide to use a third-party commissioning agent to conduct this work.

In addition to Appendix A, ICC Guideline G4 from the International Code Council provides guidance for commissioning a wide range of systems, including non-energy systems.



2.17 WHOLE BUILDING METERING

DPR Construction Office, San Diego, CA. Image credit: www.buildingdashboard.com/clients/dpr/sandiego/

Criteria

Provide the building with energy measurement equipment, including:

- Measurement devices capable of measuring whole-building electric and gas usage in one-hour intervals (electricity measurement devices shall measure both voltage and amperage).
- A user interface capable of displaying energy usage for current day, previous day, same day of previous year, monthly data and cumulative energy usage for previous 12 months.
- Storage capacity of no less than 36 months of data for all energy types connected to all measurement devices and accessible from the user interface (Remote data storage solutions are acceptable alternatives to on-site data storage provided the data is continuously available to an on-site data display system).

Implement a protocol to collect data and analyze energy use quarterly. Include a quarterly summary report in the building operations manual.

General

Daily and annual energy consumption patterns reflect the true energy performance of a building. While the *Advanced Buildings: New Construction* program is designed to deliver a building with energy-efficient features, the overall energy performance of the facility depends heavily on the operation of the building's energy systems. To ensure the building is performing to design levels, this Criterion requires the gathering and review of actual energy consumption data to identify potential issues. Meaningful diagnostic information can be obtained by comparing energy use, outdoor temperature and building use over time. While a complete picture of building performance will not emerge until after a full year of seasonal data has been collected, review of the data from the commencement of operations can help identify and diagnose performance issues. The information gathered in this process can also be used to compare the building to others of similar type, use and climate.

Purpose

Assure the persistent delivery of energy and environmental benefits from the building by collecting and reviewing ongoing energy performance data.

Energy measurement systems generally include four basic parts: measurement devices, storage, user interface and a data acquisition system. Depending on manufacturer, these elements can be separate devices or consolidated in various combinations within devices. The data acquisition system (DAS) is the nexus of the system. The DAS collects and collates the signals from the measurement devices and translates them into usage data that can then be stored and displayed on the user interface.

Many energy measurement systems will also include a gateway that gives remote access to the system. These gateways often simply connect the system to the internet; sometimes they create a direct connection to a remote location. The gateway allows parts of the energy measurement and monitoring system to be located outside the building. For example, it might allow the user interface to connect from outside the building. Many systems are sold as part of a service package, with the data storage handled by a remote database connecting to the DAS through a gateway.

Many Building Automation Systems (BAS) and Energy Management Systems (EMS) can provide all of the functionality of a standalone energy measurement and monitoring system. However, due to the complexity of many of these systems and their interfaces, getting the necessary feedback can be challenging.

2.18 ENHANCED OPAQUE WALLS

Photo credit: Pat Corkery / NREL

Criteria

When this Enhanced Measure is selected, the thermal envelope of the building shall meet the following requirements:

- All wall, roof and floor assemblies that are part of the building thermal envelope shall meet the requirements shown in Table 2.18.1.
- U-Factors for assemblies shall be calculated on an area weighted average basis for the whole wall assembly and calculated in accordance with ASHRAE Standard 90.1 Appendix A.

Purpose

Further reduce energy losses associated with thermal conductance through the building envelope, including loss through below-grade floors and walls to the earth, by increasing the insulation values in wall and floor assemblies.

Table 2.18.1 Insulation Requirements for Above- and Below-Grade Walls, Slab Edge and Below-Grade Slabs[1]

	1	2	3	4	5	6	7	8
Roof, Flat	U-0.022	U-0.022	U-0.022	U-0.020	U-0.020	U-0.020	U-0.018	U-0.018
Roof, Sloped	U-0.017	U-0.017	U-0.017	U-0.017	U-0.017	U-0.015	U-0.015	U-0.015
Walls, Above Grade	U-0.034	U-0.034	U-0.034	U-0.034	U-0.034	U-0.027	U-0.027	U-0.021
Walls, Below Grade	C-0.087	C-0.087	C-0.087	C-0.087	C-0.074	C-0.074	C-0.066	C-0.066
Floors	U-0.042	U-0.026	U-0.026	U-0.026	U-0.026	U-0.026	U-0.026	U-0.026
Slab-on-Grade Floors (unheated)								
Underslab	R-10	R-10	R-10	R-10	R-10	R-10	R-10	R-10
Edge	F-0.53	F-0.53	F-0.53	F-0.43	F-0.43	F-0.43	F-0.36	F-0.36
Slab-on-Grade Floors (heated)								
Underslab	R-15	R-15	R-15	R-15	R-15	R-15	R-15	R-15
Edge	F-0.51	F-0.51	F-0.51	F-0.49	F-0.45	F-0.45	F-0.44	F-0.44

1. U-factors, C-Factors, and F-Factors are maximum values. R-Values for underslab insulation at Below-Grade Slab Floors are minimum values.

* C-Factor and F-Factor are not the same as U-Factor. C-Factor is calculated similarly to U-Factor but accounts for the assembly being in direct contact with the earth. F-Factor denotes the heat loss of the edge of a slab per linear foot of perimeter rather than square foot of area.

2.19 ENHANCED GLAZING SYSTEM PERFORMANCE

Photo credit: Dennis Schroeder / NREL

Purpose

Further reduce energy losses via the envelope through the installation of high-performance glazing systems and the use of a consistent a performance rating standard for these products.

Criteria

When this Enhanced Measure is selected, all of the fenestration in the building shall meet the following requirements:

- The weighted average of all fenestration assemblies shall meet the U-Factor and SHGC requirements shown in Table 2.19.1.
- All vertical fenestration assemblies shall have a VLT (Visible Light Transmission) rating of no less than 1.5 times the SHGC rating of the assembly.
- All fenestration assemblies shall be rated according to the requirements of the National Fenestration Rating Council (NFRC) with respect to the performance of the fenestration in the categories of U-Factor, Solar Heat Gain Coefficient and Visible Light Transmittance, and air leakage rate.

Table 2.19.1 Enhanced Glazing System Performance

	1	2	3	4	5	6	7	8
Vertical Glazing (0-30% window-to-wall ratio)	U-0.40	U-0.40	U-0.37	U-0.29	U-0.29	U-0.22	U-0.17	U-0.17
Vertical Glazing (30-40% window-to-wall ratio)	U-0.30	U-0.30	U-0.22	U-0.22	U-0.22	U-0.17	NA	NA
Vertical SHGC	0.25	0.25	0.25	0.35	0.35	0.35	0.40	0.40
Skylight	U-0.65	U-0.55	U-0.50	U-0.50	U-0.50	U-0.50	U-0.50	U-0.50
Skylight SHGC	0.35	0.35	0.35	0.40	0.40	0.40	NR	NR

Notes: In order to meet these requirements, window performance may be averaged for the entire building on a weighted average basis. For buildings with 30-40% WWR, the weighted average performance of all fenestration must meet the 30-40% U-value requirement.

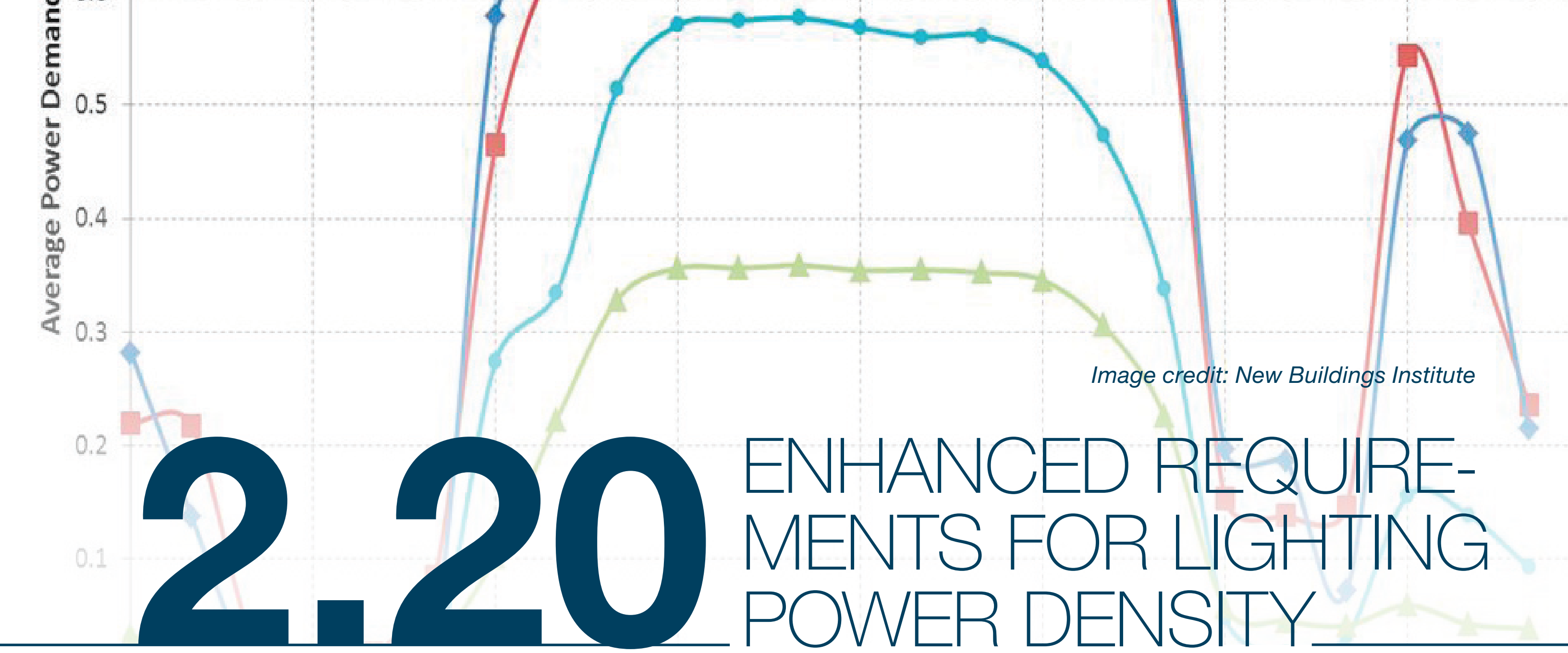


Image credit: New Buildings Institute

2.20 ENHANCED REQUIREMENTS FOR LIGHTING POWER DENSITY

Criteria

When this Enhanced Measure is selected, all lighting shall meet the following requirements:

- Installed lighting power density shall not exceed the values in Table 2.20.1. These LPD's shall be calculated based on luminaire efficiency, including lamps and ballasts.
- All LED lighting installed shall be listed on either the Energy Star Qualified Bulbs list or the DesignLights Consortium's Qualified Products List

Table 2.20.1 Enhanced Interior Lighting Power Requirements

Building Area Type[a]	LPD (W/ft²)
Automotive facility	0.70
Convention center	0.92
Courthouse	0.89
Dining: bar lounge/leisure	0.84
Dining: cafeteria/fast food	0.77
Dining: family	0.76
Dormitory	0.52
Exercise center	0.75
Fire station	0.60
Gymnasium	0.85
Healthcare clinic	0.74
Hospital	0.94
Library	1.00
Manufacturing facility	0.95
Hotel/Motel	0.75

Building Area Type[a]	LPD (W/ft²)
Motion picture theater	0.71
Multifamily	0.51
Museum	0.90
Office	0.67
Performing arts theater	1.18
Police station	0.82
Post office	0.74
Religious building	0.89
Retail	1.11
School/University	0.85
Sports arena	0.66
Town hall	0.78
Transportation	0.65
Warehouse[c]	0.51
Workshop	1.02

Purpose

To further reduce connected energy consumption attributable to lighting through the reduction of Lighting Power Density (LPD).

General

The LPD targets of this measure represent a 15% reduction beyond the base LPD requirement in Tier Two of the *Advanced Buildings New Construction Guide* (Section 2.7). These targets can be met with readily available lighting technologies and good lighting design. The design team should consult appropriate design expertise to implement these advanced strategies effectively.

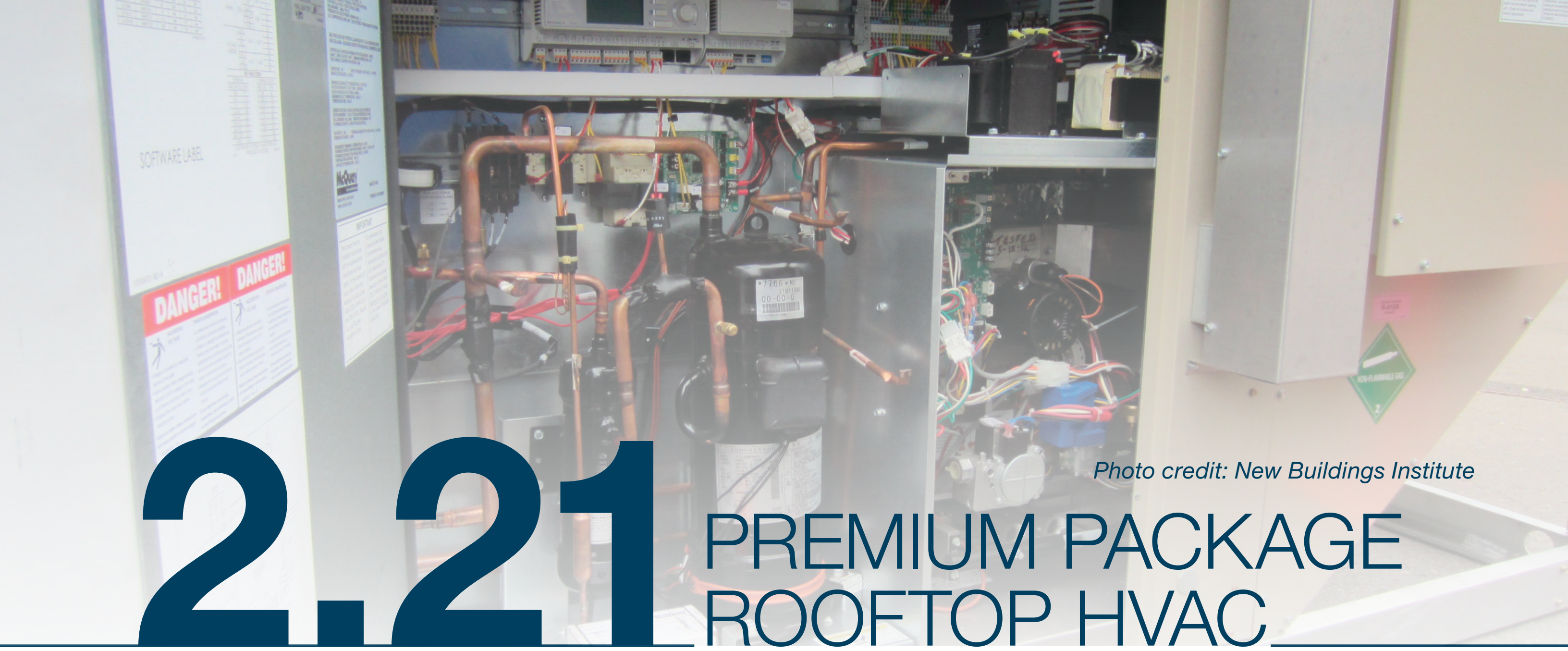


Photo credit: New Buildings Institute

2.21 PREMIUM PACKAGE ROOFTOP HVAC

Criteria

- Meet all space conditioning requirements with package rooftop HVAC units (RTUs) with a minimum IEER of 18.0.
- No electric resistance heat elements may be installed anywhere in the HVAC system.

Purpose

Reduce energy associated with HVAC loads through the use of best-in-class package rooftop HVAC equipment.

General

Package Rooftop HVAC systems (RTUs) see widespread use in commercial buildings, especially in small and simple buildings. These inexpensive systems are easy to specify and install, and are easily accommodated in a building design. However, the features that give RTUs these characteristics also create some inherent tendencies to inefficiency.

A roof is a convenient location, but it is also typically inhospitable. RTUs are exposed to the elements and increased temperature extremes, leading to a higher likelihood of equipment failure. Failures in those components of the controls that ensure efficient operation such as temperature probes and economizer controls can have a significant detrimental effect on efficiency even while the system continues to deliver space conditioning.

The US Department of Energy RTU Challenge

The DOE RTU Challenge was issued in 2011 as a way to catalyze the market to develop RTU's capable of delivering performance higher than anything on the market at the time. The core of the Challenge is an IEER (Integrated Energy Efficiency Ratio) requirement of 18, direct digital controls and operational fault detection. (See http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/cbea_rtu_spec_long.pdf for the full RTU Challenge specification.)

DOE did not specify how manufacturers would have to meet these requirements, preferring instead to allow them room to innovate. However, meeting this very high performance standard typically requires the incorporation of technologies such as multi-stage and variable fans and

Daikin McQuay's Rebel is an example of one of the first RTUs that met the specifications of DOE's RTU Challenge.

compressors and sophisticated controls that can tune operation to meet operating conditions. In May of 2012, DOE announced the availability of the first unit to meet the Challenge.

2.22 ENERGY RECOVERY VENTILATION

Photo credit: Steve Allwine / JBDG

Criteria

Where this Enhanced Measure is selected, an energy recovery ventilation system with the following characteristics shall be installed:

- The capability to provide a change in the enthalpy of the outdoor air supply of not less than 60% of the difference between the outdoor air and return air enthalpies at design conditions. The energy recovery system shall be controlled so that when the difference between the return air temperature and the outside air temperature is 10°F or less, or when the energy recover system is not in use, the air is redirected around the energy recovery device through the use of bypass dampers to reduce resistance to airflow.
- When combined with an economizer, operation of the economizer shall be controlled to take precedence over operation of the energy recovery system.
- The energy recovery system shall be designed to generate a pressure drop of no greater than 0.85 in. w.c. on the supply side and 0.65 in. w.c. on the exhaust side.

General

The capacity of the HVAC system with an energy recovery ventilation system should be calculated and sized to account for the reduced loads from the energy recovery system. Non-ventilation exhaust such as from equipment exhaust air streams, steam condensate and refrigeration condenser water should also be considered for energy recovery.

The design of energy recovery ventilation systems must account for several additional design and air quality concerns. It is important for energy recovery ventilation systems to avoid cross-contamination of the intake and exhaust airstreams. This is one reason the pressure drop on the supply and exhaust sides must be limited. The design should also account for frost protection in cold climates. Energy Recovery Ventilation Systems operate most effectively when the outdoor and exhaust airflow are close to balanced and when building pressurization is taken into account, especially the impact of any

Purpose

Reduce energy use associated with ventilation requirements by recapturing waste energy in exhaust air flow.

exhaust air stream that cannot be ducted through the energy recovery device.

Some mechanical system components include heat recovery options at a lower cost than dedicated stand-alone systems. Energy recovery options should be considered opportunistically when available as equipment options in conjunction with other systems.

Application Guide

Energy Codes often require Energy Recovery Ventilation systems in certain circumstances, but do not typically prescribe all of the characteristics needed for a successful system. Whenever an Energy Recovery Ventilation System is required by code, it should have all the technical characteristics listed above.

An energy recovery ventilation system is most effective in the following circumstances:

- Where the design supply fan airflow rate exceeds the values in Table 2.22.1.
- The building will be ventilated for extended hours, increasing the number of hours with a higher temperature differential between exterior and interior conditions.
- Buildings in cold climates.
- Buildings or systems with high outside air ventilation rates.
- Buildings with high occupant densities which drive increased ventilation rates.

Table 2.22.1 Energy Recovery Requirement

	Percent Outdoor Air at Full Design Airflow Rate	
	> 30% and < 50%	> 50%
Climate Zone	**Design Supply Fan Airflow Rate (cfm)**	
1A - 6A	1000	1000
7 and 8	500	0
All Other	2000	1000

An energy recovery ventilation system should generally not be selected in the following circumstances:

- Whenever energy recovery ventilation systems are prohibited by code.
- Systems serving spaces that are heated to less than 60°F (15.5°C) and are not cooled.
- Ventilation systems that serve spaces with chemical or biological contaminants.
- Where more than 80% of the outdoor heating energy is provided from site-recovered or site solar energy.

2.23 DEMAND CONTROL VENTILATION

Core Performance Building: Tremont Yard Building, Lowell, MA. Photo credit: National Grid

Criteria

When this Enhanced Measure is selected, a Demand Control Ventilation system with the following characteristics shall be installed:

- Vary outside air (OA) flow rates in response to building occupancy, reducing OA airflow when the building is unoccupied and increasing OA airflow in conditions of high occupant density, using one or more of the following control methods:
- Occupancy sensors that identify unoccupied conditions and reduce outside air flow accordingly.
- CO_2 sensors that measure CO_2 levels in a zone relative to the levels in the OA and increase OA flow rates in response to increased interior CO_2 levels.

When using the CO_2 sensor control method to vary the amount of OA needed in a zone, it shall meet the following requirements:

- The controller shall be able to operate the OA, return air and relief air damper to meet specified ventilation requirements.
- A minimum of one CO_2 sensor per zone for systems with greater than 500 cfm of OA.
- Regularly calibrate the CO_2 sensor as recommended by the manufacturer or annually, whichever is more frequent.

Economizer control shall be configured so that when cooling by economizer is called for, outside air damper control responds to economizer settings as a priority over demand control.

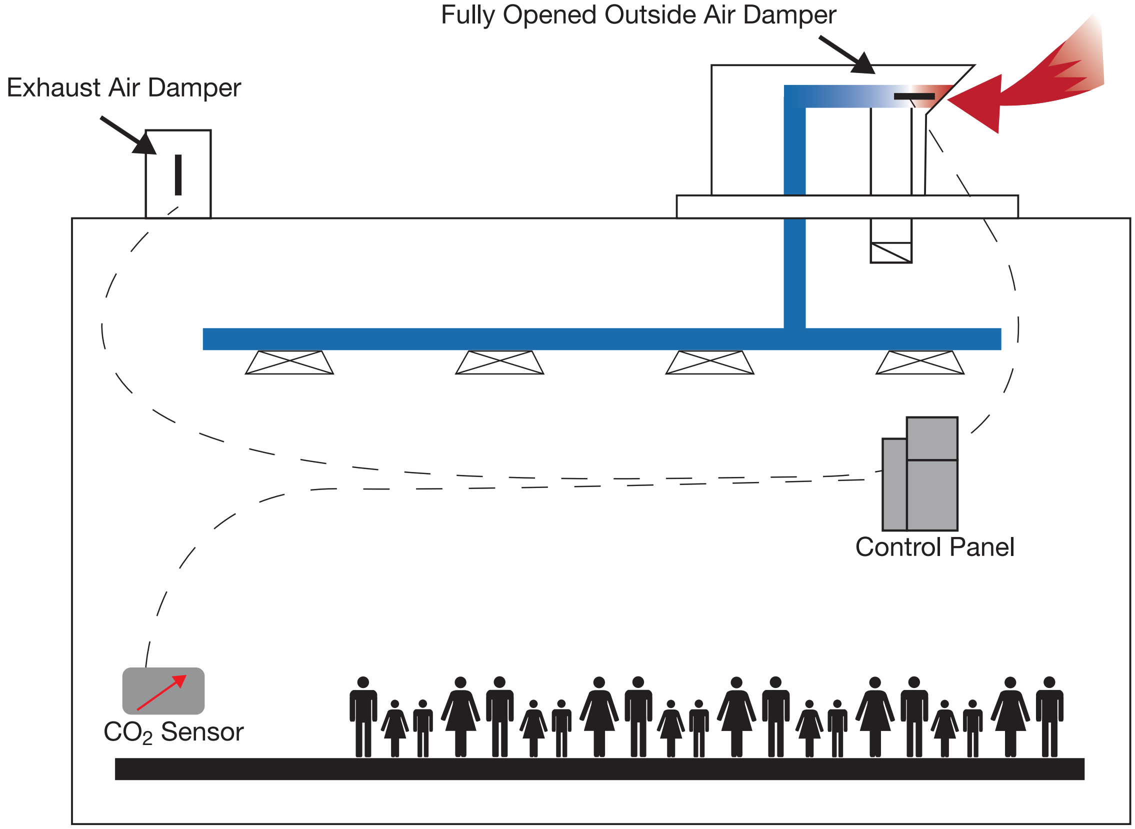
General

Reducing unneeded ventilation air flow reduces building energy use, but a minimum level of OA flow must be maintained when the building is occupied. Increasing OA flow in response to increased occupancy improves occupant health and productivity, but increases energy use for conditioning outside air.

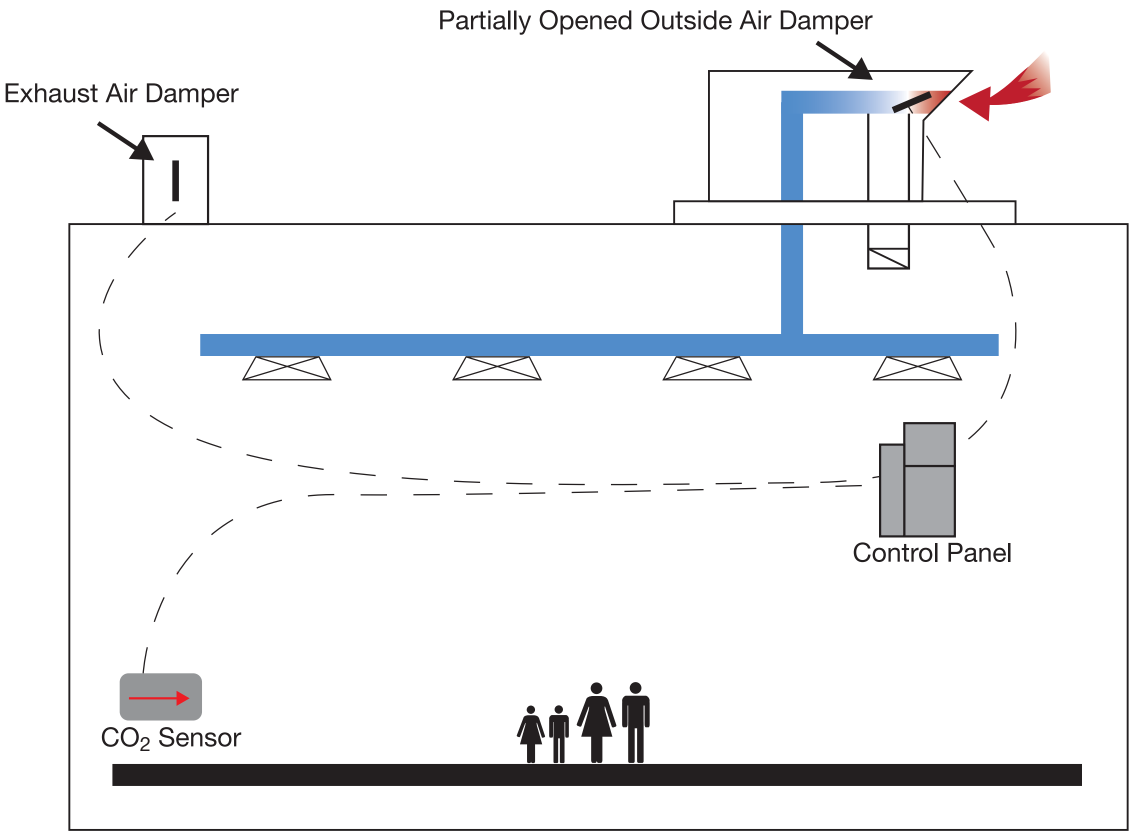
Purpose

Reduce the energy use associated with heating and cooling outside air in excess of ventilation flow rates required by building occupancy, while maintaining high indoor air quality for the building occupants.

DCV System at Full Occupancy



DCV System at Partial Occupancy



A well-implemented DCV system will respond to both low and high occupancy conditions to maximize energy and health benefits.

CO_2 controls are particularly useful in areas where occupancy is highly variable and irregular, such as meeting rooms, studios, theaters, educational facilities, etc. CO_2 control should allow for both a reduction of outside air flow when occupancy is low, and an increase in outside air flow beyond minimum setpoints when occupancy is high.

Minimum outside airflow rates under occupied conditions are described in ASHRAE Standard 62.1. This standard recognizes variation of ventilation rates based on indoor air quality monitoring as meeting the intent of that standard to maintain indoor air quality and minimum ventilation for occupants.

When possible, OA flow should be reduced when the building is unoccupied, and increased in conditions of high occupant density.

Application Guide

Demand Control Ventilation requires diversity in the occupancy schedules to deliver energy savings, so may not be an effective choice for spaces with predictable occupancy schedules. Additionally, Demand Control Ventilation is generally not appropriate in the following cases:

- Systems where the total supply air flow is less than 1000 cfm.
- Systems with exhaust air energy recovery and an exhaust air flow rate of less than 1000 cfm.
- In space types with specific contaminants (such as retail applications with VOC from retail stock), where occupant density may not be an appropriate basis for control of ventilation rate.

Tier Three

The Performance Pathways section of the *Advanced Buildings New Construction Guide* is designed to provide strategies for additional savings to projects which might be able to undertake additional efforts to increase energy efficiency levels. These pathways represent broader design strategies that require an integrated and informed design approach to more advanced efficiency strategies than those represented by individual savings measures. They may also require deeper analysis or expertise from the design team and may not be applicable to all project types or conditions. However, these design pathways often represent an opportunity for significant additional savings beyond the basic requirements of the *Advanced Buildings* program. For this reason they are considered as Tier Three of the program.

Achieving Tier Three in the *Advanced Buildings New Construction Guide* requires that projects follow the requirements of Section Zero, Section Two, and one or more Performance Pathway strategies from Section Three.

Bosarge Family Education Center at Coastal Maine Botanical Gardens, Boothbay, ME. Photo credit: Robert Benson Photography

3.0 INTRODUCTION

Tier Three – Performance Pathways

The Performance Pathways in Tier Three of the *Advanced Buildings New Construction Guide* are designed to provide strategies for further savings to projects that choose to undertake additional efforts to increase energy efficiency levels. These pathways represent broader design strategies that require a more integrated and informed design approach than those represented by individual savings measures. They may also require deeper analysis or expertise from the design team and may not be applicable to all project types or conditions. However, these design pathways often represent an opportunity for significant additional savings beyond the basic requirements of the *Advanced Buildings New Construction Guide.* For this reason they are considered as Tier Three of the Guide.

Because not all Performance Pathway strategies are applicable or effective for all project types, each Pathway has an Application Key to provide guidance about when specific strategies should be considered for additional savings opportunities and when these strategies may not be applicable. Design teams should carefully consider specific project conditions when choosing to implement the strategies described in this section.

Advanced Buildings: New Construction **Tier Three requires the implementation of all of the Criteria in the Design Strategies Section (Criteria 0.1-0.5), the Tier Two base measures (Criteria 2.0-2.17) and one or more Performance Pathway strategies from Tier Three of the Guide.**

3.1 PATHWAY PREREQUISITES

Core Performance Building: Gibney Family Vision Center, So. Burlington, VT. Photo credit: Efficiency Vermont

Purpose

Define the base level of performance and requirements for projects pursuing one or more of the Performance Pathways in Tier Three of *Advanced Buildings New Construction Guide.*

Criteria

1. All buildings shall implement all of the Criteria in the Design Strategies Section (Criteria 0.1 - 0.5) of this Guide.
2. All buildings shall meet or exceed the requirements of *Advanced Buildings: New Construction* Tier Two.

3.2 ADVANCED ENVELOPE

Photo credit: Ed Hancock / NREL

Criteria

Design and construct a building envelope system that meets the following requirements:

- Infiltration performance verified with a whole-building blower door test in accordance with Criterion 2.2: Air Barrier Verification
- Energy Recovery Ventilation in accordance with Criterion 2.18
- A window-to-wall Ratio (WWR) no greater than 15%
  Exception: Buildings that meet the requirements of Criterion 3.3: Advanced Daylighting and have a WWR no greater than 20%
- Envelope assemblies that meet the requirements of Table 3.2.1

Purpose

Reduce building energy use through the design and construction of an extremely well-insulated building envelope system that significantly reduces energy losses associated with thermal conduction.

Table 3.2.1 Envelope Assembly Requirements

	All Climate Zones
Roof	U-0.012
Walls, Above Grade	U-0.018
Walls, Below Grade	C-0.055
Floors	U-0.018
Slab-on-Grade Floors	
- Underslab	R-15
- Edge	F-0.32
Vertical Glazing	U-0.14
Vertical SHGC	0.25
VT	0.35
Skylight	U-0.25
Skylight SHGC	0.25

General

Because of the stringent requirements of the construction assembly, projects pursuing this measure will need to pay special attention to ventilation and humidity control within the building. Additionally, the restricted WWR can increase the challenge of meeting the daylighting requirements in Criteria 2.5: Daylighting. Design teams will also need to pay special attention to maximizing the daylighting potential of the fenestration and skylights and to the arrangement of interior spaces to maximize access to daylight.

Application Guide

A super-insulated building shell is appropriate for all climates and most building types. It is especially effective in climates that are more extreme – either hot or cold – and building types that require tighter control of the building environment. Combining this Pathway with the Advanced Daylighting Pathway is very challenging due to the limitations on WWR. However, through making thorough use of toplighting and choosing building proportions, orientation and internal configurations that maximize the sidelighting potential it is possible to pursue both simultaneously.

3.3 ADVANCED DAYLIGHTING

Terry Thomas Building, Seattle, WA. Photo credit: Daylighting Pattern Guide

Criteria

The building shall have no less than 85% of its conditioned floor area within a daylit zone meeting the following requirements:

- The daylit zone area shall be determined using the area definitions of the current versions of one of the following: International Energy Conservation Code, ASHRAE Standard 90.1, International Green Construction Code or Massachusetts Stretch Code
- Where the daylit zone calculation identifies primary and secondary daylit zones, the primary and secondary zones shall be controlled separately.
- The surface finishes in the daylit zone shall have a minimum reflectance of 90% for ceilings, 80% for walls and 50% for floors
- All lighting power in the daylit zone shall be controlled by automatic daylighting controls with the following capabilities:
    - » Continuous dimming from 100% power down to no more than 10% before turning off
    - » A 15-minute delay or other means to avoid cycling due to rapidly changing sky conditions
- The lighting in each daylit zone shall be separately controlled unless it is an adjacent zone associated with one building façade.
- All lighting controls in the daylit zone shall be installed and configured in accordance with manufacturer's instructions and commissioned in accordance with the Acceptance Testing Protocol in Appendix A.

General

This Criterion builds on the information provided in Criteria 2.5: Daylighting.

Most building configurations can achieve the base daylighting requirements of this guide without impacting the fundamental design and configuration of the building. However, achieving the pervasive daylighting required by this measure requires a design that is highly compatible with daylighting strategies.

Purpose

Significantly reduce energy consumption attributable to lighting loads by incorporating pervasive daylighting and automatic daylighting controls into the fundamental design.

For the majority of building designs, this will require that daylighting be one of the driving design elements. In order to achieve the required 85% daylighting, buildings will have to be designed to place the vast majority of conditioned space near exterior windows or under the roof in order to provide access to sufficient daylight.


Terry Thomas Building

Application

For high bay applications, code already requires a certain amount of daylighting be incorporated. For those buildings required to include daylighting by code – such as high-bay retail and warehouses – this measure may not be used as a Performance Pathway.

3.4 ADVANCED OFFICE LIGHTING DESIGN

Glumac Office Interior, Irvine, CA. Photo credit: Glumac

Criteria

The lighting and spatial design of 75% of building floor area must meet the following criteria:

- Be an office use type.
- Ambient LPD < .45 W/sf.
- Task LPD <.15 W/sf.
- Partitions no higher than 42".
- If partitions are not permanent, luminaires must be on 12' whip to allow lighting to be reconfigured if workspaces are reconfigured.
- A ceiling surface reflectance greater than 80%, a wall surface reflectance greater than 70%, a floor surface reflectance greater than 20%, a desktop surface reflectance greater than 60%, and other wall and partition reflectances greater than 70%.
- Hard-wired vacancy controls (manual on/off, auto off, no auto on) for task lighting. To increase savings, occupancy sensors (auto on) with vacancy controls (auto off) can also be used for the ambient lighting.
- Control zones no larger than individual work spaces or 150 sf, whichever is smaller, for task lighting. For ambient lighting, control zones should include no more than approximately 4-6 workstations, or 1,000 sf.

Purpose

Significantly reduce the energy consumption of office lighting through the implementation of a very low-energy lighting design and specification.

General

There are two essential elements of a very efficient lighting system: efficient equipment and efficient design. The LPD approach to energy efficiency focuses primarily on equipment efficiency. Efficient design takes into account factors such as configuration of the space, surface reflectance, controls, zones and the placement of light sources. This measure focuses on both efficient equipment and efficient design. The LPD requirements cannot be met without selecting more efficient lighting equipment. However, these low levels of LPD also require a space that makes the most of the light being delivered to the space: high-reflectance surfaces and reduced obstructions. The measure

Glumac Interior

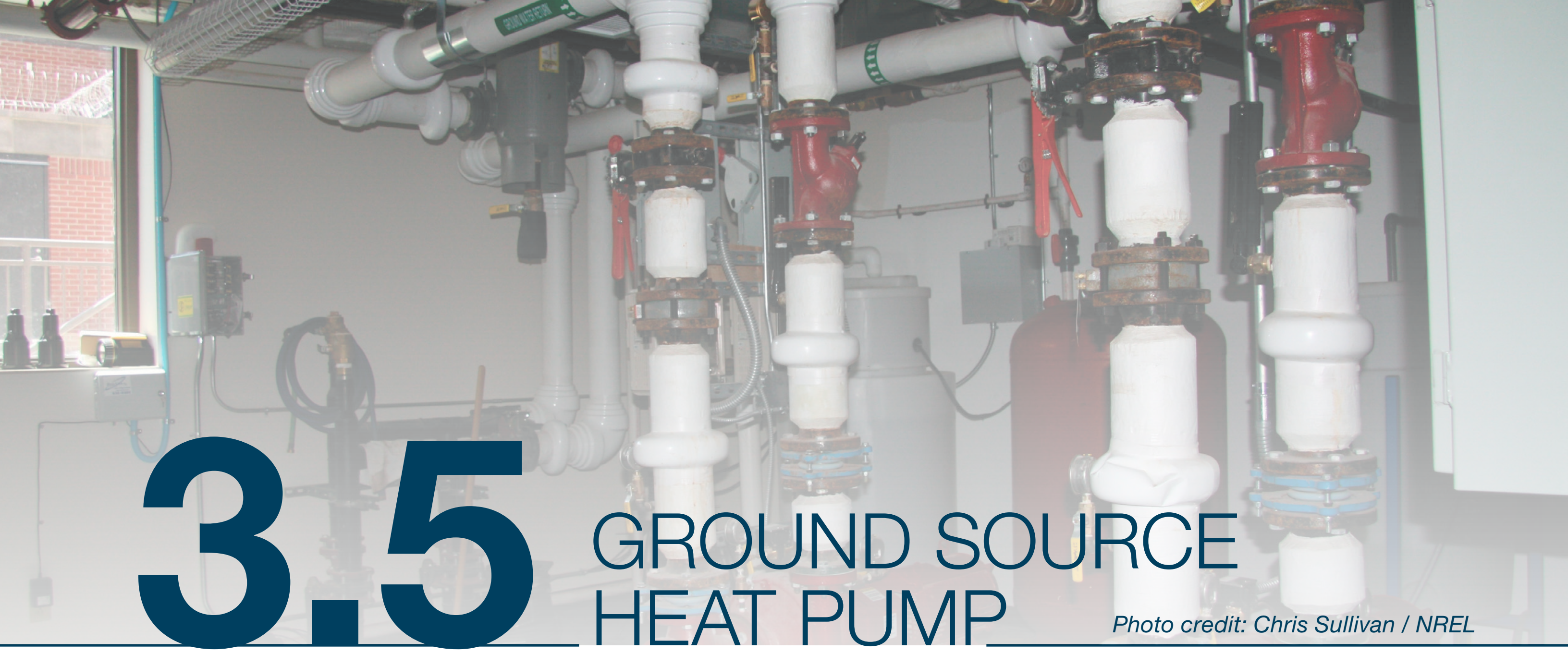
goes beyond just efficiency; other requirements affect the design choices of the space and the control strategy for the equipment.

A core element of this measure is luminaire placement. All-purpose lighting is simple and straightforward but has inherent inefficiencies. Different activities require different levels of lighting. For example, space navigation does not require the same amount of light as reading tasks. Detail work like jewelry repair does not require the same amount of light as computer use. Yet all-purpose lighting must provide sufficient lighting for the highest intensity use. All-purpose lighting essentially over-illuminates the parts of the space and the times of use in the space that do not require such high levels. In an office environment, an aggressive task-ambient approach allows the lighting to be tailored to the task and avoids the energy wasted through over-illuminating some parts of the space.

Another core element of this measure is luminaire control and zoning. The modern office environment does not strictly adhere to 9-to-5 notions of the work schedule. Travel, telecommuting, collaborative meetings, flexible schedules, etc. all lead to workspaces that may be unpredictably and only partially occupied during a typical work week. Significant savings can be achieved by providing lower levels of ambient light for basic tasks like space navigation and safety while providing much greater control of the higher light levels required by office tasks.

Application

This measure applies to offices only and is not intended for other space types.



3.5 GROUND SOURCE HEAT PUMP

Photo credit: Chris Sullivan / NREL

Requirements

Meet primary heating and cooling loads with an installed ground source heat pump system designed to meet the following requirements:

- The ground heat exchange portion of any installed Ground Source Heat Pump system shall be a closed-loop system in which all the fluid is recirculated and there is no possibility of local ground water contamination.
- The ground loop heat exchanger shall be sufficiently sized to handle, at a minimum, the full heating and cooling load of the building or zone. Sizing calculations shall take into account future ground temperature shifts due to unbalanced heating and cooling energy extraction/rejection.
- All pump systems serving the GSHP system shall cycle only on a call for heating or cooling; no continuous pumping systems are allowed. Systems with central pumping systems larger than 1 horsepower shall include variable speed pumping.
- The ground heat exchange portion of the piping shall be designed to attain a pressure drop no greater than 25 feet of static head under typical operation.
- Ground loop source side distribution system loss shall be no more than 40 feet of static head under typical operation.
- If the building includes a load-side water system, total load-side distribution system loss shall be no more than 40 feet of static head under typical operation.
- The fluid in the ground heat exchange portion of the piping shall be supplied with appropriate levels of antifreeze for the climate and design. Design to a minimum of no less than 30°F fluid temperature (water temperature entering the ground loop).

Purpose

Reduce the energy needed to provide heating and cooling by selecting equipment that utilizes the high thermal capacitance of the earth.

General

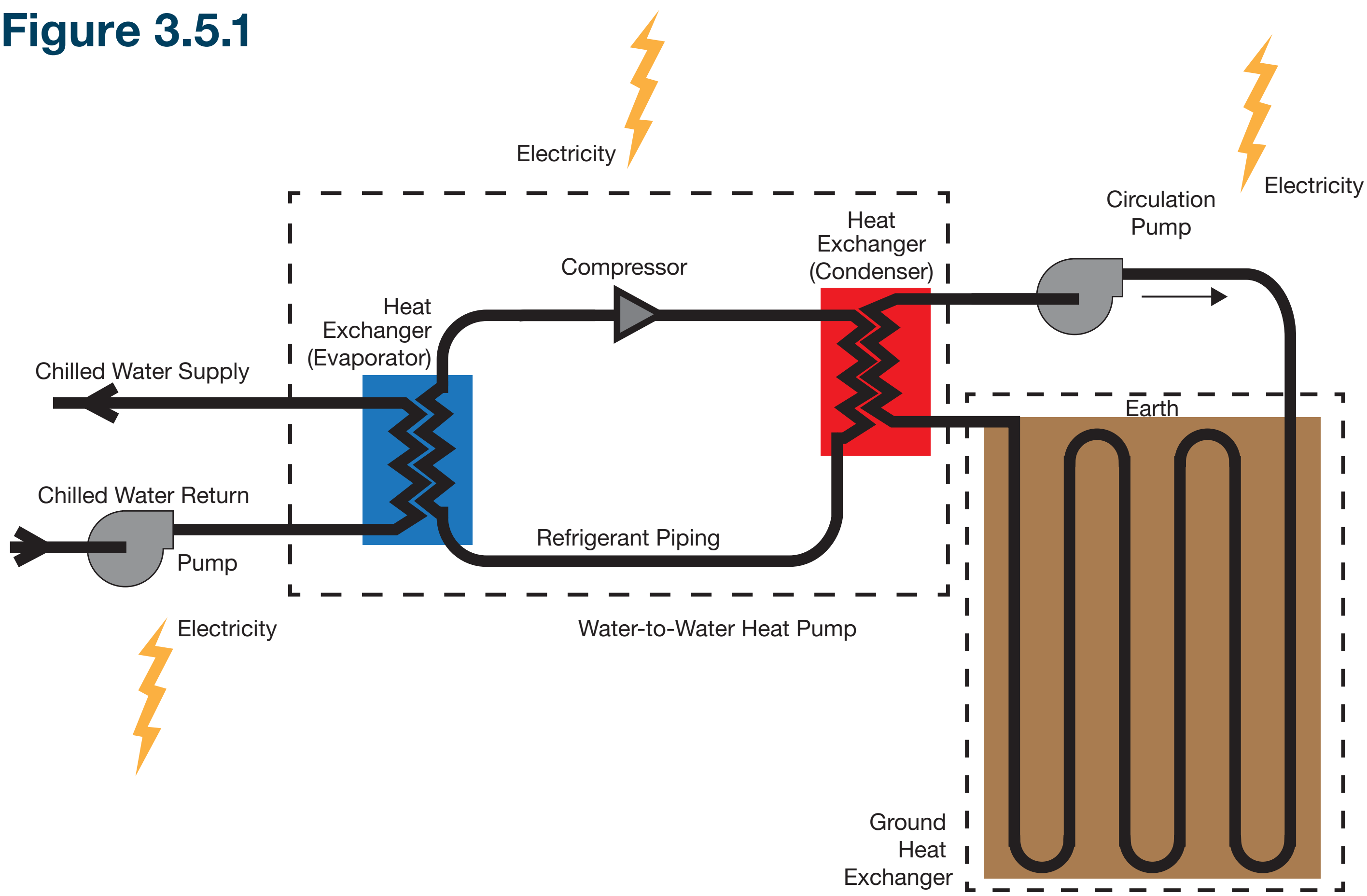
The following design principles should be used to guide the design and specification of a GSHP system:

- If using hydronic systems for heating and cooling distribution, use outdoor temperature reset to control supply water temperatures from heat pumps for the smallest delta T and highest efficiencies possible.
- When designing an effective GSHP system it is critical to design for pumping efficiency as this can lead to systems that are simpler to install, balance and purge, which in turn can lead to significantly reduced upfront costs.
- Minimize pump sizes and focus on part-load performance. Choose variable speed equipment wherever applicable.
- Consider designing so that the GHX pumps can be shut off and the bore field bypassed when fluid temperature is in a prescribed deadband (55–80°F) or when temperature is moderate.
- In a well-designed system, pump power should not exceed 10 hp/100 tons of equipment.
- For buildings where test wells are not completed prior to construction, vertical wells can be assumed to be a minimum of 200 feet per ton.
- High conductivity grout can improve performance. Generally grout conductivity should be a minimum of 0.8 Btu/hr-ft-°F.
- It is preferable for ventilation requirements to be met by a Dedicated Outdoor Air System (DOAS) (see Criteria 3.6 or 3.7 for DOAS requirements) provided with an Energy Recovery Ventilation system meeting the requirements of Criterion 2.22.

Application Guide

Ground Source Heat Pump systems are an especially appropriate selection for electric-based heating in cold climates.

Figure 3.5.1



Mercy Corps Headquarters, Portland, OR. Photo credit: THA Architecture

3.6 VARIABLE CAPACITY HEAT PUMP SYSTEMS (VARIABLE REFRIGERANT FLOW, VARIABLE REFRIGERANT VOLUME)

Criteria

All VCHP systems shall include the following design features:

- The compressor shall be variable speed with capacity control that varies the amount of refrigerant flowing in the system based on the load in the zones.
- All indoor units shall include an electronic expansion valve that continually controls the flow rate of refrigerant.
- Maximum refrigerant piping lengths shall be limited to manufacturer specifications.
- In climates with low-temperature ambient conditions, frost protection shall be provided to defrost the outdoor heat exchanger when in heating mode.
- Utilize ductless fan coils whenever possible. If ducted units are used, only low/medium (no more than ¾" SP dirty filter) static models are allowed. Ducted units shall account for less than 25% of the total installed airflow.
- No electric resistance heating is allowed in the DOAS system or as back-up for the heat pump unless outside design temperatures drop below 20°F. All electric heating shall be locked out until temperatures drop below 20°F.
- Controls supplied by the VCHP manufacturer shall be utilized for all control operations. Third-party controls such as a DDC system shall be used only for adjusting setpoints and schedules or for relaying alarms.
- Only one temperature control point (or a single average) shall be used per zone. No heating and cooling shall be allowed simultaneously in the same zone. A zone is defined as a completely enclosed room.
- Indoor-unit fans shall be set up to cycle on a call for heating or cooling only. Continuous fan operation shall not be used.
- All ventilation requirements shall be met by a Dedicated Outdoor Air System (DOAS) meeting the following requirements:
  - » Sized in accordance with ASHRAE Standard 62.1.
  - » Electric resistance heating elements shall not be utilized in any part of the system.

Purpose

Efficiently respond to temperature fluctuations in multiple zones by providing heating and cooling via a variable capacity heat pump system (VCHP).

» No outside air should be ducted directly to the indoor VCHP cassettes.

» Dehumidified air shall not be heated before delivery to a conditioned space when the radiant system is in cooling mode. If air tempering is required, it shall be accomplished passively or through air mixing.

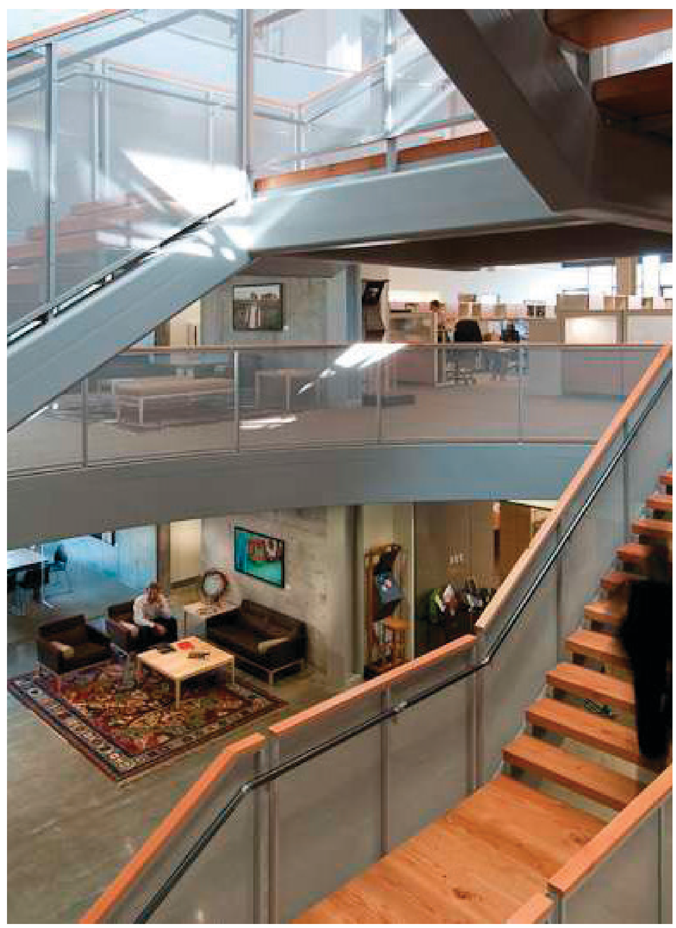
» An Energy Recovery Ventilation system meeting the requirements of Criteria 2.22.

General

Using refrigerant instead of air as the basic medium for transporting heating and cooling energy around the building is inherently more efficient as a distribution strategy. By utilizing variable speed compressors with multiple-capacity control VCHP systems can achieve high efficiencies by varying the amount of refrigerant provided to each zone depending on fluctuating zone loads. There are a variety of VCHP configurations and options that should be considered depending on the project in which it is applied. The small piping size of the refrigerant loop makes it an attractive option for existing buildings looking for a low-impact way to meet heating and cooling requirements. VCHP is especially well suited to projects in more temperate climates and projects with a high level of diversity in the conditioning needs of the different zones in the building.

The following are general recommendations to consider when incorporating VCHP systems:

- 2-Pipe systems can be substantially less expensive - both in terms of material and labor cost - than 3-pipe systems. However, 2-pipe systems can only operate in either heating or cooling mode, while 3-pipe systems are capable of having some zones in heating mode and others in cooling. Therefore, 3-pipe systems offer an opportunity for greater energy savings in buildings with zones that experience opposite conditioning needs.
- VCHP systems are also capable of producing hot water. Consider including this feature in buildings with high hot water loads and heat rejections needs. Utilizing the heat rejected by the space cooling function of the system for water heating results in higher combined energy savings.
- Some VCHP systems with heat recovery are exempt from having to include economizer operation.
- There are limitations on the indoor coil maximum and minimum entering dry and wet bulb temperatures which makes it not applicable for 100% OA applications in cold or hot and humid climates.
- Excessive use of supplemental heating shall be accounted for and avoided through proper sequencing of operation and commissioning.
- For safe design, construction, installation and operation of the refrigerant system reference ANSI/ASHRAE Standards 15 and 34 (2010).
- During periods of extreme cold VCHP system heating capacity drops significantly, and defrost cycles limit heating output further. Consider control strategies that limit temperature setback or start the system earlier during extreme cold periods, or design the system in stages so that not all stages are operating in defrost at the same time. Turn down the ventilation system during warm-up to reduce load on the heat pump.



The Mercy Corp retrofit and addition in Portland OR benefits from a VRF installation. Photo credit: THA Architecture

3.7 RADIANT HEATING/COOLING

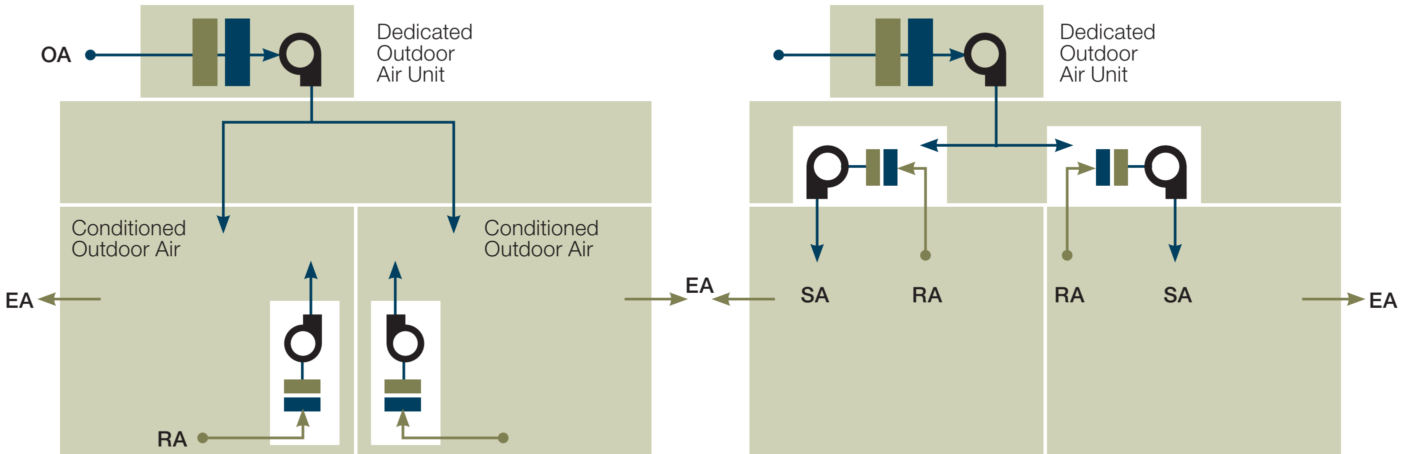
Photo credit: Dennis Schroeder / NREL

Criteria

- Primary space conditioning shall be provided by radiant equipment. No more than 20% of the floor area may incorporate non-radiant, fan-based distribution. In the radiant areas, fans may only be used to distribute ventilation air (for "Active Chilled Beams" or similar systems that incorporate fan distribution systems directly into the design of the radiant system).
- All pipes conveying heated or cooled fluid to the radiant equipment shall be insulated to a thickness no less than the nominal diameter of the pipe.
- All pumps over 1 HP in the distribution system shall have variable speed drives (VSDs). Smaller pumps shall use electronically commutated motors (ECMs).
- Distribution pumps shall be controlled to eliminate continuous pumping. Pumps shall only cycle when there is a call for heating or cooling.
- Each separate zone shall have a method for zone control or balancing.
- Envelopes shall be designed to limit peak design heating loads to less than 15 Btu/SF, or max water temperatures below 96°F in heating.
- Envelopes shall be designed to limit peak design cooling loads to less than 12 Btu/SF, and minimum design surface temperatures shall not be below the space dew point.
- All ventilation requirements shall be met by a Dedicated Outdoor Air System (DOAS) meeting the following requirements:
  - » Sized in accordance with ASHRAE Standard 62.1. The DOAS shall not be oversized for dehumidification, space conditioning or to meet a higher air flow rate demand in an actively induced chilled beam system.
  - » Electric resistance heating elements shall not be utilized in any part of the system
  - » Dehumidified air shall not be heated before delivery to a conditioned space when the radiant system is in cooling mode. If air tempering is required, it must be accomplished passively or through air mixing.
  - » An Energy Recovery Ventilation system meeting the requirements of Criterion 2.22.

Purpose

Reduce the energy associated with space conditioning through decoupling ventilation and space conditioning, using more efficient liquid-based distribution systems and making use of radiant heating/cooling's comfort profile



Fan coil units
Radiant panels
Water source heat pumps
Convectors

Single Zone Configurations

Fan coil units
Zone Air Handlers
Water source heat pumps
Parallel fan boxes

General

Radiant systems possess a handful of characteristics that can provide energy savings compared to traditional air-based HVAC systems if designed carefully. Air is actually a very poor medium for delivering and removing heat from a space. Air has a very low ability to carry heat (low specific heat, and low density) compared to water, so it requires a larger mass of air to move heat and cool around a building than it does for a hydronic system. Generally, water has a specific heat 4 times that of air and a density of 100 times that of air. The required fan energy therefore far exceeds the equivalent pump energy needed for liquid distribution systems to move the same amount of energy. Pumping energy can be further reduced by careful design of the distribution system. Using larger piping, shorter distances and smooth transitions (such as wye and sweep radius connections) reduces pressure drops in the system which reduces the pumping energy required.

Radiant heating and cooling allows fan energy to be limited to only that required for ventilation. Additionally, due to the realities of the way humans perceive thermal comfort, space conditioning through radiant bodies in the space can allow lower air temperatures in heating mode and higher air temperatures in cooling mode while still retaining thermal comfort. This reliance on Mean Radiant temperature rather than air temperature to meet conditioning needs makes radiant systems particularly suited to applications that require or experience higher levels of air changes.

Humidity can be a significant concern for radiant cooling applications. Air-based cooling systems dehumidify the air as a function of their normal operation. Radiant cooling systems require separate humidity control in some climates or else the cooling surfaces can cause condensation that can lead to problems ranging from mold and mildew growth to dripping water and slip hazards. In climates that require humidity control, proper design of the DOAS system so that it adequately controls humidity is essential. When combined with natural ventilation in a humid climate, this also creates the need for a system lock-out for when the natural ventilation system is active and bringing humid air into the building.

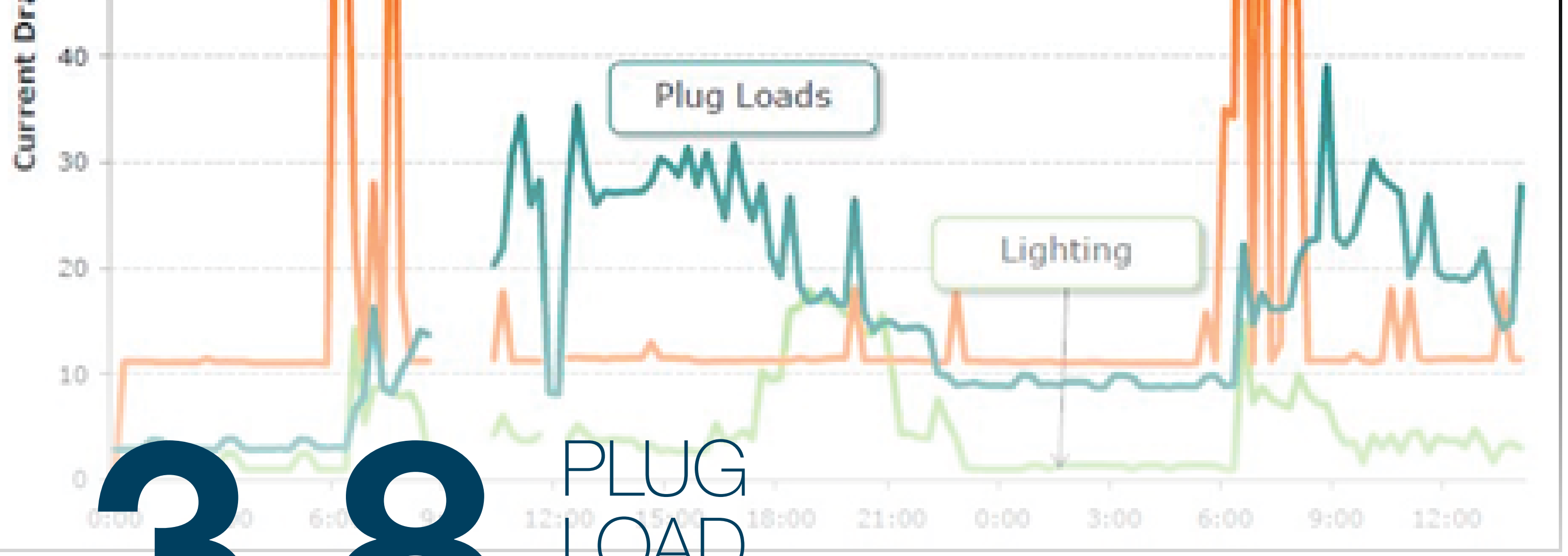
There are design choices that can decrease the efficiency of radiant systems. Circulation pumps shouldn't be run constantly, but should be equipped with controls that shut them down when circulation is not needed. Some chilled beams rely on active induction and require airflow in order to meet the cooling needs. Depending on the design parameters of the application, this can lead to an oversizing of the DOAS in order to provide sufficient airflow, but this adds extra fan-energy consumption and is prohibited in this Criterion.

Although radiant systems have some characteristics that can make them inherently more efficient than other HVAC systems, they also have characteristics that can make them a poor match for some uses. Radiant systems are not as responsive as air-based systems, so they require longer warm-up and cool-down periods than air-based systems. This can make them a poor match for spaces with unpredictable schedules or load characteristics where responsiveness is required and/or desired.

Application Guide

If a radiant system is used for only heating, any mechanical cooling must be provided by a system meeting the requirements of Criteria 3.5 or 3.6 otherwise this cannot be considered a Performance Pathway.

If the climate demands more dehumidification than can be provided by a system sized for ventilation only (in accordance with ASHRAE Standard 62.1), radiant space conditioning is not an appropriate choice.



3.8 PLUG LOAD CONTROLS

Purpose

Reduce energy use associated with plug loads through the automatic control of a portion of the circuits that serve plug loads and the selection of more efficient equipment.

Criteria

A minimum of 50% of circuits serving convenience receptacles shall meet the following requirements:

- Be connected to a time clock or occupancy sensing control that de-powers the outlets during unoccupied hours.
- Receptacles served by switched circuits shall be clearly labeled or color-coded.
- Where individual duplex receptacles are connected to both controlled and uncontrolled circuits, the top outlet shall be connected to the controlled circuit.
- At least one controlled receptacle shall be installed within 6 feet of each uncontrolled receptacle when individual duplex receptacles are not connected to both controlled and uncontrolled circuits.

Equipment and appliances installed in the building shall meet the following requirements:

- All equipment and appliances that are intended to be plugged into building power outlets shall be Energy Star certified when available. After initial fit-out with Energy Star equipment, tenant guidelines should be provided to guide subsequent equipment acquisitions.
- Display case lighting in refrigeration display cases and lights in point-of-sale box doors shall be equipped to automatically turn off display lighting during non-business hours or be equipped with occupancy sensors that turn off display lighting after ten minutes of inactivity.
- All task lighting shall utilize LED lamps.
- Water coolers shall be provided with timers capable of turning the power off during off hours. They are prohibited from having heaters that heat previously chilled water.

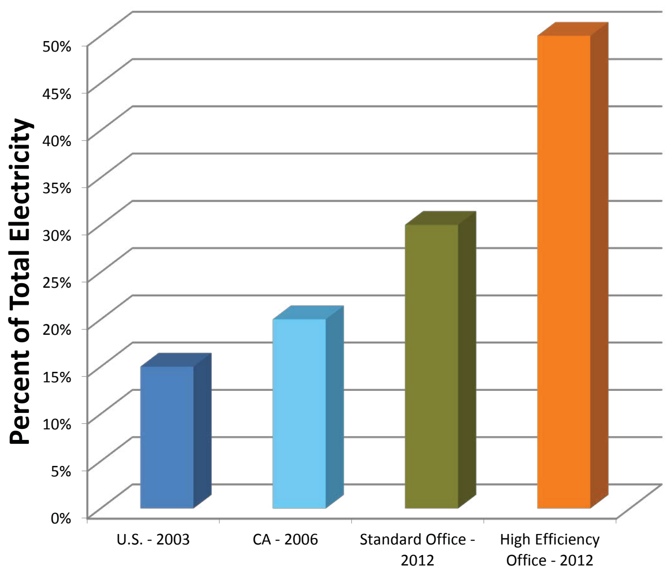
General

Even in very efficient buildings that are considered well operated, off-hour plug load usage has been typically demonstrated to represent 50% of on-hour

Figure 3.8.1

Office Equipment Plug Loads as a Percent of Total Office Electricity

Plug load energy use for computers and office equipment is increasing. In office buildings that have improved the efficiency of lights, heating and cooling it can represent as much as 50% of the total electricity use.



Sources:
US - Energy Information Agency
CA -CEUS
2012 offices - NBI Measured Data

usage. This means that 50% of the plugged-in equipment is running even when the space is unoccupied. (For perspective, most energy modelers assume that off-hour plug loads are only 5% of on-hour loads.) In typical buildings, off-hour plug load usage is much higher. With so many control points for equipment and equipment that often still draws power when "off," minimizing off-hour plug loads can be very challenging. Control of plug loads at the circuit level simplifies the problem, creating just one control point and putting equipment into a truly zero-consumption mode. Equipment that is not needed during off hours – monitors, task lighting, chargers, production equipment, etc. – is plugged into the controlled circuit to be turned off during off hours. Equipment that needs to operate off-hours – servers and some other computers, telecom infrastructure, security systems, equipment that must be powered down before disconnecting power, etc. – is plugged into the uncontrolled circuit.

BEST PRACTICES

Duplex receptacles that combine both a controlled and uncontrolled circuit can help minimize both material and labor costs. By using wiring that can carry both circuits to a single duplex receptacle, traditional receptacle locations and wiring routes can still be used and the multiplication of receptacles and wire runs avoided.

Computer Energy Saving Settings: Computer energy saving settings that can be set globally for the entire population of computers provide savings that are much more persistent than energy saving settings that are set computer by computer. EPA's Energy Star program maintains a list of software solutions that can accomplish this. Whether set globally or locally, computer systems should be set to turn off the monitor after 5 minutes, turn off hard disks after 15 minutes and, when available, go into sleep/standby/hibernate mode after 15 minutes.

Computer Equipment Selection: Many new computers are considerably over-powered for most desktop computing needs. Laptops, thin-client computers and other computers specifically designed to operate at low power significantly reduce the energy consumption attributable to computer equipment.

Server Options: Computing power needs can also be minimized through locating server resources in centers that can optimize performance and power consumption. These server centers reduce energy consumption through redundant resource reduction, dynamic capacity scaling and virtualization. However, it must be noted that simply moving servers out of the building does not improve efficiency. Those resources must be moved to a location that facilitates greater efficiency.

Application Guide

Retail building types generally have significantly lower plug loads and consequently very limited opportunity for this Criteria to generate significant energy savings. Therefore, in retail building types, this Criteria shall not be available as a Performance Pathway and shall be considered an Enhanced Measure.

Appendices

APPENDIX A: ACCEPTANCE REQUIREMENTS FOR HIGH PERFORMANCE BUILDINGS

Introduction

Acceptance Requirements are defined as the application of targeted inspection checks and functional and performance testing conducted to determine whether specific building components, equipment, systems and interfaces between systems conform to the Criteria set forth in the *Advanced Buildings New Construction Guide* and to the construction documents. Acceptance Requirements can effectively improve building performance and help determine whether equipment meets operational goals and whether it should be adjusted to increase efficiency and effectiveness.

This section describes the process for completing the Acceptance Requirements. The steps include the following:

- Compile a list of systems, equipment and components that require acceptance testing
- Document plans showing sensor locations, devices, control sequences and notes
- Review the installation, perform acceptance tests and document results
- Document the operating and maintenance information, indicate test results on the Construction Certification, and submit the Certificate to the implementing agency prior to receiving final project approval

Acceptance testing is not intended to take the place of commissioning or test and balance procedures that an owner might incorporate into a building project. It is an adjunct process focusing only on demonstrating equipment performance.

The installing contractor, engineer of record or owner's agent shall be responsible for reviewing the plans and specifications to assure they conform to the Acceptance Requirements. This is typically done prior to signing the Design Certification.

The installing contractor, engineer of record or owner's agent shall be responsible for providing all necessary instrumentation, measurement and

Purpose and Scope

This appendix defines acceptance procedures identified in Criteria 1.13 and 2.16 that must be completed as part of the Advanced Buildings: New Construction program.

monitoring, and undertaking all required acceptance requirement procedures in this Appendix. They shall be responsible for correcting all performance deficiencies and again implementing the acceptance requirement procedures until all specified systems and equipment are performing in accordance with the individual Criteria.

The installing contractor, engineer of record or owner's agent shall be responsible for documenting the results of the acceptance requirement procedures, including paper and electronic copies of all measurement and monitoring results. They shall be responsible for performing data analysis, calculation of performance indices and crosschecking results with the requirements of the individual Criteria. They shall be responsible for issuing a Certificate of Acceptance. Implementing agencies shall not release a final project approval until a Certificate of Acceptance is submitted demonstrating that the specified systems and equipment have been shown to be performing in accordance with the Criteria. Upon completion of all required acceptance requirement procedures, the installing contractor, engineer of record or owner's agent shall record their Contractor's License Number or their Professional Registration License Number on each Certificate of Acceptance they issue.

A.1 OUTDOOR AIR

A.1.1 Variable Air Volume (VAV) Systems outdoor Air Acceptance

Construction Inspection

Prior to Acceptance Testing, verify and document the following:

- Outside airflow station is calibrated OR a calibration curve of outside air versus outside air damper position, inlet vane signal or VFD signal was completed during system testing and balancing (TAB) procedures.

Equipment Start-Up

Step 1: If the system has an outdoor air economizer, force the economizer high limit to disable economizer control (e.g., for a fixed dry-bulb high limit, lower the setpoint below the current outdoor air temperature).

Step 2: Drive all VAV boxes to the greater of the minimum airflow or 30% of the total design airflow. Verify and document the following:

- » Measured outside airflow CFM corresponds to no less than 90% of the total value determined in Criterion 0.4.
- » System operation stabilizes within 15 minutes after test procedures are initiated (no hunting).

Step 3: Drive all VAV boxes to achieve design airflow. Verify and document the following:

- » Measured outside airflow CFM corresponds to no less than 90% of the total value determined in Criterion 0.4.
- » System operation stabilizes within 15 minutes after test procedures are initiated (no hunting).

A.1.2 Constant Volume System Outdoor Air Acceptance

Construction Inspection

Prior to Acceptance Testing, verify and document the following:

- » The system has a fixed or motorized minimum outdoor air damper, or an economizer capable of maintaining a minimum outdoor air damper position.

Equipment Testing

Step 1: If the system has an outdoor air economizer, force the economizer high limit to disable economizer control (e.g. for a fixed dry-bulb high limit, lower the setpoint below the current outdoor air temperature).

- » Measured outside airflow CFM with damper at minimum position corresponds to no less than 90% of the total value determined in Criterion 0.4.

A.2 PACKAGE HVAC SYSTEMS

Acceptance Requirements apply only to constant volume, direct expansion (DX) packaged systems with gas furnaces or heat pumps.

A.2.1 Constant Volume Packaged HVAC System Acceptance

Construction Inspection

Prior to Performance Testing, verify and document the following:

- Thermostat is located within the zone served by the HVAC system
- Space temperature thermostat is factory-calibrated (proof required) or field-calibrated
- Appropriate temperature deadband has been programmed
- Appropriate occupied, unoccupied and holiday schedules have been programmed.
- A one-hour pre-occupancy purge has been programmed
- Economizer lockout control sensor, if applicable, is factory-calibrated (proof required) or field-calibrated and setpoint properly set (refer to the economizers acceptance requirements section for detail)
- Demand-control ventilation controller, if applicable, is factory-calibrated (proof required) or field-calibrated and setpoint properly set (refer to the demand control ventilation acceptance requirements section for detail)

Equipment Testing

Step 1: Simulate heating load during occupied condition (e.g. by setting time schedule to include actual time and placing thermostat heating setpoint below actual temperature). Verify and document the following:

- » Supply fan operates continually during occupied condition
- » Gas-fired furnace, heat pump or electric heater, if applicable, stages on
- » Outside air damper is open to the minimum position

Step 2: Simulate "no-load" during occupied condition (e.g. by setting time schedule to include actual time and placing thermostat heating setpoints above actual temperature and cooling setpoint below actual temperature). Verify and document the following:

- » Supply fan operates continually during occupied condition
- » Neither heating nor cooling are provided by the unit
- » Outside air damper is open to the minimum position

Step 3: If there is an economizer, simulate cooling load and economizer operation, if applicable, during occupied condition (e.g. by setting time schedule to include actual time and placing thermostat cooling setpoint above actual temperature). Verify and document the following:

- » Supply fan operates continually during occupied condition
- » Refer to the economizer acceptance requirements section for testing protocols

Step 4: If there is no economizer, simulate cooling load during occupied condition (e.g. by setting time schedule to include actual time and placing thermostat cooling setpoint above actual temperature). Verify and document the following:

- Supply fan operates continually during occupied condition
- Compressor(s) stage on
- Outside air damper is open to the minimum position

Step 5: Change the time schedule to force the unit into unoccupied mode. Verify and document the following:

- Supply fan turns off
- Outside air damper closes completely

Step 6: Simulate heating load during setback conditions (e.g. by setting time schedule to exclude actual time and placing thermostat setback heating setpoint below actual temperature). Verify and document the following:

- Supply fan cycles on
- Gas-fired furnace, heat pump or electric heater, if applicable, stages on
- Supply fan cycles off when heating equipment is disabled

Step 7: If there is an economizer, simulate cooling load and economizer operation, if applicable, during unoccupied condition (e.g. by setting time schedule to exclude actual time and placing thermostat setup cooling setpoint above actual temperature). Verify and document the following:

- Supply fan cycles on
- Refer to the economizers acceptance requirements section for testing protocols
- Supply fan cycles off when call for cooling is satisfied (simulated by lowering the thermostat setpoint to below actual temperature)
- Outside air damper closes when unit cycles off

Step 8: If there is no economizer, simulate cooling load during setup condition (e.g. by setting time schedule to exclude actual time and placing thermostat setup cooling setpoint above actual temperature). Verify and document the following:

- Supply fan cycles on
- Compressor(s) stage on to satisfy cooling space temperature setpoint
- Supply fan cycles off when cooling equipment is disabled

Step 9: Simulate manual override during unoccupied condition (e.g. by setting time schedule to exclude actual time or by pressing override button). Verify and document the following:

- System reverts to “occupied” mode and operates as described above to satisfy a heating, cooling, or no-load condition
- System turns off when manual override time period expires

A.3 AIR DISTRIBUTION SYSTEMS

A.3.1 Air Distribution Acceptance

Construction Inspection

Prior to Performance Testing, verify and document the following:

- Duct connections are made with mechanical fasteners
- Flexible ducts are not constricted in any way (for example, pressing against immovable objects or squeezed through openings)
- Any duct leakage tests required by Criterion 2.11 shall be performed before access to ductwork and associated connections are blocked by permanently installed construction material
- Joints and seams are sealed with mastic
- Duct R-values are verified
- Insulation is protected from damage and suitable for outdoor service if applicable

A.4 AIR ECONOMIZER CONTROLS

Economizer testing is performed on all built-up systems and on packaged unitary systems. Air economizers installed by the HVAC system manufacturer and certified as being factory- calibrated and tested do not require field testing.

A.4.1 Economizer Acceptance

Construction Inspection

Prior to Performance Testing, verify and document the following:

- Economizer lockout setpoint complies with Criterion 2.10
- System controls are wired correctly to ensure economizer is fully integrated (i.e. economizer will operate when mechanical cooling is enabled)
- Economizer lockout control sensor location is adequate (open to air but not exposed to direct sunlight nor in an enclosure; away from sources of building exhaust; at least 25 feet from cooling towers)
- Relief fan system (if applicable) operates only when the economizer is enabled
- If no relief fan system is installed, barometric relief dampers are installed to relieve building pressure when the economizer is operating

Equipment Testing

Step 1: Simulate a cooling load and enable the economizer by adjusting the lockout control (fixed or differential dry-bulb or enthalpy sensor depending on system type) setpoint. Verify and document the following:

» Economizer damper modulates opens to maximum position to satisfy cooling space temperature setpoint

» Return air damper modulates closed and is completely closed when economizer damper is 100% open

» Economizer damper is 100% open before mechanical cooling is enabled.

» Relief fan is operating or relief dampers freely swing open

» Mechanical cooling is only enabled if cooling space temperature setpoint is not met with economizer at 100% open

» Doors are not pushed ajar from over pressurization

Step 2: Continue from Step 1 and disable the economizer by adjusting the lockout control (fixed or differential dry-bulb or enthalpy sensor depending on system type) setpoint. Verify and document the following:

» Economizer damper closes to minimum position

» Return air damper opens to normal operating position

» Relief fan shuts off or relief dampers close

» Mechanical cooling remains enabled until cooling space temperature setpoint is met

A.5 DEMAND CONTROL VENTILATION (DCV) SYSTEMS

A.5.1 Packaged Systems DCV Acceptance

Construction Inspection

Prior to Performance Testing, verify and document the following:

- Carbon dioxide control sensor is factory calibrated (proof required) or field- calibrated with an accuracy of no less than 75 ppm
- The sensor is located in the room between 1 foot and 6 feet above the floor
- System controls are wired correctly to ensure proper control of outdoor air damper system

Equipment Testing

Step 1: Simulate a high CO_2 load and enable the demand control ventilation by adjusting the demand control ventilation controller setpoint below ambient CO_2 levels. Verify and document the following:

» Outdoor air damper modulates open per Standards to maximum position to satisfy outdoor air requirements

Step 2: Continue from Step 1 and disable demand control ventilation by adjusting the demand control ventilation controller setpoint above ambient CO_2 levels. Verify and document the following:

» Outdoor air damper closes to minimum position

A.6 VARIABLE AIR VOLUME SYSTEMS WITH VARIABLE FREQUENCY DRIVES

A.6.1 Supply Fan Variable Flow Controls

Construction Inspection

Prior to Performance Testing, verify and document the following:

- Discharge static pressure sensor is factory calibrated (proof required) or field-calibrated with secondary source
- Disable discharge static pressure reset sequences to prevent unwanted interaction while performing tests

Equipment Testing

Step 1: Drive all VAV boxes to achieve design airflow. Verify and document the following:

- » Witness proper response from supply fan (e.g. VFD ramps up to full speed; inlet vanes open full)
- » Supply fan maintains discharge static pressure within ±10% of setpoint
- » Measured maximum airflow corresponds to design and/or TAB report within ±10%
- » System operation stabilizes within a reasonable amount of time after test procedures are initiated (no hunting)

Step 2: Drive all VAV boxes to minimum flow or to achieve 30% total design airflow, whichever is larger. Verify and document the following:

- » Witness proper response from supply fan (VFD slows fan speed; inlet vanes close)
- » Supply fan maintains discharge static pressure within ±10% of setpoint
- » System operation stabilizes within a reasonable amount of time after test procedures are initiated (no hunting)

A.7 HEAT RECOVERY SYSTEMS ACCEPTANCE

Construction Inspection

Prior to Performance Testing, verify and document the following:

- Review Test and Balance Report
- Inspect valves, piping and ductwork for correct configuration and installation
- Inspect heat wheels for correct wheel rotation and wheel alignment within manufacturer's specifications
- Intake and exhaust air flow directions are properly oriented and clearly labeled

Equipment Testing

Step 1: Adjust the setpoint of each thermostat, humidistat, etc., until the controlled response begins.

Step 2: Note the setpoint when that occurs, and note the reading on a calibrated thermometer (or other instrument as required) held in close proximity.

- » If the units are controlled by a building energy management system (EMS), compare the sensor input to the EMS to the simultaneous field measurement made on a calibrated thermometer (or other instrument as required) held in close proximity. With the system in the full recovery mode, the measured value for tests on exhaust side delta temperature and exhaust side standard CFM must be within ±15% of the design value.

Step 3: Describe the controls sequences for start/stop control, capacity control, freeze protection and any other modes of performance, then describe what tests were done to verify each. (Since there are many possible controls sequences for heat recovery systems, it is impossible to write a generic test for system controls.)

A.8 HYDRONIC SYSTEM CONTROLS ACCEPTANCE

Hydronic controls Acceptance Testing will be performed on:

- Variable Flow Controls
- Automatic Isolation Controls
- Supply Water Temperature Reset Controls
- Water-Loop Heat Pump Controls
- Variable Frequency Drive Control

A.8.1 Variable Flow Controls

Construction Inspection

Prior to Acceptance Testing, verify and document the following:

- Valve and piping arrangements were installed per the design drawings to achieve flow reduction requirements
- Installed valve and hydronic connection pressure ratings meet specifications
- Installed valve actuator torque characteristics meet specifications

Equipment Testing

Step 1: Open all control valves. Verify and document the following:

» System operation achieves design conditions

Step 2: Initiate closure of control valves. Verify and document the following:

» The design pump flow control strategy achieves flow reduction requirements

» Ensure all valves operate correctly against the minimum flow system pressure condition

A.8.2 Automatic Isolation Controls

Construction Inspection

Prior to Acceptance Testing, verify and document the following:

- Valve and piping arrangements were installed per the design drawings to achieve equipment isolation requirements
- Installed valve and hydronic connection pressure ratings meet specifications
- Installed valve actuator torque characteristics meet specifications

Equipment Testing

Step 1: Open all control valves. Verify and document the following:

» System operation achieves design conditions

Step 2: Initiate shut-down sequence on individual pieces of equipment. Verify and document the following:

» The design control strategy meets isolation requirements automatically upon equipment shut-down

» Ensure all valves operate correctly at shut-off system pressure conditions

A.8.3 Supply Water Temperature Reset Controls

Construction Inspection

Prior to Acceptance Testing, verify and document the following:

- All sensors have been calibrated
- Sensor locations are adequate to achieve accurate measurements
- Installed sensors comply with specifications

Equipment Testing

Step 1: Manually change design control variable to maximum setpoint. Verify and document the following:

» Chilled or hot water temperature setpoint is reset to appropriate value

» Actual supply temperature changes to meet setpoint

Step 2: Manually change design control variable to minimum setpoint. Verify and document the following:

» Chilled or hot water temperature setpoint is reset to appropriate value

» Actual supply temperature changes to meet setpoint

A.8.4 Water-Loop Heat Pump Controls

Construction Inspection

Prior to Acceptance Testing, verify and document the following:

- Valves were installed per the design drawings to achieve equipment isolation requirements
- Installed valve and hydronic connection pressure ratings meet specifications
- Installed valve actuator torque characteristics meet specifications
- All sensor locations comply with design drawings
- All sensors are calibrated
- VFD minimum speed setpoint exceeds motor manufacturer's requirements
- VFD minimum speed setpoint should not be set below the pumping energy curve inflection point (combination of pump-motor-VFD efficiency at reduced load may cause power requirements to increase upon further reduction in load)

Equipment Testing

Step 1: Open all control valves. Verify and document the following:

» System operation achieves design conditions ±5%

» VFD operates at 100% speed at full flow conditions

Step 2: Initiate shut-down sequence on each individual heat pumps. Verify and document the following:

» Isolation valves close automatically upon unit shut-down

» Ensure all valves operate correctly at shut-off system pressure conditions

» Witness proper response from VFD (speed decreases as valves close)

» System operation stabilizes within 5 minutes after test procedures are initiated (no hunting)

Step 3: Adjust system operation to achieve 50% flow. Verify and document the following:

» VFD input power less than 30% of design

Step 4: Adjust system operation to achieve a flow rate that would result in the VFD operating below minimum speed setpoint. Verify and document the following:

» Ensure VFD maintains minimum speed setpoint regardless of system flow operating point

A.8.5 Variable Frequency Drive Controls

Construction Inspection

Prior to Acceptance Testing, verify and document the following:

- All valves, sensors and equipment were installed per the design drawings
- All installed valves, sensors and equipment meet specifications
- All sensors are calibrated
- VFD minimum speed setpoint exceeds motor manufacturer's requirements
- VFD minimum speed setpoint should not be set below the pumping energy curve inflection point (combination of pump-motor-VFD efficiency characteristics at reduced load may cause input power to increase upon further reduction in load)

Equipment Testing

Step 1: Open all control valves. Verify and document the following:

» System operation achieves design conditions ±5%

» VFD operates at 100% speed at full flow conditions

Step 2: Modulate control valves closed. Verify and document the following:

» Ensure all valves operate correctly at system operating pressure conditions

» Witness proper response from VFD (speed decreases as valves close)

» System operation stabilizes within 5 minutes after test procedures are initiated (no hunting)

Step 3: Adjust system operation to achieve 50% flow. Verify and document the following:

» VFD input power less than 30% of design

Step 4: Adjust system operation to achieve a flow rate that would result in the VFD operating below minimum speed setpoint. Verify and document the following:

» Ensure VFD maintains minimum speed setpoint regardless of system flow operating point

A.9 DAYLIGHTING CONTROL SYSTEMS

Construction Inspection

Prior to Performance Testing, verify and document the following:

- All control devices (photocells) have been properly located, field-calibrated in the presence of daylighting, and set for appropriate set points, deadbands and threshold light levels
- Installer has provided documentation of setpoints, setting and programming for each device
- Architect has documented daylit zones on construction plans, and that all luminaires located in either a sidelighted zone(s) or a top-lighted area(s) are powered by a separate lighting circuit from non-daylit areas.

Equipment Testing

Continuous Dimming Control Systems

Step 1: Simulate bright conditions for a continuous dimming control system. Verify and document the following:

- » 65% electric light reduction is achieved through continuous dimming
- » Lighting power reduction is at least 90%; only luminaires in daylit zone are affected by daylight control
- » Automatic daylight control system reduces the amount of light delivered to the space uniformly
- » Dimming control system provides reduced flicker operation over the entire operating range
- » Illuminance measurements in the space, location of measurements and specific device settings, program settings and other measurements are documented

Step 2: Simulate dark conditions for a continuous dimming control system. Verify and document the following:

- » Electric light increase is achieved through continuous dimming
- » Automatic daylight control system increases the amount of light delivered to the space uniformly
- » Dimming control system provides reduced flicker operation over the entire operating range
- » Illuminance measurements in the space, location of measurements and specific device settings, program settings and other measurements are documented

A.10 OCCUPANCY SENSOR ACCEPTANCE

Construction Inspection

Prior to Performance Testing, verify and document the following:

- Occupancy sensitivity has been located to minimize false signals
- Occupancy sensors do not encounter any obstructions that could adversely affect desired performance
- Ultrasound occupancy sensors do not emit audible sound

Equipment Testing

Step 1: For a representative sample of building spaces, simulate an unoccupied condition. Verify and document the following:

» Lights or receptacles controlled by occupancy sensors turn off within a maximum of 30 minutes from the start of an unoccupied condition

» The occupant sensor does not trigger a false "on" from movement in an area adjacent to the controlled space or from HVAC operation

» Signal sensitivity is adequate to achieve desired control, including entry tests, hand-motion tests and perimeter tests

Step 2: For a representative sample of building spaces, simulate an occupied condition. Verify and document the following:

» Status indicator or annunciator operates correctly

» Lights or receptacles controlled by occupancy sensors turn on immediately upon an occupied condition, OR sensor indicates space is "occupied" and lights are turned on manually (automatic OFF and manual ON control strategy)

A.11 AUTOMATIC TIME SWITCH CONTROL ACCEPTANCE

Construction Inspection

Prior to Performance Testing, verify and document the following:

- Automatic time switch control is programmed with acceptable weekday, weekend and holiday (if applicable) schedules.
- Document for the owner automatic time switch programming including weekday, weekend and holiday schedules as well as all set-up and preference program settings
- Verify the correct time and date is properly set in the time switch
- Verify the battery is installed and energized
- Override time limit is no more than two hours

Equipment Testing

Step 1: Simulate occupied condition. Verify and document the following:

» All lights, receptacles or other controlled equipment can be turned on and off by their respective control switch

» For lights and receptacles, the switch only operates lighting and/or receptacles in the ceiling-height partitioned area in which the switch is located

» For other controlled equipment, override switches control only the equipment for which they are intended

Step 2: Simulate unoccupied condition. Verify and document the following:

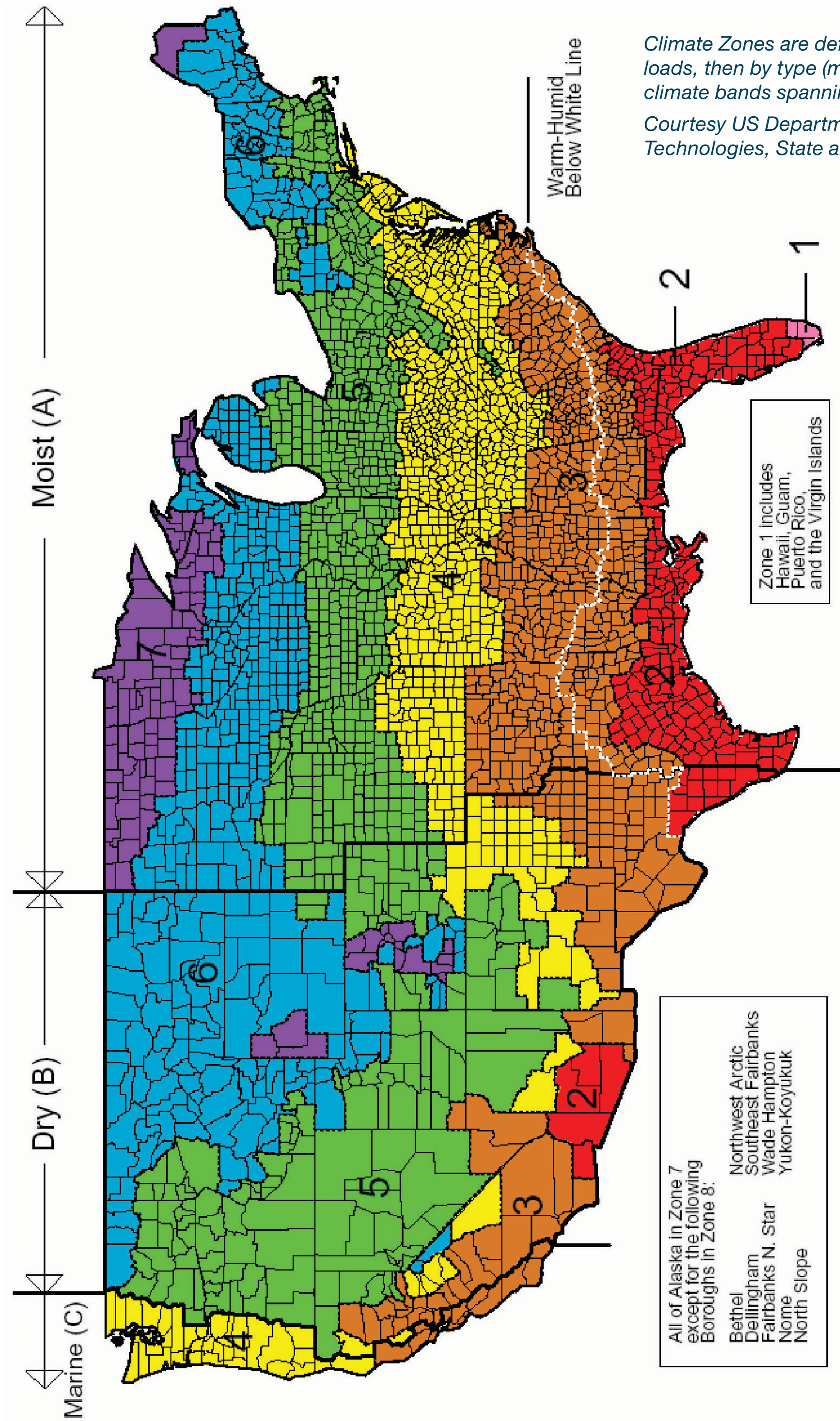
» All non-exempt lighting, receptacles or other equipment turn off

» For lighting and receptacles, manual override switch allows only the lights and/or receptacles in the selected ceiling height partitioned space where the override switch is located, to turn on or remain on until the next scheduled shut off occurs

APPENDIX B: CLIMATE ZONE MAP

Climate Zones are defined primarily by heating or cooling loads, then by type (marine, Dry, Moist), creating a set of climate bands spanning the country.

Courtesy US Department of Energy, Office of Building Technologies, State and Federal Programs



APPENDIX C:
ACRONYMS AND DEFINITIONS

The following definitions apply throughout the Guidelines:

1.1 Acronyms

ASHRAE – American Society of Heating, Refrigerating and Air-conditioning Engineers

HVAC – Heating, Ventilating and Air Conditioning

IECC – International Energy Conservation Code

IESNA – Illuminating Engineering Society of North America

LEED – Leadership in Energy and Environmental Design

USGBC – US Green Buildings Council

VAV – Variable Air Volume

VSD – Variable Speed Drive

1.2 Definitions

ballast: a device used in conjunction with an electric-discharge lamp to cause the lamp to start and operate under the proper circuit conditions of voltage, current, wave form, electrode heat, etc.

boiler: a self-contained low-pressure appliance for supplying steam or hot water.

building envelope: The elements of a building which enclose conditioned spaces through which thermal energy is capable of being transferred to or from the exterior or to or from unconditioned spaces.

Building Information Modeling (BIM): a building modeling and information tool developed for the construction industry to allow information sharing across all providers and facets of a project using a common database. It is available from several providers.

cfm: cubic feet per minute.

coefficient of performance (COP) – cooling: the ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigeration system or some specific portion of that system under designated operating conditions.

conductance: see thermal conductance.

construction documents: drawings and specifications used to construct a building, building systems, or portions thereof.

continuous insulation (cont. ins. or ci): insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior, exterior, or is integral to any opaque surface of the building envelope.

control device: a specialized device used to regulate the operation of equipment.

critical demand period: the period of peak electricity or natural gas demand, as defined by a utility tariff, that establishes annual system peak load. The critical demand period is different from typical demand periods as traditionally defined by utility tariffs.

daylit area: building floor area in proximity to glazing that is affected by natural daylight. Daylit area relative to glazing is generally defined as follows:

(a) vertical glazing: the daylit area extends perpendicularly from the wall 1.5 times the head height of the glazing, or to the nearest 60-inch or higher opaque partition, whichever is less; and a width of the window plus either 2 feet on each side.

(b) horizontal glazing: the daylit area is the footprint of the skylight well at the ceiling plus, in each of the lateral and longitudinal dimensions of the skylight, a distance of 0.75 times the ceiling height from the edge of the skylight well.

daylight glazing: exterior glazing over 6 feet above the finished floor.

demand: the highest amount of power (average kW over an interval) recorded for a building or facility in a selected time frame.

Demand Control Ventilation (DCV): A system of control based on real-time monitoring of carbon dioxide (CO_2) to either insure indoor air quality and/or reduce energy consumption in unoccupied spaces.

design conditions: specified environmental conditions, such as temperature and light intensity, required to be produced and maintained by a system and under which the system must operate.

distribution system: conveying means, such as ducts, pipes, and wires, to bring energy from a source to the point of use. The distribution system includes such auxiliary equipment as fans, pumps, and transformers.

door: all operable opening areas (which are not fenestration) in the building envelope, including swinging and roll-up doors, fire doors, and access hatches. Doors that are more than one-half glass are considered fenestration. (See fenestration.) For the purposes of determining building envelope requirements, the classifications are defined as follows:

(a) non-swinging: roll-up, sliding, and all other doors that are not swinging doors.

(b) swinging: all operable opaque panels with hinges on one side and opaque revolving doors.

door area: total area of the door measured using the rough opening and including the door slab and the frame. (See fenestration area.)

DX – Direct Expansion: Refers to cooling systems that pass the air to be cooled directly over refrigerant cooling coils rather than using an intermediary fluid, such as water.

economizer, air: a duct and damper arrangement and automatic control system that together allow the use of outside air directly to reduce or eliminate the need for mechanical cooling during mild or cold weather.

ERV – Energy Recovery Ventilator: A device that uses heat and moisture exchangers to transfer both sensible and latent heat between the supply air and return air to minimize energy use and improve comfort. See also HRV.

efficiency: actual performance compared to ideal performance at specified rating conditions.

emittance: the ratio of the radiant energy emitted by a specimen to that emitted by an ideal blackbody at the same temperature and under the same conditions.

energy: the capacity for doing work. It takes a number of forms that may be transformed from one into another such as thermal (heat), mechanical (work), electrical, and chemical. Customary measurement units are British thermal units (Btu) and watt hours (Wh) where 1 Wh = 3.413 Btu.

energy efficiency ratio (EER): the ratio of net cooling capacity in Btu/h to total rate of electric input in watts under designated operating conditions. (See coefficient of performance (COP)—cooling.)

energy performance rating: the energy use of a proposed building under simulated operating conditions normalized for a specific variable. Projected energy use targets can be used for buildings in the design or construction process. Examples include kBtu/sf/yr, $/sf/yr, $/gross sales, Energy Performance Rating Score (US EPA), or like expressions of energy performance.

EPAct 05: federal energy policy act adopted in 2005. EPAct05 provides a number of important incentives to reduce energy costs for institutional and commercial buildings.

FDD – Fault Detection and Diagnostics: software, typically embedded in building operations software, that identifies and, if possible, diagnoses faults in building equipment and/or operations. Some packages also take remedial action automatically.

fenestration: all areas (including the frames) in the building envelope that let in light, including windows, plastic panels, clerestories, skylights, glass doors that are more than one-half glass, and glass block walls. (See building envelope and door.) A skylight is a fenestration surface having a slope of less than 60 degrees from the horizontal plane. Other fenestration, even if mounted on the roof of a building, is considered vertical fenestration.

fenestration area: total area of the fenestration measured using the rough opening and including the glazing, sash, and frame. For doors where the glazed vision area is less than 50% of the door area, the fenestration area is the glazed vision area. For all other doors, the fenestration area is the door area.

fixture: the component of a luminaire that houses the lamp or lamps (and ballast if present), positions the lamp, shields it from view, and distributes the light. The fixture also provides for connection to the power supply.

flue damper: a device in the flue outlet or in the inlet of or upstream of the draft control device of an individual, automatically operated, fossil fuel-fired appliance that is designed to automatically open the flue outlet during appliance operation and to automatically close the flue outlet when the appliance is in a standby condition.

F-value: value of the heat loss through the edge and body of a slab-on-grade floor expressed in terms of Btu/hrF per linear foot of perimeter. It represents the integral of all the various pathways heat travels out of the slab.

heating seasonal performance factor (HSPF): the total heating output of a heat pump during its normal annual usage period for heating (in Btu) divided by the total electric energy input (in kWh) during the same period.

HRV – Heat Recovery Ventilator: A device that uses a heat exchanger to transfer sensible heat between the supply air and return air flows to minimize energy use and improve comfort. See also ERV.

HVAC system: Heating, Ventilation, and Air Conditioning; the equipment, distribution systems, and terminals that provide, either collectively or individually, the processes of heating, ventilating, or air conditioning to a building or portion of a building.

infiltration: the uncontrolled inward air leakage into a building caused by pressure differences across these elements due to factors such as wind, inside and outside temperature differences (stack effect), and/or imbalance between supply and exhaust air systems.

integrated part-load value (IPLV): a single-number figure of merit based on part-load EER, COP, or kW/ton expressing part-load efficiency for air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment.

kilowatt (kW): the basic unit of electric power, equal to 1000 W and 3413 Btu/h.

labeled: equipment or materials to which a symbol or other identifying mark has been attached by the manufacturer indicating compliance with specified standards or performance in a specified manner.

lamp: a generic term for a man-made light source often called a bulb or tube.

(a) compact fluorescent lamp: a fluorescent lamp of a small compact shape, with a single base that provides the entire mechanical support function.

(b) fluorescent lamp: a low-pressure electric discharge lamp in which a phosphor coating transforms some of the ultraviolet energy generated by the discharge into light.

(c) general service lamp: a class of incandescent lamps that provide light in virtually all directions. General service lamps are typically characterized by bulb shapes such as A, standard; S, straight side; F, flame; G, globe; and PS, pear straight.

(d) high-intensity discharge (HID) lamp: an electric discharge lamp in that light is produced when an electric arc is discharged through a vaporized metal such as mercury or sodium. Some HID lamps may also have a phosphor coating that contributes to the light produced or enhances the light color.

(e) incandescent lamp: a lamp in which light is produced by a filament heated to incandescence by an electric current.

(f) reflector lamp: a class of incandescent lamps that have an internal reflector to direct the light. Reflector lamps are typically characterized by reflector shapes such as R, reflector; ER, ellipsoidal reflector; PAR, parabolic aluminized reflector; MR, multi-faceted reflector; and others.

lighting system: a group of luminaires circuited or controlled to perform a specific function.

lighting power density (LPD): the connected lighting load power (in Watts) per unit area. Calculation of LPD includes combined energy use of lamp and ballast systems. It is typically characterized by building classification or space function and is used as an energy code limit value for a given building type or space use.

mechanical cooling: reducing the temperature of a gas or liquid by using vapor compression, absorption, desiccant dehumidification combined with evaporative cooling, or another energy-driven thermodynamic cycle. Indirect or direct evaporative cooling alone is not considered mechanical cooling.

occupant sensor: a device that detects the presence of people within an area.

opaque envelope: all areas in the building envelope, except fenestration and building service openings such as vents and grilles. (See building envelope and fenestration.)

operational performance requirements: A written document that details the functional requirements of a project and the expectations of how it will be used and operated. This includes project and design goals, measurable performance Criteria, budgets, schedules, success Criteria and supporting information.

orientation: the direction an envelope element faces relative to know referent, such as True North, i.e., the relative direction of a vector perpendicular to and pointing away from the surface outside of the element.

OA or OSA - outdoor (outside) air: air that is outside the building envelope or is taken from outside the building that has not been previously circulated through the building.

projection factor (PF): the ratio of the horizontal depth of the external shading projection divided by the sum of the height of the fenestration and the distance from the top of the fenestration to the bottom of the farthest point of the external shading projection, in consistent units.

proposed design: a computer representation of the actual proposed building design or portion thereof used as the basis for calculating the design energy cost.

PTAC – Packaged Terminal Air Conditioning units: also known as “window-shakers, a factory-selected combination of heating and cooling components, assemblies or sections intended to serve a single room or zone.

R-value of insulation: the thermal resistance of the insulation alone as specified by the manufacturer in units of $h \cdot ft^2 \cdot °F/Btu$ at a mean temperature of 75°F. Rated R-value refers to the thermal resistance of the added insulation in framing cavities or insulated sheathing only and does not include the thermal resistance of other building materials or air films. (See thermal resistance.)

record drawings: drawings that record the conditions of the project as constructed. These include any refinements of the construction or bid documents (often referred to as “as-builts”.

reflectance: the percentage of the light reflected by a surface relative to the light incident upon it.

roof: the upper portion of the building envelope, including opaque areas and fenestration, that is horizontal or tilted at an angle of less than 60° from horizontal.

seasonal energy efficiency ratio (SEER): the total cooling output of an air conditioner during its normal annual usage period for cooling (in Btu) divided by the total electric energy input during the same period (in Wh).

utility service: the equipment for delivering energy from the supply or distribution system to the premises served.

single-zone system: an HVAC system serving a single HVAC zone.

skylight: see fenestration.

solar heat gain coefficient (SHGC): the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space. (See fenestration area.)

space: an enclosed space within a building. Spaces are defined as follows for the purpose of determining building envelope requirements.

(a) conditioned space: a heated or cooled space, or both, within a building and, where required, provided with humidification or dehumidification means so as to be capable of maintaining a space condition falling within the comfort envelope set forth in ASHRAE 55.

(b) unconditioned space: a space other than a conditioned space.

system: a combination of equipment and auxiliary devices (e.g., controls, accessories, interconnecting means, and terminal elements) by which energy is transformed so it performs a specific function such as HVAC, service water heating, or lighting.

TAB – Test and Balance: the process of verifying and calibrating the air flow through a building air conditioning system under varying operating conditions.

thermal resistance (R-value): the reciprocal of the time rate of heat flow through a unit area induced by a unit temperature difference between two defined surfaces of material or construction under steady-state conditions. Units of R are h·ft^2·°F/Btu.

thermostatic control: an automatic control device or system used to maintain temperature at a fixed or adjustable set point.

tinted: (as applied to fenestration) coloring that is integral to the glazing material. Tinting does not include surface applied films such as reflective coatings, applied either in the field or during the manufacturing process.

Ton: a unit of cooling equal to 12,000 Btu. Derived from the amount of heat absorbed by a ton of ice while melting.

U-factor (thermal transmittance): heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side. Units of U are Btu/h·ft^2·°F.

unitary equipment: one or more factory-made assemblies that normally include an evaporator or cooling coil and a compressor and condenser combination. Units that perform a heating function are also included.

VAV – Variable Air Volume: a system designed to supply only the volume of conditioned air to a space that is needed to satisfy the thermal or ventilation load, saving fan energy.

ventilation: the process of supplying fresh air by natural or mechanical means to or from any space.

Visible Light Transmittance (VLT): a measure of the percentage (0-100%) of visible light transmitted by the glazing.

VSD (variable speed drive) or VFD (variable frequency drive) or ASD (adjustable speed drive): an electronic controller that allows an electric motor to operate over a range of speeds. Typically used on fans and pumps in variable flow systems.

wall area, gross: the area of the wall measured on the exterior face from the top of the floor to the bottom of the roof.

warm-up: increase in space temperature to occupied set point after a period of shutdown or setback.

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