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30%

Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities

Achieving 30% Energy Savings Toward a Net Zero Energy Building

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

Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities

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

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Contents

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Shanti Pless
SP127 Chair
July 2009

Abbreviations and Acronyms

A	=	area, ft^2
AABC	=	Associated Air Balance Council
ACCA	=	Air Conditioning Contractors of America
AEDG-SHC	=	*Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities*
AFUE	=	annual fuel utilization efficiency, dimensionless
AHA	=	American Hospital Association
AHU	=	air-handling unit
AIA	=	American Institute of Architects
ANSI	=	American National Standards Institute
ASHE	=	American Society for Healthcare Engineering
ASHRAE	=	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	=	ASTM International
BAS	=	building automation system
BF	=	ballast factor
bhp	=	brake horsepower
BoD	=	Basis of Design
Btu	=	British thermal unit
C-factor	=	thermal conductance, $Btu/(h \cdot ft^2 \cdot °F)$
CFL	=	compact fluorescent lamp
cfm	=	cubic feet per minute
CHP	=	*Advanced Energy Design Guide* code for combined heat and power systems
CHW	=	chilled water
c.i.	=	continuous insulation
CKI	=	Commercial Kitchens Initiative
CM	=	construction manager
CMH	=	ceramic metal halide
CMS	=	Centers for Medicare & Medicaid Services
CMU	=	concrete masonry unit

CO_2	=	carbon dioxide
COP	=	coefficient of performance, dimensionless
CPSE	=	chlorosulfonated polyethylene
CRI	=	color rendering index
CRRC	=	Cool Roof Rating Council
Cx	=	commissioning
CxA	=	commissioning authority
D&T	=	diagnostic and treatment
DCV	=	demand-controlled ventilation
DL	=	*Advanced Energy Design Guide* code for daylighting
DOAS	=	dedicated outdoor air system
DOE	=	U.S. Department of Energy
DV	=	displacement ventilation
DX	=	direct expansion
E_c	=	efficiency (combustion), dimensionless
E_t	=	efficiency (thermal), dimensionless
E	=	emittance
ED	=	*Advanced Energy Design Guide* code for electrical distribution
EEM	=	energy efficiency measure
EER	=	energy efficiency ratio, Btu/W·h
EF	=	energy factor
EISA	=	Energy Independence and Security Act
EIA	=	Energy Information Agency
EL	=	*Advanced Energy Design Guide* code for electric lighting
EN	=	*Advanced Energy Design Guide* code for envelope
EPA	=	U.S. Environmental Protection Agency
ERV	=	energy recovery ventilator
EX	=	*Advanced Energy Design Guide* code for exterior lighting
fc	=	footcandles
F-factor	=	slab edge heat loss coefficient per foot of perimeter, Btu/(h·ft·°F)
FFR	=	daylighting fenestration to floor area ratio, dimensionless
fps	=	feet per second
FSTC	=	Food Service Technology Center
GC	=	general contractor
GPH	=	gallons per hour
GPM	=	gallons per minute
GSHP	=	ground-source heat pump
Guide	=	*Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities*
HC	=	heat capacity, Btu/(ft^2·°F)
HEPA	=	high efficiency particulate air
HID	=	high intensity discharge
H_2O	=	water
hp	=	horsepower
HSPF	=	heating season performance factor, Btu/W·h
HV	=	*Advanced Energy Design Guide* code for HVAC systems and equipment
HVAC	=	*Advanced Energy Design Guide* code for heating, ventilating, and air-conditioning
ICC	=	International Code Council

IEEE	=	Institute of Electrical and Electronics Engineers
IEER	=	Integrated Energy Efficiency Ratio, Btuh/watt
IES	=	Illuminating Engineering Society of North America
IPLV	=	integrated part-load value, dimensionless
IR	=	infrared reflecting
ISO	=	International Standards Organization
kBtuh	=	thousands of British thermal units per hour
kW	=	kilowatt
LBNL	=	Lawrence Berkeley National Laboratory
LCD	=	liquid crystal display
LDR	=	labor, delivery, and recovery
LDRP	=	labor, delivery, recovery, and post-partum
LED	=	light-emitting diode
LEED	=	Leadership in Energy and Environmental Design
LPD	=	lighting power density, W/ft^2
LSG	=	light-to-solar gain
MERV	=	minimum efficiency reporting value
MLPW	=	mean lumens per watt
N/A	=	not applicable
NEBB	=	National Environmental Balancing Bureau
NEMA	=	National Electrical Manufacturers Association
NFRC	=	National Fenestration Rating Council
NICU	=	neonatal intensive care unit
NREL	=	National Renewable Energy Laboratory
NZEB	=	net zero energy building
O&M	=	operation and maintenance
OPR	=	Owner’s Project Requirements
PACU	=	patient anesthetic care unit
PD	=	pre-design
PF	=	projection factor, dimensionless
PIR	=	passive infrared
PL	=	*Advanced Energy Design Guide* code for plug loads
ppm	=	parts per million
psf	=	pounds per square foot
PV	=	photovoltaic
PVC	=	polyvinyl chloride
QA	=	quality assurance
QMH	=	quartz metal halide
R	=	thermal resistance, (h·ft^2·°F)/Btu
RE	=	*Advanced Energy Design Guide* code for renewable energy
RFP	=	request for proposal
RFQ	=	request for qualifications
S/MH	=	spacing to mounting height
SAT	=	supply air temperature
SD	=	schematic design
SEER	=	seasonal energy efficiency ratio, (h·ft^2·°F)/Btu
SFU	=	supply fixture unit
SHGC	=	solar heat gain coefficient, dimensionless
SMACNA	=	Sheet Metal and Air Conditioning Contractors National Association

SP	=	standard series lamps
SPx	=	premium series lamps
SRI	=	Solar Reflectance Index
SSPC	=	Standing Standards Project Committee
Std.	=	standard
SWH	=	service water heating
TAB	=	testing, adjusting, and balancing
TC	=	Technical Committee
TDV	=	thermal displacement ventilation
TSO	=	thermoplastic polyolefin
U	=	thermal transmittance, Btu/(h·ft^2·°F)
UPS	=	uninterruptible power supply
USGBC	=	U.S. Green Building Council
VAV	=	variable-air-volume
VFD	=	variable-frequency drive
VT	=	visible transmittance
W	=	watts
w.c.	=	water column
WH	=	*Advanced Energy Design Guide* code for water heating systems and equipment
WSHP	=	water-source heat pump
WWR	=	window-to-wall ratio

Foreword: A Message to Healthcare Systems and Hospital Administrators

The mission for healthcare facilities is to provide environments for healing patients. Healthcare facilities and their systems must support that primary mission. The challenge is to reduce energy use in healthcare facilities while enhancing patient outcomes.

Building system design criteria for healthcare facilities vary as much as the medical services provided. For example, there are vast differences between the medical services provided in a in-patient wing and those in a surgery suite or in a doctor's office. The set of criteria is completely different if the facility is a hospital operating 24/7 with patients incapable of self-preservation as compared to a medical office that operates similar to other office buildings.

There are also several fundamentally different healthcare delivery models, including specialty, community, nonprofit, and for-profit operations. These facilities operate under very different business models with regards to reimbursement taxes, capital availability, and cash flow.

However, four critical areas that all project teams and building owners need to address are: reliability, flexibility, integrated design and commissioning, and economics. Now, a fifth category is being added to this list on many projects: sustainability. Energy efficiency and energy use are major components of sustainability.

Equipment failures or poorly performing equipment can affect the most important elements of the healthcare business: patient and staff satisfaction, and revenue from patient services. If the systems are operating poorly or not at all, the patients and staff are uncomfortable and patients and procedures may have to be rescheduled, which translates into lower patient satisfaction and lost revenue.

Healthcare facilities and their infrastructure and systems must be flexible in order to adapt to the changes and advancements in medical equipment as well as patient services. Medical equipment will be obsolete in 5 years or fewer, yet the facilities may be in place for 50 years. The degree of flexibility often will come down to economics. Finding ways to provide affordable flexibility is the challenge.

The *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities* can help in the design of new healthcare facilities that are 30% more energy efficient than current industry standards using ANSI/ASHRAE/IESNA Standard 90.1-1999 as a benchmark. This saves energy but also supports the other design goals important to healthcare facilities: to improve the patient experience, enhance the healing environment, increase staff retention, lower construction and operating costs, contribute to an environmentally conscious building design, and improve the bottom-line performance of the healthcare facility.

ENHANCED HEALING ENVIROMENT

A healthcare facility that includes favorable light, sound, and temperature provides a better experience for patients and their families by enhancing comfort and control while reducing stress and anxiety.

Access to views and daylighting, which uses the sun to produce high-quality, glare-free light in a space, has been found to favorably affect both patient outcomes and staff productivity. In a recent report by R.S. Ulrich, "How Design Impacts Wellness,"[1] it was found that a patient room providing good outdoor views and daylighting can increase patient well-being and create a psychological state resulting in reduced stress and anxiety, lower blood pressure, improved post-operative recovery, reduced need for pain medication, and shorter hospital stays. Daylighting will also significantly reduce ambient electric light energy consumption; lighting power savings during daylight hours in controlled spaces can be as high as 87%.

Related research also shows that the ability to control their personal environment, including bedside control of lighting and window shades, can improve patients' psychological outlooks, rates of healing, and quality of stay.

According to the American Society of Healthcare Engineers (ASHE), the health of patients, staff, and visitors can be profoundly affected by the quality of the indoor air. A recent study[2] completed by the Lawrence Berkeley National Laboratory (LBNL) reported that improvements to indoor environment could reduce healthcare costs and work losses from communicable respiratory disease by 9% to 20%. Advanced, energy-efficient heating and cooling systems can also create cleaner, healthier indoor environments that reduce the threat of infection for both patients and staff.

Advanced energy-efficient systems can also be much quieter than previous technology. This produces quieter, more comfortable, and more productive spaces. This all translates to better patient outcomes, shorter patient stays, reduced sick-days for healthcare staff, and lower overall costs.

ATTRACT PATIENTS AND BETTER RECRUIT/RETAIN THE BEST DOCTORS AND SKILLED NURSES

A growing advantage of energy-efficient, sustainable healthcare facilities is market differentiation. More and more hospitals are demonstrating their commitment to their local community and the global environment while enhancing their bottom-line performance.

An enhanced patient experience translates to improved satisfaction survey results. There is no better promotion for a hospital than the recommendation of satisfied patients and families where the facility and service exceeded their expectations. And the ability to recruit and retain the best and brightest doctors and skilled nurses will be improved by providing an efficient, comfortable, clean, and healthy place to work and treat patients. Improving these attributes will help the physicians, nurses, and staff to deliver high-quality care.

LOWER CONSTRUCTION COSTS/FASTER PAYBACK

Thoughtfully designed, energy-efficient hospitals can cost less to build than typical hospitals. For example, optimizing the envelope to match the climate can substantially reduce the size of the mechanical systems. A hospital with strategically designed glazing

1. R.S. Ulrich, "How Design Impacts Wellness," *Healthcare Forum Journal* 20 (1992): 23.
2. Brett C. Singer, Paul Mathew, Steve Greenberg, Bill Tschudi, and Dale Sartor (Lawrence Berkeley National Laboratory) and Susan Strom and Walter Vernon (Mazzetti Nash Lipsey Burch). 2009. Hospital energy benchmarking guidance. LBNL Report, Lawrence Berkeley National Laboratory, Berkeley, CA.

will have lower mechanical costs than the one without—and will cost less to build. In general, an energy-efficient hospital

- requires less heating,
- costs less to maintain,
- has less expensive installation,
- requires fewer lighting fixtures due to more efficient lighting,
- allows for downsized heating systems due to better insulation and windows, and
- allows for downsized cooling systems with a properly designed daylighting system and a better envelope.

Some strategies may cost more up front, but the energy they save means they often pay for themselves within a few years.

REDUCED OPERATING COSTS

According to the most recent Commercial Buildings Energy Consumption Survey (CBECS)[1] conducted by the Energy Information Administration (EIA), the average hospital in North America consumes nearly 250% more energy than the average commercial building. By using energy efficiently and lowering a hospital's energy bills, hundreds of thousands of dollars can be redirected each year into upgrading existing facilities, caregivers' salaries, and investing in the latest technology in medical equipment.

Strategic up-front investments in energy efficiency provide significant long-term savings. In the financial performance of the hospital, every dollar saved in energy and operating costs is equal to generating $20 growth in new top line revenues.

In an average hospital, lighting uses a large portion of the overall energy budget. Therefore the design should include an energy-efficient lighting design and efficient lighting fixtures but also should evaluate opportunities for dimming controls and multi-level switching systems. In the many areas where the design team brings quality daylight into the space, lighting controls can be used to regulate the output of electric lights to optimize the quality of the visual environment while saving significant amounts of energy.

The smart use of a site's climatic resources and more efficient envelope design are keys to reducing a building's overall energy requirements. Efficient equipment and energy management programs then help meet those requirements more cost-effectively.

Because of growing water demand and shrinking aquifers, the price of water is escalating in many areas. Saving water can thus save money but also can generally save energy.

Lower operating costs mean less fluctuation in budgets because of price instabilities of energy. Purchasing energy efficiency is buying into energy futures at a known fixed cost.

REDUCED GREENHOUSE GAS EMMISSIONS BENEFIT THE COMMUNITY

According to some estimates, buildings are responsible for nearly 40% of all carbon dioxide emissions annually in the United States. Carbon dioxide, which is produced when fossil fuel is burned, is the primary contributor to greenhouse gas emissions. Healthcare facilities can be a part of the solution when they reduce their consumption of fossil fuels for heating, cooling, and electricity. The local community, patients, and staff will appreciate such forward-thinking leadership.

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

Introduction 1

The *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities* (AEDG-SHC; the Guide) is intended to provide a simple approach for contractors and designers who create small to medium size acute care, outpatient and inpatient buildings, up to 90,000 ft^2. Application of the recommendations in the Guide should result in small healthcare facilities with 30% energy savings when compared to those same facilities designed to the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999. This document contains recommendations and is *not* a minimum code or standard. It is intended to be used in addition to existing codes and standards and is not intended to circumvent them. This Guide represents *a way*, but *not the only way*, to build energy-efficient small healthcare buildings that use significantly less energy than those built to minimum code requirements. The recommendations in this Guide provide benefits for the owner while maintaining quality and functionality of the space.

The mission of a healthcare facility is to facilitate the care and treatment of people of varying stages of disease or disability. The performance requirements of a building intended to serve these needs will be the driving force behind most design decisions for the building, and the benefits of some energy-saving measures could compromise the fundamental goal. The energy-saving measures in this Guide are intended to complement, or at least to avoid compromising, the delivery of healthcare services in these buildings.

The energy savings projections of this Guide are based on site energy consumption rather than source energy. *Site energy* refers to the number of units of energy consumed on the site and typically metered at the property line. *Source energy* takes into account the efficiency with which raw materials are converted into energy and transmitted to the site and refers to the total amount of energy originally embodied in the raw materials. For example, it is generally accepted that site electrical energy is 100% efficient, but in fact it takes approximately 3 kWh of total energy to produce and deliver 1 kWh to the customer because the production and distribution of electrical energy is roughly 33% efficient.

This Guide is intended to show that achieving the 30% energy savings target is possible. Case studies in the Guide show facilities around the country that have achieved or exceeded this target. The technologies are available to do the job. The goal of the Guide is to help designers and owners attain the energy savings through identification of packages of design measures and strategies and selection of the state-of-the-art building systems and design concepts that result in efficient and high-quality spaces.

The Guide was developed by a project committee that represents a diverse group of professionals. Guidance and support was provided through a collaboration of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the American Institute of Architects (AIA), the Illuminating Engineering Society (IES) of North America, the U.S. Green Building Council (USGBC), and the U.S. Department of Energy (DOE). Members of the project committee came from these partner organizations, ASHRAE SSPC 90.1, the ASHRAE TC 9.6, and the American Society of Healthcare Engineers (ASHE).

The 30% energy savings target is the first step toward achieving net zero energy healthcare facilities—buildings that, on an annual basis, draw from outside energy sources an amount that is less than or equal to the energy that they generate on site from renewable energy sources. For more information on net zero energy buildings, see the references in Appendix E.

Other Guides in this series include the *Advanced Energy Design Guide for Small Office Buildings,* the *Advanced Energy Design Guide for Small Retail Buildings,* the *Advanced Energy Design Guide for K-12 School Buildings,* the *Advanced Energy Design Guide for Small Warehouses and Self-Storage Buildings,* and the *Advanced Energy Design Guide for Highway Lodging.* (Additional information is available at www.ashrae.org/aedg).

GOAL OF THIS GUIDE

There is a specific quantitative energy savings goal measured against ASHRAE/IESNA Standard 90.1-1999, the “turn of the millennium” standard. In addition to Standard 90.1-1999, other healthcare design requirements, such as the AIA *2006 Guidelines for Design and Construction of Health Care Facilities*, are used to determine the turn-of-the-millennium baseline.

- *Measure of Achieving Energy Savings*. The specific prescriptive recommendations yield an aggregate 30% savings beyond a typical benchmark building built to ASHRAE/IESNA Standard 90.1-1999 for each climate zone contained in the guide. It is not an average of the national energy savings. The cities used for testing in previous Guides should also be used for this Guide.
- *Numeric Goal*. This is a hard value as opposed to an approximate target. The 30% energy savings value was set to be as consistent as feasible with USGBC Leadership in Energy and Environmetal Design (LEED) criteria, given that LEED works from a *cost* basis while this document is based on *energy.* It is desired that this Guide will be able to be used for LEED for Health Care Facilities EA compliance for facilities smaller than 90,000 ft^2. The 30% savings is determined based on whole-building energy savings, which includes process and plug loads.
- *Method of Achieving Goal*. The goal of this Guide is to attain the energy savings through identification of packages of design measures and strategies and selection of the state-of-the-art building systems and design concepts that result in efficient and high-quality spaces.

SCOPE

This Guide applies to small healthcare facilities up to 90,000 ft^2 in areas including acute care, outpatient surgical, small critical access, and inpatient community hospitals. These facilities typically include all or some of the following types of space usage: patient rooms, surgery, emergency department, radiology, administration, dining and food preparation, post anesthesia care unit (PACU), and recovery. The primary focus of this Guide is new construction, but recommendations may be similarly applicable in their entirety to facilities undergoing total renovation and in part to many other healthcare renovation, addition, remodeling, and modernization projects (including changes to one or more systems in existing buildings).

The small healthcare facilities included in the scope of this Guide are facilities smaller than 90,000 ft^2 defined as

- small acute care hospitals,
- small inpatient community hospitals,
- critical access hospitals with 25 beds or fewer,
- outpatient surgical facilities,
- freestanding birthing centers (similar to outpatient surgical centers),
- gastrointestinal endoscopy facilities (similar to outpatient surgical centers),
- renal dialysis centers (similar to medical office buildings),
- primary care outpatient centers,
- small primary (neighborhood) outpatient facilities,
- freestanding outpatient diagnostic and treatment facilities,
- freestanding urgent care facilities, or
- medical office buildings (greater than 20,000 ft^2).

Included in the Guide are recommendations for the design of the building envelope; fenestration; lighting systems (including electrical lights and daylighting); heating, ventilation, and air-conditioning (HVAC) systems; building automation and controls; outside air (OA) treatment; and service water heating (SWH). Additional savings recommendations are also included but are not necessary for 30% savings. These additional savings recommendations are discussed in the Bonus Savings section of Chapter 5 and provide recommendations for process/plug/phantom loads, renewable energy systems, alternative hot water systems, alternative HVAC systems, and electrical distribution.

The recommendation tables do not include all the components listed in ASHRAE/IESNA Standard 90.1-1999. Though this Guide focuses only on the primary energy systems within a building, the underlying energy analysis presumes that all the other components are built to the criteria in Standard 90.1 and *ASHRAE Standard 170, Ventilation of Health Care Facilities*.

Certain aspects of energy-efficient design, including steam heat, vehicles and other maintenance areas, and sewage disposal, are excluded from this Guide. Significant energy efficiency opportunities may be available in these areas, and Guide users are encouraged to take advantage of these opportunities and treat them as “bonuses” beyond the 30% target.

In addition, the Guide is not intended to substitute for rating systems or references that address the full range of sustainable issues in healthcare design, such as acoustics, productivity, indoor air quality (IAQ), water efficiency, landscaping, and transportation, except as they relate to energy use. Nor is it a design text. The Guide assumes good design skills and expertise in healthcare and hospital design.

HEALTHCARE PROTOTYPES

To provide a baseline for this Guide, two healthcare prototype designs with a variety of envelope, lighting, and HVAC configurations were developed and analyzed by using hourly building simulations in eight climate zones**.** The designs include a 65,000 ft^2 community hospital and a 41,000 ft^2 ambulatory surgery center that includes a diagnostic and acute care center and medical office space. Each prototype was carefully assembled to be representative of the construction for healthcare of that class. Information was drawn from a number of sources including CBECS, Dodge Construction Data, and various healthcare templates from around the country. The space types included in each prototype designs are shown in Table 1-1.

Two sets of simulations were run for each prototype: the first meets the minimum requirements of ASHRAE/IESNA Standard 90.1-1999; the second uses the recommendations in this Guide to achieve a 30% energy savings. This process was repeated for all climate zones. For the baseline models, the critical care areas are served by multiple-zone, constant-volume air-handling units with zone-level reheat coils. All other areas are served by multiple-zone, variable-air-volume (VAV) air-handling units. Cooling is

Table 1-1. Prototype Designs Space Types

Space Types	Hospital	Surgery Center
Emergency Room	X	
Patient Anesthetic Care Unit/Recovery	X	X
Exam/Treatment	X	X
Nurse Station	X	X
Pharmacy	X	X
Patient Room	X	
Operating Room	X	X
Nursery	X	
Staff Work/Supply	X	X
Physical Therapy	X	X
Radiology/Imaging	X	X
Laundry		
Office/Administration	X	X
Conference	X	X
Lobby	X	X
Lounge/Waiting	X	X
Dining	X	
Food Preparation	X	
Corridors/Stairs	X	X
Storage	X	X

provided by air-cooled direct-expansion (DX) equipment and heating is provided by gas-fired, hot-water boilers or electric heaters. In addition to the requirements in Standard 90.1, the AIA *2006 Guidelines for Design and Construction of Health Care Facilities* was used to determine minimum airflow rates for both sets of simulations.[1]

The energy savings for the recommendations in this Guide vary between climate zones, daylighting options, HVAC system types, and building use type, but in all cases they are at least 30% when compared to ASHRAE/IESNA Standard 90.1-1999. These savings as compared to Standard 90.1-1999 ranged from 32% to 45%.

Analysis was also done to determine the energy savings as compared to ASHRAE 90.1-2004. The savings as compared to Standard 90.1-2004 over the climate zones, daylighting options, HVAC system types, and building use types ranged from 26% to 40%.

Complete results of the prototype facility simulations are presented in the "Technical Support Document: the Development of the Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities," available at www.ashrae.org/aedg.

1. The guidelines in Table 2.1-2 were used. The Facility Guidelines Institute and the American Institute of Architects Academy of Architecture for Health, *Guidelines for Design and Construction of Health Care Facilities,* 2006 edition. (Washington DC: American Institute of Architects, 2006).

ACHIEVING 30% ENERGY SAVINGS

Meeting the 30% energy savings goal is not difficult, but it requires more than doing business as usual. Here are the essentials.

1. ***Obtain the buy-in of the owner/hospital administration.*** There must be strong buy-in from the owner and operator's leadership and staff. The more they know about and participate in the planning and design process, the better able they will be to help achieve the 30% goal after the facility becomes operational. The building owner must decide on the goals and provide the leadership to make the goals reality.

2. ***Assemble an experienced, innovative design team.*** Interest and experience in designing energy-efficient healthcare facilities, innovative thinking, and the ability to work together as a team are all critical to meeting the 30% goal. The team achieves this goal by creating a building that maximizes daylighting, minimizes process loads and heating and cooling loads, and has highly efficient lighting and HVAC systems. Energy goals should be communicated in the request for proposal (RFP) and design team selection based, in part, on the team's ability to meet the goals. The design team strives to implement the goals as set by the owner.

3. ***Adopt an integrated design approach.*** Cost-effective, energy-efficient design requires trade-offs between potential energy-saving features. This requires an integrated approach to design. A highly efficient lighting system, for instance, may cost more than a conventional one, but because it produces less heat, the building's cooling system can often be downsized. And perhaps the reduced energy required for lighting will permit the use of a reduced-size main electrical service for the building as well as a reduced-size distribution system, also reducing overall building cost. The greater the energy savings the more complicated the trade-offs become and the more design team members must work together to determine the optimal mix of energy-saving features. Because many options are available, the design team will have wide latitude in exploring and implementing energy-saving trade-offs.

4. ***Consider energy modeling.*** This Guide is designed to help achieve energy savings of 30% without energy modeling, but energy modeling programs that simulate hourly operation of the building and provide annual energy usage data make evaluating energy-saving trade-offs faster and far more precise. These programs have learning curves of varying difficulty, but energy modeling for healthcare design is highly encouraged and is considered necessary for achieving energy savings beyond 30%. See DOE's Building Energy Software Tools Directory at www.eere.energy.gov/buildings/tools_directory for links to energy modeling programs. Part of the key to energy savings is using the simulations to make envelope decisions first and then evaluate heating, cooling, and lighting systems. Developing HVAC load calculations is not energy modeling, nor is it a substitute for energy modeling.

5. ***Use building commissioning.*** In the experience of the committee members, most building systems, no matter how carefully designed, are often improperly installed or set up and do not operate as efficiently as expected. The 30% goal can only be achieved through systems that operate as intended; thus, facilities require a systematic process of verifying that all building systems—including envelope, lighting, and HVAC—perform as intended. The commissioning (Cx) process works because it integrates the traditionally separate functions of building design, system selection, equipment startup, system control calibration, testing, adjusting and balancing, documentation, and staff training.

   A commissioning authority (CxA) ensures that the energy- and water-saving methods and devices selected by the design team are incorporated in the building plans and specifications; that everything is built and tested accordingly; and that hospital personnel, including those occupying the building, are provided the necessary documentation and training to operate the building properly after it is occupied.

The more comprehensive the Cx process, the greater the likelihood of energy savings. A CxA should be appointed at the beginning of the project and work with the design team throughout the project. Solving problems at the design phase is more effective and less expensive than making changes or fixes during construction. More information on commissioning is available in the Quality Assurance section of Chapter 5 and in Appendix C. Additional resources are listed in Appendix E.

6. ***Train building users and operations staff.*** Staff training can be part of the building Cx process, but a plan must be in place to train staff for the life of the building to meet energy savings goals. Studies have shown that buildings designed to save energy often do not, and the primary reason is the way the building is operated. These buildings often fail to operate as designed because of poor or lack of initial and ongoing operator training. The building's designers and contractors normally are not responsible for the building after it becomes operational, so the owner must establish a continuous training program that helps occupants and operation and maintenance (O&M) staff maintain and operate the building for maximum energy efficiency. This training should include information about the impact of process and plug loads on energy use and the importance of using energy-efficient equipment and appliances.

7. ***Monitor the building.*** A monitoring plan is necessary to ensure that energy goals are met over the life of the building. Even simple plans such as recording and plotting monthly utility bills can help ensure that the energy goals are met. Buildings that do not meet the design goals often have operational issues that should be corrected.

HOW TO USE THIS GUIDE

- Review Chapter 2 to understand how an integrated design approach is used to achieve 30% or greater energy savings. Checklists show how to establish and maintain the energy savings target throughout the project.
- Use Chapter 3 to select specific energy-saving measures by climate zone. This chapter provides a prescriptive path that does not require modeling for energy savings. These measures also can be used to earn credits for LEED and other building rating systems.
- Review the case studies in Chapter 4 to see how the 30% energy savings goal has been met in healthcare facilities in climate zones across the country.
- Use Chapter 5 to apply the energy-saving measures in Chapter 3. This chapter has suggestions about best design practices, how to avoid problems, and how to achieve additional savings with energy-efficient appliances, plug-in equipment, and other energy-saving measures.
- Various appendices provide additional information, including:
  - Appendix A—Envelope Thermal Performance Factors
  - Appendix B—Climatic Zones for Canada and Mexico
  - Appendix C—Commissioning Information and Examples
  - Appendix D—ENERGY STAR Equipment
  - Appendix E—Additional Resources
- Note that this Guide is presented in inch-pound (IP) units only and it will be up to the individual users to provide metric conversion as required.

Integrated Process for Achieving Energy Savings

2

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

- *A narrative discussion of the design and construction process that points out the opportunities for energy savings in each phase.* It further explains the steps that each team member or discipline should take to identify and implement energy savings concepts and strategies. It also includes a discussion on how the quality assurance measures are worked into the process at each phase and how some of these measures can be used by the owner to maintain energy performance for the life of the facility.
- *A reference table or matrix that leads the Guide's user through the process of identifying and selecting energy-saving measures to meet major energy design goals.* This information is presented in Table 2-1, which ties together detailed strategies, recommendations to meet the 30% energy use reduction target, and related how-to information.

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

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

Figure 2-1. Stages of design.

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

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

BENEFITS OF INTEGRATED DESIGN

The primary mission of healthcare is healing, and of hospitals and healthcare facilities it is first to do no harm. For healthcare facilities, the emphasis on achieving energy savings is still relatively new, as compared to other building types. Healthcare design is strongly impacted by building codes, licensing requirements, and medical planning, making it more challenging to justify energy efficiency goals. However, these goals can gain additional weight when supported by their ancillary benefits such as improved indoor environment, improved staff satisfaction, improved patient outcomes, and other benefits inherent in many energy reduction strategies.

Using integrated design will allow better ability to achieve multiple design goals without adversely impacting first cost. For example, a 2006 study by Matthiessen and Morris concluded that many green building strategies can be implemented with minimal or no additional cost, while some can reduce first cost through improved design or reduced complexity of design.

A largely untapped benefit arising from energy efficiency is reduced building size or more usable space. A typical building of this type might include 16 ft floor-to-floor height with 9 ft ceilings. This volume, together with spaces used to house mechanical and electrical equipment, means that more than 40% of the building volume is building space dedicated to ductwork and equipment. The net usable space is barely more than half of the building volume. Integrated design can achieve less overhead space and more net usable space.

Much of the HVAC energy consumption in a healthcare building is driven by the various code requirements, operating schedules, and medical equipment. Even so, optimizing the shape of the building, the envelope, and architectural planning can minimize additional energy loss. Moreover, the way a room is defined by the architecture can have a dramatic impact on the code-required HVAC parameters for a particular space. The integrated design process targets the energy demand side by lowering envelope and interior building loads of the building, optimizing site layout and building shape and orientation, and increasing envelope thermal efficiency. This reduces the demands for the subsystems such as HVAC, lighting, plumbing, and power. Integration allows the “right-sizing” of building systems and components, which reduces first and life-cycle costs.

FEATURES OF INTEGRATED DESIGN

A successful integrated design approach provides the best energy performance at the least cost and is characterized as follows.

It is goal driven. In a goal-setting session early in the design process, strategies are identified to meet energy-efficiency goals in relation to the owner's mission. Goals must be quantifiable and measurable. Defining energy performance as a project goal from the beginning of the project is necessary to ensure that the energy performance is equally prioritized in the design and prevails throughout the project. By including medical equipment planners, the client's user groups, and engineering and facility departments in this session, each group's interests can be aligned with the project goals and successful implementation into the project can be ensured. Selecting medical equipment planners who consider energy consumption can have a substantial impact on facility energy use.

It is resourceful. Integrated design begins with site assessment and site layout studies to optimize orientation and fenestration for the best light to solar gain ratio. Layout and orientation are opportunities to obtain free energy resources. As an example, some of the artificial lighting can be replaced by daylight through the windows. Passive solar strategies such as direct gain can reduce mechanical heating energy consumption in colder climates, and passive shading can reduce cooling energy consumption. On the supply side, geothermal and solar energy (domestic hot water, heating water, and/or photovoltaic systems) reduce the amount of energy required from fossil fuels. Optimal building orientation, form, and layout achieve substantial energy savings.

It is multidisciplinary. Integrative design is a radically different process to the conventional approach used for project design and delivery. The traditional practice relies on isolated specialists, each optimizing their own systems, and can result in component and equipment sizing by rule of thumb and vastly oversizing systems. Instead, integrated design involves the owner, designers, technical consultants, construction manager (CM), general contractor (GC), CxA, facility staff, and end users in all phases of the project working to optimize the whole design. The process requires cross-disciplinary design and validation at all phases of the process.

The CxA, who may be a member of the healthcare facility staff, an independent staff member from the design firm, or an outside consultant, is an integral part of this iterative process. He or she validates that the design documents meet the energy savings goals; that the building is constructed as designed; and that the staff knows how to use, operate, and maintain the building to achieve the energy savings goals.

It is iterative. A goal-setting session is just the start. As the design concept takes shape, strategies need to be tested to determine if the results meet the desired energy performance targets and whether maintenance requirements need optimizing and life-cycle costs need reducing. Even when a team follows prescriptive energy-saving strategies such as those in this document, energy modeling can provide further refinement and optimized performance. It is imperative to make energy performance a standing agenda item during design reviews to discuss trade-off opportunities at the system level.

THE INTEGRATED DESIGN PROCESS

The following description delineates an integrated design process for tracking and achieving energy savings in new small healthcare facilities, outlining the involvement of owners, architects, consultants, and builders who decide to augment and improve their practices to include energy efficiency at each stage of the development process from project conception through building operation. In the following tables and throughout this Guide, the expression consultants is used as an abbreviated term defined as including special consultants from mechanical, electrical, and all other engineering disciplines. The tasks to be completed in each phase of design, construction, and operation are identified, and responsibilities are assigned in Table 2-1 through Table 2-4.

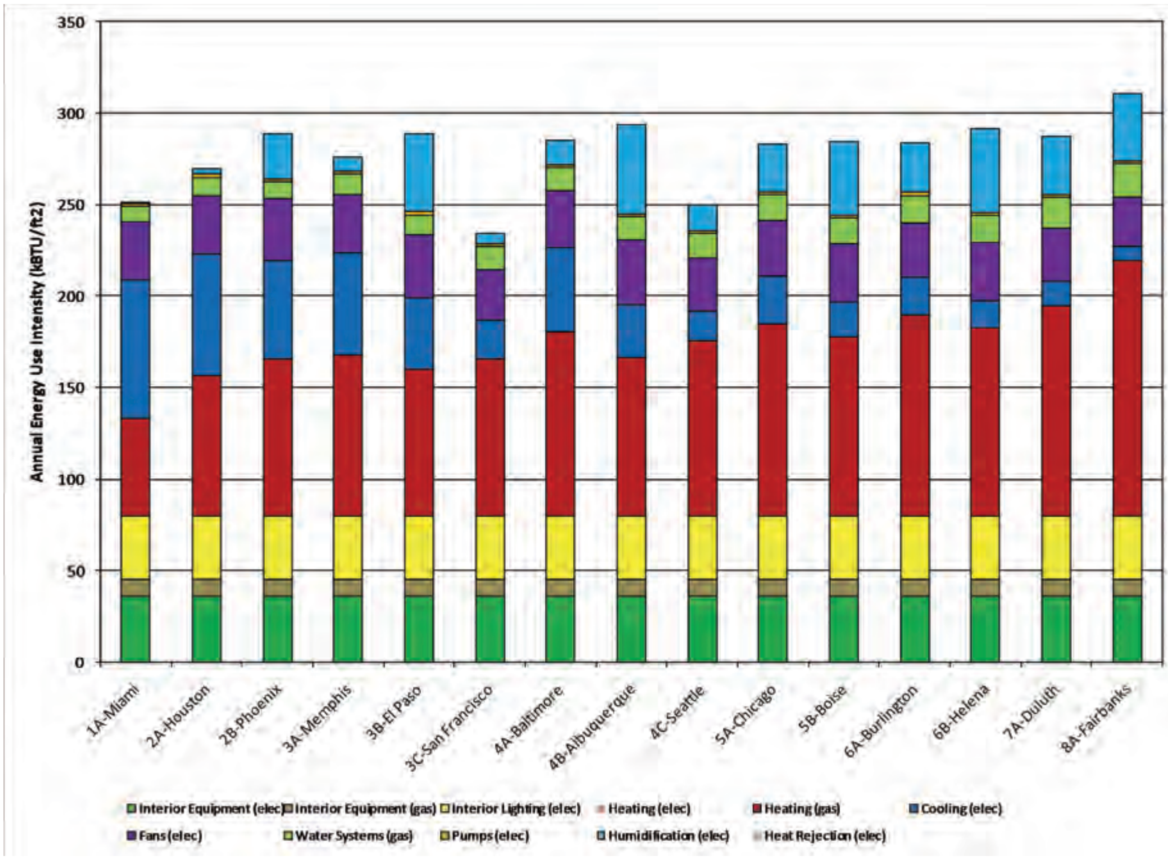


Figure 2-2. Small healthcare baseline end uses across climate zones.

1. PRE-DESIGN (PD) (OR PLANNING AND PROGRAMMING) PHASE

Adopting measurable energy goals at the beginning of the project will guide the team and provide a benchmark during the project's life. General strategies that relate to these goals will be identified at this phase as part of the goal discussions. Strategies will be further refined and confirmed during the design phase.

Analyze the site and program to identify the largest savings potentials and focus attention on these first. Priorities are likely to vary significantly from one climate zone to another and may vary between small healthcare facilities in the same climate zone. Site conditions can significantly affect energy performance. For example, differences in building application, climate, and even orientation will affect the selection of various energy goals and strategies. Figure 2-2 shows the baseline energy use for a typical small healthcare facility in the 15 climate zones. It demonstrates that cooling and lighting energy predominates in Climate Zone 1 (Miami is in 1A, a subset of Climate Zone 1), so the goals and strategies for cooling and lighting should be the highest priorities. In Climate Zone 8 (Fairbanks), the goals and strategies for heating and lighting should receive the highest priority.

Because of the high air change rates and humidity control required in many of the space types found in healthcare facilities, the constant-volume reheat HVAC systems that have traditionally been used in these facilities use a lot of energy for reheat. The baseline energy modeling for this Guide shows that reheat represents over 20% of the total energy use of the building, and this occurs in all climate zones. For additional information, see Figure 5-29 at the beginning of the HVAC how-to tips in Chapter 5.

Table 2-1 lists strategies to follow to keep the pre-design phase in line with energy design goals.

2. DESIGN PHASE

In the design phases (schematic design and design development), the project team develops energy efficiency strategies and tests them for compliance with project goals before incorporating them into building drawings and specifications. Systems are optimized in a systemic way and selected based on their aggregate performance rather than evaluating component by component. Strategy choices should be prioritized according to their overall efficacy in energy consumption reduction. Selecting and prioritizing energy conservation measures need to include consideration of the impact on the owner's facility operating staff. Some strategies would require additional staff with increased capabilities.

- Select energy-efficient mechanical systems.
- Reduce thermal building loads.
- Optimize on-site energy resources.
- Size systems to comply with reduced loads.
- Incorporate efficient mechanical equipment and lighting.

Table 2-1. Energy Goals in the Context of the Pre-Design Phase

Activities	Responsibilities	Where to Find Information
1. Select the core team a. Include integrated delivery method (IDP) and energy goals in the RFP b. Architects, designers, medical planners, engineers, cost consultants, and consultants in energy, daylighting, sustainability. c. Client's team including user and engineering representation d. CxA e. Construction manager	Owner	Chapter 5, QA1, QA2
2. Adopt energy goals	Owner, Architect, Engineers, Consultants	Chapter 5, QA3
3. Assess the site a. Evaluate options for district heat or cooling b. Identify on-site energy opportunities c. Identify best building orientation d. Evaluate access to public transportation	Owner, Architect, Engineers, Consultants, CM	Chapter 5, QA3
4. Identify applicable energy code requirements	Owner, Designers, Engineers, Consultants	Chapter 3 Chapter 5, QA3
5. Develop massing, footprint studies, define functional and spatial programs	Owner, Medical Equipment Planners, Architect	Chapter 3 Chapter 5, QA3
6. Identify energy efficiency potential and budget benchmarks	Owner, Architect, Engineers, Consultants, CM, Estimator	Chapter 3 Chapter 5, QA3
7. Prepare the design and construction schedule and milestones	Owner, Architect, CM	Chapter 3 Chapter 5, QA3
8. Determine building envelope and systems preferences	Owner, Architect, Engineers, Consultants, CM	Chapter 3 Chapter 5, QA3
9. Perform cost/benefit analysis for energy strategies	Owner, Architect, Engineers, Consultants	Chapter 3 Chapter 5, QA3

At each point, the decisions should take into account priorities and systems decisions. For example, cooling system sizing should take into account daylighting measures, glazing sizes, and building orientation.

The CxA reviews the design to verify that the project goals are being met. The CxA should also verify that the assumptions for HVAC load calculations and other modeling assumptions are based on actual design parameters rather than on rule of thumb. Information about how to integrate the commissioning process into each project is included in Chapter 5. Table 2-2 lists strategies to follow to keep the design phase in line with energy design goals.

Table 2-2. Energy Goals in the Context of the Design Phase

Activities	Responsibilities	Where to Find Information
1. Define building layout and volume and prepare diagrammatic drawings that satisfy functional program requirements	Architect, Engineers, Medical Planners	Chapter 5, QA3, DL2, DL5, DL6
2. Develop specific energy-efficiency strategies; set benchmarks for systems	Owner, Designers, Consultants, CM, CxA	Chapter 5, QA3
3. Study building orientation to make best use of climatic conditions and daylighting strategies; validate with medical planning	Architect, Engineers	Chapter 5, QA3, DL1, DL2
4. Select/optimize building systems to meet desired energy-efficiency target	Owner, Architect, Engineers, Consultants, CM	Chapter 5, QA3
5. Develop building plans, sections, and systemic details incorporating the above strategies	Architect	Chapter 5, QA3
6. Develop façade and fenestration systems and exterior or integrated solar control devices to comply with their energy implications; create architectural drawing set	Architect	Chapter 5, QA3, Envelope, Daylighting
7. Refine design: optimize façade and fenestration systems to balance programmatic, aesthetic, and performance requirements	Architect, Engineers	Chapter 5, QA3, Envelope, Daylighting
8. Schedule and perform design reviews at each phase of the project to verify that the project meets functional and energy goals	Owner, Architect, Engineers, CM, CxA	Chapter 5, QA5
9. Calculate building HVAC loads and run energy models to optimize design at each design stage to ensure that energy goals are being met; use recommended loads for lighting power density from this Guide	Engineers, Consultants	Chapter 3 Chapter 5, QA3
10. Match capacity of HVAC systems to design loads to avoid costly overdesign; specify equipment efficiency as recommended by this Guide	Engineers, Consultants	Chapter 3 Chapter 5, QA3
11. Perform final coordination and integration of architectural, mechanical, and electrical systems	Architect, Engineers	Chapter 3 Chapter 5, QA3
12. Prepare specifications for all systems	Architect, Engineers	Chapter 3 Chapter 5, QA3
13. Integrate Cx specifications into project manual	Architect, Engineer, CxA	Chapter 5, QA4
14. Prepare cost estimates at each phase of design	CM, CxA, Estimator	Chapter 5, QA3
15. Review and revise final design documents	Owner, Architect, CxA	Chapter 5, QA3, QA5

3. CONSTRUCTION PHASE

Even the best design will not operate successfully and yield the expected energy savings if the construction drawings and specifications are not correctly executed. Table 2-3 lists strategies that the project team can use to keep the construction process in line with energy design goals.

4. ACCEPTANCE, OCCUPANCY, AND OPERATION PHASE

The integrated project team will use acceptance procedures such as those described in Chapter 5 of this document.

Occupancy is a critical time in the process, and is often neglected by the project teams. Energy savings are difficult to attain if the medical, engineering, and O&M staff do not know how to use, operate, and maintain the building. The CxA should ensure timely submittals of the O&M manuals through specifications and regular reminders at construction meetings and ensure adequate and timely training of all facility and medical staff.

A performance review should be conducted during the first year of building operation. The building operator should discuss any systems that are not performing as expected with the design and construction team so they can be resolved during the warranty period. Over time, the building's energy use, changes in operating hours, and any addition of energy-consuming equipment should be documented by the owner's facilities staff. This information can be used to determine how well the building is performing and for taking lessons back to the design table for future projects. Performance evaluations should take place on a schedule specified in a maintenance manual provided to the owner as part of final project acceptance. Ongoing training of facility staff, including medical staff, administrators, and instructional staff should be provided to such address changes and to address staff turnover. Table 2-4 lists strategies to help keep the acceptance phase in line with energy design goals. Additional information about commissioning is available in the Quality Assurance How-to tips in Chapter 5 of the guide.

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

Activities	Responsibilities	Where to Find Information
1. At the pre-bid conference, make energy efficiency measures (EEMs) and the Cx process a priority agenda item	Owner, Architect, CM, CxA, Engineers, Consultants	Chapter 5, QA6
2. At all job meetings, review EEMs and Cx procedures	Owner, Architect, CM, CxA, Engineers, Consultants	Chapter 5, QA4
3. Verify that building envelope construction strictly follows the drawings and specifications and meets performance target	Architect, CxA	Chapter 5, QA7
4. Verify that HVAC and electrical systems meet specifications and meet performance target	CxA	Chapter 5, QA8

Table 2-4. Energy Goals in the Context of the Acceptance, Occupancy, and Operation Phase

Activities	Responsibilities	Where to Find Information
1. Prepare pre-occupancy punch list	Owner, Architect, CM, CxA, Consultants	Chapter 5, QA9
2. Conduct system performance tests	Architect, CM, CxA, GC, Subcontractor(s), Consultants	Chapter 5, QA9
3. Submit completed O&M manuals and record documents	CxA, GC, Subcontractor(s)	Chapter 5, QA10
4. Provide O&M training for medical and engineering staff	CxA, GC, Subcontractor(s), possibly Architect and Consultants	Chapter 5, QA10
5. Establish building O&M program	CxA, GC, Subcontractor(s), Facility Staff	Chapter 5, QA10
6. Resolve any remaining Cx issues identified during the construction or occupancy phase	Owner, CM, CxA, GC, Subcontractor(s)	Chapter 5, QA7, QA8, QA9
7. Certify building as substantially complete	Owner, Architect, CM, CxA	Chapter 5, QA9
8. Purchase computers and other energy-using appliances that meet ENERGY STAR efficiency to reduce plug loads	Owner, Facility Staff	Chapter 5, PL5
9. Monitor post-occupancy performance for one year	CxA, Facility Staff	Chapter 5, QA11
10. Create post-occupancy punch list	CxA, Facility Staff	Chapter 5, QA11
11. Grant final acceptance	Owner, Architect, CM, CxA	Chapter 5, QA11

Recommendations by Climate 3

This chapter contains a unique set of energy efficiency recommendations for each climate zone. The recommendation tables represent *a way*, but *not the only way*, to reach the 30% energy savings target over ANSI/ASHRAE/IESNA Standard 90.1-1999. Other approaches may also save energy, but they are not part of the scope of this Guide; assurance of those savings is left to the user. The recommendation tables do not include all the components listed in Standard 90.1 since the Guide focuses only on primary energy systems. To achieve 30% energy savings, this Guide assumes compliance with the more stringent of either the applicable edition of Standard 90.1 or the local code requirements in all areas not addressed in the climate-specific recommendation tables. Future editions of energy codes may have more stringent values. In these cases, the more stringent values are recommended.

Users should determine the recommendations for their construction project by first locating the correct climate zone. The U.S. Department of Energy (DOE) has identified eight climate zones for the United States, with each defined by county borders, as shown in Figure 3-1 and as listed in the recommendation tables that follow. These climate zones are based on temperature and in some cases are divided into sub-zones based on humidity levels. Humid sub-zones are A zones, dry sub-zones are B zones, and marine sub-zones are C zones. This Guide uses these zones to define the energy recommendations. Tables with the climatic zones for locations in Canada and Mexico are in Appendix B. Each climate zone recommendation table includes a set of common items arranged by building subsystem: envelope, lighting/daylighting, HVAC, and service water heating (SWH). Recommendations are included for each item, or subsystem, by component within that subsystem. For some subsystems, recommendations depend on the construction type, HVAC system type, or space type. For example, insulation values are given for mass, steel-framed, and wood-framed wall types. For others, recommendations are given for each attribute. For example, glass recommendations are given for size, thermal transmittance, solar heat gain coefficient (SHGC), and exterior sun control.

Daylighting recommendations are provided for specific space types to maximize sidelighting potential. If carefully designed, vertical fenestration and skylights can provide interior illumination without excessive solar heat gain. Electric lighting systems can then be extinguished or dimmed for most daytime hours, saving significant energy and maintenance costs. The key to daylighting is integrated design in which HVAC and electric lighting controls are optimized to take full advantage of and “harvest” energy savings, and added first costs of fenestration are offset by reduced costs in HVAC equipment. Because of the additional non-energy benefits from daylighting (see the foreword to this Guide), a design that uses daylighting should be pursued whenever possible. Proper daylighting design requires an integrated approach and good design skills. If these are possible, lighting and daylighting design can provide predictable and persisting lighting energy savings.

For interior electrical lighting, recommendations are provided that use efficient, state-of-the art products and lighting design techniques. The recommendations provided in this section include whole-building lighting power density (LPD); light source system efficacy for lighting systems that use the most current, energy-efficient lamps and ballasts; and integrated controls. Because lighting energy savings also produce cooling savings, HVAC energy savings of 10% to 15% are also possible in cooling-dominated climates. Moreover, even though the cost of high-performance lighting may be about the same or more than a basic solution, the cost of HVAC capacity can also be reduced.

For HVAC there are three possible system types (see HV1 through HV3 in Chapter 5 for detailed descriptions). Some system types, however, are not recommended for critical care areas of the healthcare facility. Unique recommendations are included for each HVAC system type based on the practicality of implementation and the 30% energy reduction goal.

Where “Comply with Standard 90.1” is indicated in the “Recommendation” column of the tables, the project must meet the more stringent of the requirements of either the applicable edition of Standard 90.1 or the local code requirements.

The “How-To Tips in Chapter 5” column in each table lists references to how-to tips for implementing the recommended criteria. The tips are found in Chapter 5 under separate sections coded for quality control (QA), envelope (EN), lighting (EL), daylighting (DL), HVAC systems and equipment (HV), and SWH systems and equipment (WH) suggestions. Besides design and maintenance suggestions that represent good design practice, these tips include cautions for what to avoid. Each tip in Chapter 5 is tied to the applicable climate zones. The final column of each recommendation table is provided as a simple checklist to identify the recommendations that are being used for a specific building design and construction.

Chapter 5 provides additional recommendations and strategies for energy savings over and above the 30% recommendations contained in the eight climate regions. These additional savings are in the areas of plug loads, alternative HVAC systems, renewable energy systems, and others.

The recommendations presented are either minimum or maximum values.

Minimum values include:

- R-values
- mean lumens/watt (MLPW)
- Solar Reflectance Index (SRI)
- energy efficiency ratio (EER)
- integrated energy efficiency ratio (IEER)
- integrated part-load value (IPLV)
- coefficient of performance (COP)
- effectiveness
- combustion efficiency (E_c)
- thermal efficiency (E_t)
- energy factor (EF)
- duct or pipe insulation thickness

Maximum values include:

- fenestration U-factors
- fenestration solar heat gain coefficient (SHGC)
- total fenestration to gross wall area ratio
- lighting power density (LPD)
- fan brake horsepower (bhp)
- fan input power per cfm of supply airflow (W/cfm)
- window-to-wall ratio (WWR)

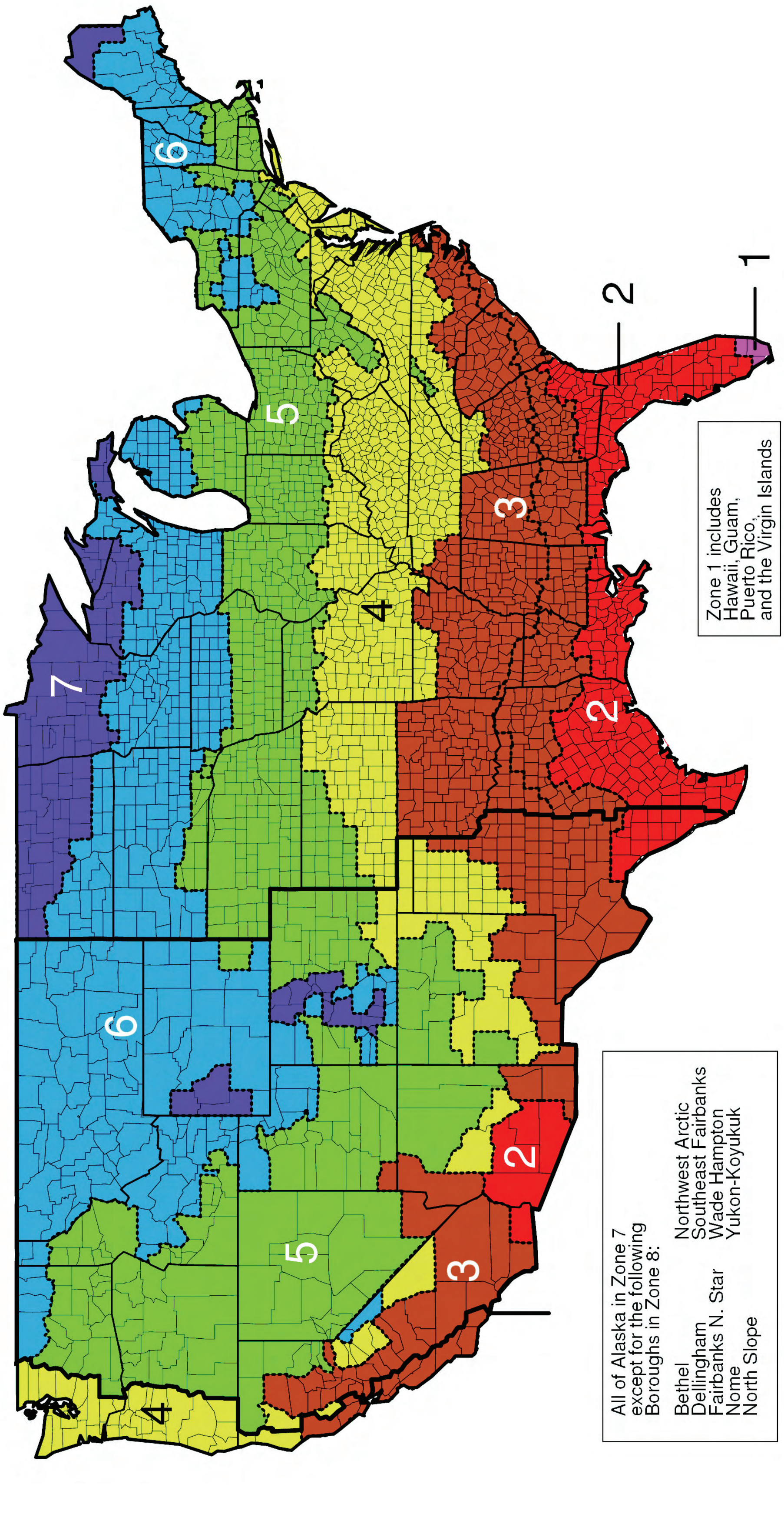
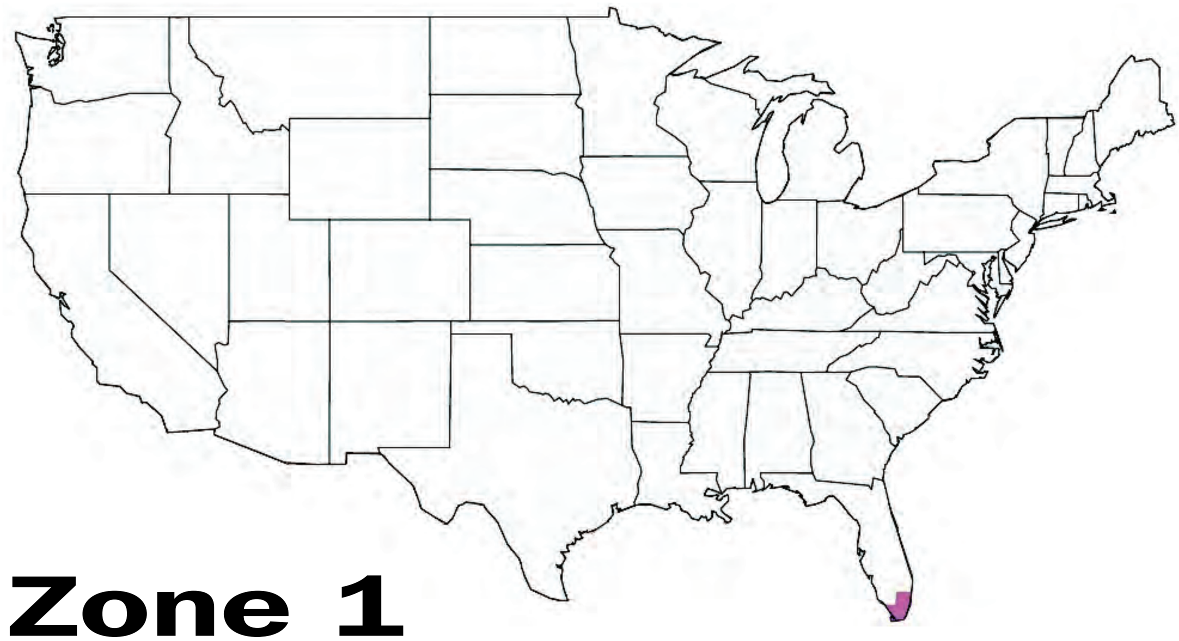


Figure 3-1. DOE climate zone map. A list of counties and their respective climate zones can be found on the following pages and at www.energycodes.gov.



Zone 1

Florida

Broward
Miami-Dade
Monroe

Guam

Hawaii

Puerto Rico

U.S. Virgin Islands

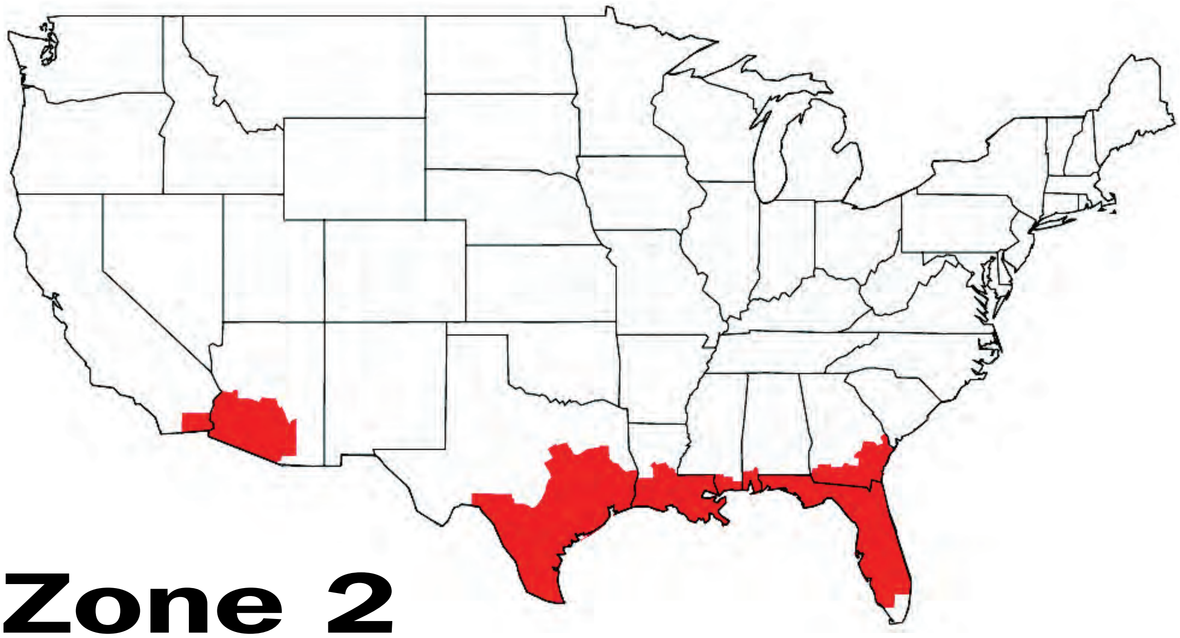
Climate Zone 1 Recommendation Table for Small Hospitals and Healthcare Facilities

	Item	Component	Recommendation (Minimum or Maximum)	How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-25 c.i.	EN2, EN11, EN13	
		SRI	78	EN1	
	Walls	Mass (HC > 7 Btu/ft^2)	R-5.7 c.i.	EN3, EN11, EN13	
		Steel-framed	R-13 +R-7.5 c.i.	EN4, EN11, EN13	
		Below-grade walls	Comply with Standard 90.1*	EN5, EN11, EN13	
	Floors	Mass	R-4.2 c.i.	EN6, EN11, EN13	
		Steel-framed	R-19	EN7, EN11, EN13	
	Slabs	Unheated	Comply with Standard 90.1*	EN8, EN11, EN13	
	Doors	Swinging	U-0.70	EN9, EN13	
		Non-swinging	U-1.450	EN10, EN13	
	Vertical Fenestration	Total fenestration to gross wall area ratio	40% Max	EN15, EN17–18	
		Thermal transmittance (all types and orientations)	U-0.43	EN14	
		SHGC (all types and orientations)	SHGC-0.26	EN14, EN20	
		Visible Transmittance	VT-0.63	EN14, EN 20, EN25	
		Exterior sun control (S, E, and W only)	Projection factor > 0.5	EN16, EN19, EN21, EN26–31, DL5–6, DL20	
	Skylights	Area (percent of roof area)	3% maximum	DL13–16	
		Thermal transmittance (all types)	0.75	DL17	
		SHGC (all types)	SHCG-0.35	DL19	
Lighting/Daylighting	Daylighting	Design the building to maximize access to natural light through sidelighting and toplighting: · Staff areas (exam rooms, nurse stations, offices, and corridors) · Public spaces (waiting and reception)	Diagnostic and treatment block: shape the building footprint such that the area within 15 ft of the perimeter exceeds 40% of the floorplate	DL1–20	
			Inpatient units: ensure that 75% of the occupied space not including patient rooms lies within 20 ft of the perimeter	DL1–20	
	Interior Finishes	Daylighted room interior surface average reflectance	88% on ceilings and walls above 7 ft 50% on walls below 7 ft	EL1, DL22	
	Interior Lighting	LPD	1.0 W/ft^2 or space-by-space method using values in Table 5-9 in EL13	EL13–31, DL1–20	
		Light source system efficacy (linear fluorescent and HID)	90 mean lumens/watt minimum	EL2, EL3	
		Light source system efficacy (all other sources)	50 mean lumens/watt minimum	EL4, EL5	
		Lighting controls (general)	Manual on, auto-off all zones except: no auto-off in 24-h patient care areas (patient rooms, nurses station, etc.)	EL7–11, EL15–32, DL21, DL24–27	
		Daylight-harvesting dimming controls	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	EL12, DL25	
HVAC	Critical Care Areas — Central Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
		DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
		Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
		Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
		Cooling towers	VFD on tower fans	HV19	
		Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
		Economizer	Comply with Standard 90.1*	HV9	
		Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
		Zone airflow setback	Yes	HV1, HV23	

Climate Zone 1 Recommendation Table for Small Hospitals and Healthcare Facilities *(Continued)*

		Item	Component	Recommendation (Minimum or Maximum)	How-To Tips in Chapter 5	✓
HVAC (cont.)	Non-Critical Care Areas	Central VAV Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
			DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
			Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
			Economizer	Comply with Standard 90.1*	HV9	
			Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
			Space temperature setback	Yes	HV17, HV22	
		WSHP System	WSHP < 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.5 COP at 68°F	HV2, HV5, HV6	
			WSHP ≥ 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.2 COP at 68°F	HV2, HV5, HV6	
			Water pumps	VFD and NEMA premium efficiency	HV19, HV20	
			Cooling towers/fluid cooler	VFD on fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV2, HV5, HV6, HV20	
			Economizer	Comply with Standard 90.1*	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness	HV4, HV10	
			WSHP fans	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
		Fan-Coil and Chiller System	Air-cooled chiller efficiency	10.0 EER, 11.5 IPLV	HV3, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV3, HV5, HV6, HV20	
			Economizer	Comply with Standard 90.1*	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness	HV4, HV10	
			Fan-coil units	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
	Ducts and Dampers		Outdoor air damper	Motorized	HV8	
			Duct seal class	Supply and ducts located outdoors = Seal Class A Return and exhaust = Seal Class B	HV13	
			Insulation level	R-6	HV12	
SWH	Service Water Heating		Gas storage (>75 kBtu/h)	90% E_t	WH1–5	
			Gas instantaneous	0.81 EF or 81% E_t	WH1–5	
			Electric (storage or instantaneous)	EF > 0.99–0.0012 × Volume	WH1–5	
			Pipe insulation (d < 1.5 in. / d ≥ 1.5 in.)	1 in./1.5 in.	WH6	

*Note: If the table contains "Comply with Standard 90.1" for a component, the user must meet the more stringent of either the applicable edition of Standard 90.1 or the local code requirements.



Zone 2

Alabama

Baldwin
Mobile

Arizona

La Paz
Maricopa
Pima
Pinal
Yuma

California

Imperial

Florida

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

Georgia

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

Louisiana

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

Mississippi

Hancock
Harrison
Jackson
Pearl River
Stone

Texas

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

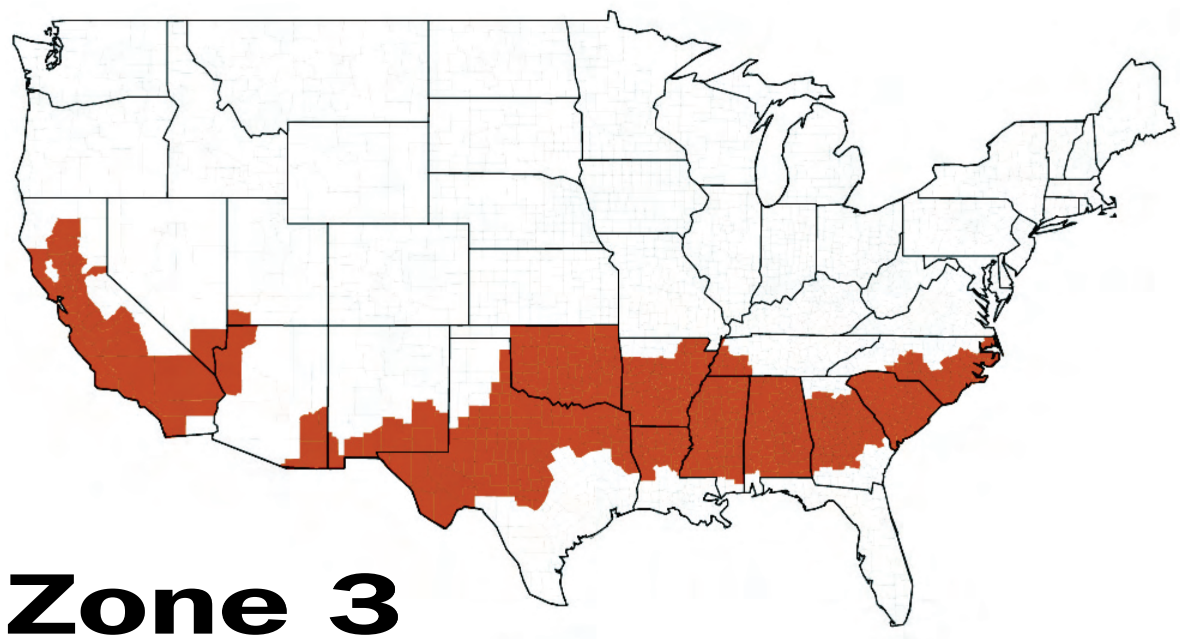
Climate Zone 2 Recommendation Table for Small Hospitals and Healthcare Facilities

	Item	Component	Recommendation	How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-25 c.i.	EN2, EN11, EN13	
		SRI	78	EN1	
	Walls	Mass (HC > 7 Btu/ft^2)	R-7.6 c.i.	EN3, EN11, EN13	
		Steel-framed	R-13 + R-7.5 c.i.	EN4, EN11, EN13	
		Below-grade walls	Comply with Standard 90.1*	EN5, EN11, EN13	
	Floors	Mass	R-10.4 c.i.	EN6, EN11, EN13	
		Steel-framed	R-30	EN7, EN11, EN13	
	Slabs	Unheated	Comply with Standard 90.1*	EN8, EN11, EN13	
	Doors	Swinging	U-0.70	EN9, EN13	
		Non-swinging	U-0.50	EN10, EN13	
	Vertical Fenestration	Total fenestration to gross wall area ratio	40% Max	EN15, EN17–18	
		Thermal transmittance (all types and orientations)	U-0.43	EN14	
		SHGC (all types and orientations)	SHGC-0.26	EN14, EN20	
		Visible transmittance	VT-0.63	EN14, EN 20, EN25	
		Exterior sun control (S, E, and W only)	Projection factor > 0.5	EN16, EN19, EN21, EN26–31, DL5–6, DL20	
Lighting/Daylighting	Skylights	Area (percent of roof area)	3% maximum	DL13–16	
		Thermal transmittance (all types)	0.75	DL17	
		SHGC (all types)	SHCG-0.35	DL19	
	Daylighting	Design the building to maximize access to natural light through sidelighting and toplighting: · Staff areas (exam rooms, nurse stations, offices, and corridors) · Public spaces (waiting and reception)	Diagnostic and treatment block: shape the building footprint such that the area within 15 ft of the perimeter exceeds 40% of the floorplate	DL1–20	
			Inpatient units: ensure that 75% of the occupied space not including patient rooms lies within 20 ft of the perimeter	DL1–20	
	Interior Finishes	Daylighted room interior surface average reflectance	88% on ceilings and walls above 7 ft 50% on walls below 7 ft	EL1, DL14	
	Interior Lighting	LPD	1.0 W/ft^2 or space-by-space method using values in Table 5-9 in EL13	EL13–31, DL1–19	
		Light source system efficacy (linear fluorescent and HID)	90 mean lumens/watt minimum	EL2, EL3	
		Light source system efficacy (all other sources)	50 mean lumens/watt minimum	EL4, EL5	
		Lighting controls (general)	Manual on, auto-off all zones except: no auto-off in 24-h patient care areas (patient rooms, nurses station, etc.)	EL7–11, EL15–32, DL16	
		Daylight-harvesting dimming controls	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	EL12, DL16	
HVAC	Critical Care Areas — Central Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
		DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
		Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
		Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
		Cooling towers	VFD on tower fans	HV19	
		Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
		Economizer	Humid zones A: Not required Dry zones B: Yes	HV9	
		Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
		Zone airflow setback	Yes	HV1, HV23	

Climate Zone 2 Recommendation Table for Small Hospitals and Healthcare Facilities *(Continued)*

	Item		Component	Recommendation	How-To Tips in Chapter 5	✓
HVAC (cont.)	Non-Critical Care Areas	Central VAV Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
			DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
			Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
			Economizer	Humid zones A: Not required Dry zones B: Yes	HV9	
			Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
			Space temperature setback	Yes	HV17, HV22	
		WSHP System	WSHP < 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.5 COP at 68°F	HV2, HV5, HV6	
			WSHP ≥ 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.2 COP at 68°F	HV2, HV5, HV6	
			Water pumps	VFD and NEMA premium efficiency	HV19, HV20	
			Cooling towers/fluid cooler	VFD on fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV2, HV5, HV6, HV20	
			Economizer	Comply with Standard 90.1*	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness	HV4, HV10	
			WSHP fans	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
		Fan-Coil and Chiller System	Air-cooled chiller efficiency	10.0 EER, 11.5 IPLV	HV3, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV3, HV5, HV6, HV20	
			Economizer	Humid zones A: Not required Dry zones B: Water-side economizer	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness	HV4, HV10	
			Fan-coil units	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
	Ducts and Dampers		Outdoor air damper	Motorized	HV8	
			Duct seal class	Supply and ducts located outdoors = Seal Class A Return and exhaust = Seal Class B	HV13	
			Insulation level	R-6	HV12	
SWH	Service Water Heating		Gas storage (>75 kBtu/h)	90% E_t	WH1–5	
			Gas instantaneous	0.81 EF or 81% E_t	WH1–5	
			Electric (storage or instantaneous)	EF > 0.99–0.0012 × Volume	WH1–5	
			Pipe insulation (d < 1.5 in. / d ≥ 1.5 in.)	1 in./1.5 in.	WH6	

*Note: If the table contains “Comply with Standard 90.1” for a component, the user must meet the more stringent of either the applicable edition of Standard 90.1 or the local code requirements.



Zone 3

Alabama

All counties except:
Baldwin
Mobile

Arizona

Cochise
Graham
Greenlee
Mohave
Santa Cruz

Arkansas

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

California

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

Georgia

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

Louisiana

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

Mississippi

All counties except:
Hancock
Harrison
Jackson
Pearl River
Stone

New Mexico

Chaves
Dona Ana
Eddy
Hidalgo
Lea
Luna
Otero

Nevada

Clark

Texas

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

Utah

Washington

North Carolina

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

Oklahoma

All counties except:
Beaver
Cimarron
Texas

South Carolina

All counties

Tennessee

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

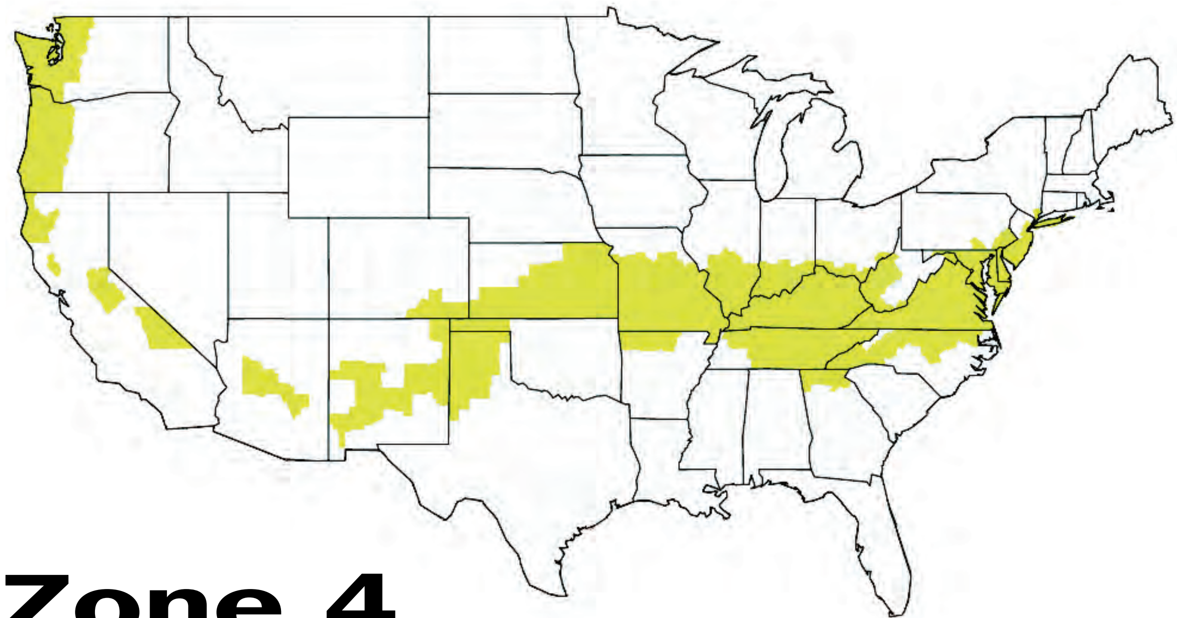
Climate Zone 3 Recommendation Table for Small Hospitals and Healthcare Facilities

	Item	Component	Recommendation	How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-25 c.i.	EN2, EN11, EN13	
		SRI	78	EN1	
	Walls	Mass (HC > 7 Btu/ft^2)	R-11.4 c.i.	EN3, EN11, EN13	
		Steel-framed	R-13 + R-7.5 c.i.	EN4, EN11, EN13	
		Below-grade walls	R-7.5 c.i.	EN5, EN11, EN13	
	Floors	Mass	R-12.5 c.i.	EN6, EN11, EN13	
		Steel-framed	R-30	EN7, EN11, EN13	
	Slabs	Unheated	Comply with Standard 90.1*	EN8, EN11, EN13	
	Doors	Swinging	U-0.70	EN9, EN13	
		Non-swinging	U-0.50	EN10, EN13	
	Vertical Fenestration	Total fenestration to gross wall area ratio	40% Max	EN15, EN17–18	
		Thermal transmittance (all types and orientations)	U-0.43	EN14	
		SHGC (all types and orientations)	SHGC-0.26	EN14, EN20	
		Visible transmittance	VT-0.63	EN14, EN 20, EN25	
		Exterior sun control (S, E, and W only)	Projection factor > 0.5	EN16, EN19, EN21, EN26-31, DL5–6, DL20	
	Skylights	Area (percent of roof area)	3% maximum	DL13–16	
		Thermal transmittance (all types)	0.65	DL17	
		SHGC (all types)	SHCG-0.35	DL19	
Lighting/Daylighting	Daylighting	Design the building to maximize access to natural light through sidelighting and toplighting: · Staff areas (exam rooms, nurse stations, offices, and corridors) · Public spaces (waiting and reception)	Diagnostic and treatment block: shape the building footprint such that the area within 15 ft of the perimeter exceeds 40% of the floorplate	DL1–20	
			Inpatient units: ensure that 75% of the occupied space not including patient rooms lies within 20 ft of the perimeter	DL1–20	
	Interior Finishes	Daylighted room interior surface average reflectance	88% on ceilings and walls above 7 ft 50% on walls below 7 ft	EL1, DL14	
	Interior Lighting	LPD	1.0 W/ft^2 or space-by-space method using values in Table 5-9 in EL13	EL13–31, DL1–19	
		Light source system efficacy (linear fluorescent and HID)	90 mean lumens/watt minimum	EL2, EL3	
		Light source system efficacy (all other sources)	50 mean lumens/watt minimum	EL4, EL5	
		Lighting controls (general)	Manual on, auto-off all zones except: no auto-off in 24-h patient care areas (patient rooms, nurses station, etc.)	EL7–11, EL15–32, DL16	
		Daylight-harvesting dimming controls	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	EL12, DL16	
HVAC	Critical Care Areas — Central Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
		DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
		Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
		Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
		Cooling towers	VFD on tower fans	HV19	
		Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
		Economizer	Humid zones A: Not required Dry zones B: Yes Marine zones C: Yes	HV9	
		Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
		Zone airflow setback	Yes	HV1, HV23	

Climate Zone 3 Recommendation Table for Small Hospitals and Healthcare Facilities *(Continued)*

		Item	Component	Recommendation	How-To Tips in Chapter 5	✓
HVAC (cont.)	Non-Critical Care Areas	Central VAV Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
			DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
			Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
			Economizer	Humid zones A: Not required Dry zones B: Yes Marine zones C: Yes	HV9	
			Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
			Space temperature setback	Yes	HV17, HV22	
		WSHP System	WSHP < 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.5 COP at 68°F	HV2, HV5, HV6	
			WSHP ≥ 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.2 COP at 68°F	HV2, HV5, HV6	
			Water pumps	VFD and NEMA premium efficiency	HV19, HV20	
			Cooling towers/fluid cooler	VFD on fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV2, HV5, HV6, HV20	
			Economizer	Comply with Standard 90.1*	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness Marine zones C: 50% total effectiveness	HV4, HV10	
			WSHP fans	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
		Fan-Coil and Chiller System	Air-cooled chiller efficiency	10.0 EER, 11.5 IPLV	HV3, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV3, HV5, HV6, HV20	
			Economizer	Humid zones A: Not required Dry zones B: Water-side economizer Marine zones C: Water-side economizer	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness Marine zones C: 50% total effectiveness	HV4, HV10	
			Fan-coil units	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
	Ducts and Dampers		Outdoor air damper	Motorized	HV8	
			Duct seal class	Supply and ducts located outdoors = Seal Class A Return and exhaust = Seal Class B	HV13	
			Insulation level	R-6	HV12	
SWH	Service Water Heating		Gas storage (> 75 kBtu/h)	90% E_t	WH1–5	
			Gas instantaneous	0.81 EF or 81% E_t	WH1–5	
			Electric (storage or instantaneous)	EF > 0.99–0.0012 × Volume	WH1–5	
			Pipe insulation (d < 1.5 in. / d ≥ 1.5 in.)	1 in./1.5 in.	WH6	

*Note: If the table contains "Comply with Standard 90.1" for a component, the user must meet the more stringent of either the applicable edition of Standard 90.1 or the local code requirements.



Zone 4

Arizona
Gila
Yavapai

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

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

Colorado
Baca
Las Animas
Otero

Delaware
All counties

District of Columbia

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

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

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

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

Kentucky
All counties

Maryland
All counties except:
Garrett

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

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

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

New York
Bronx
Kings
Nassau
New York
Queens
Richmond
Suffolk
Westchester

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

Ohio
Adams
Brown
Clermont
Gallia
Hamilton
Lawrence
Pike
Scioto
Washington

Oklahoma
Beaver
Cimarron
Texas

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

Pennsylvania
Bucks
Chester
Delaware
Montgomery
Philadelphia
York

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

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

Virginia
All counties

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

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

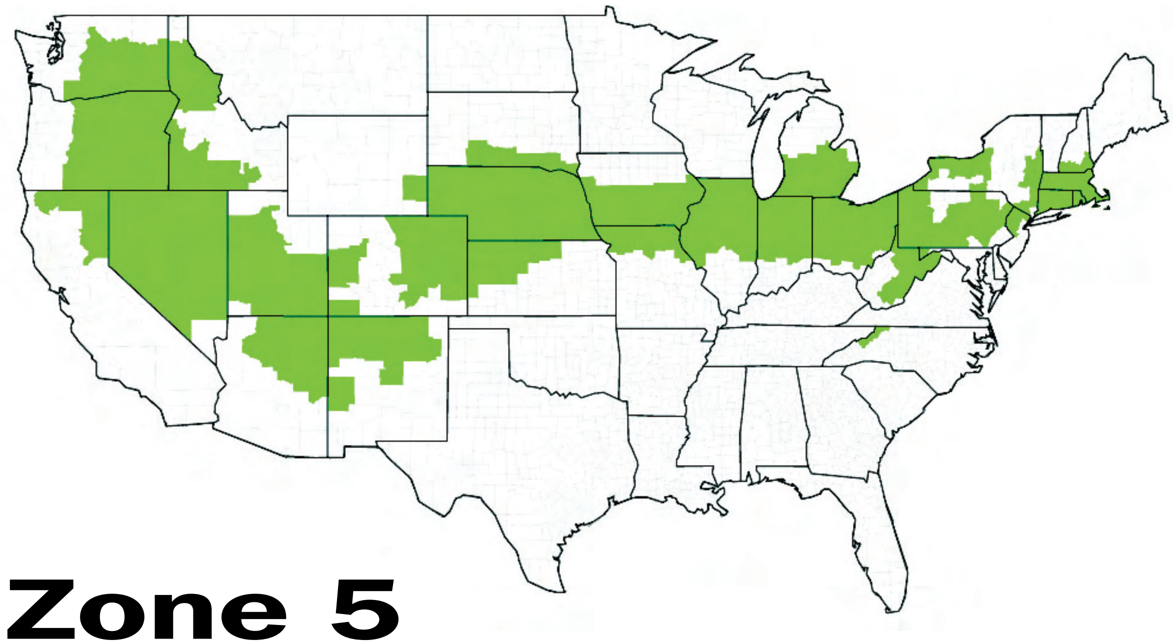
Climate Zone 4 Recommendation Table for Small Hospitals and Healthcare Facilities

	Item		Component	Recommendation	How-to Tips in Chapter 5	✓
Envelope	Roof		Insulation entirely above deck	R-30 c.i.	EN2, EN11, EN13	
			SRI	Comply with Standard 90.1*	EN1	
	Walls		Mass (HC > 7 Btu/ft^2)	R-13.3 c.i.	EN3, EN11, EN13	
			Steel-framed	R-13 + R-7.5 c.i.	EN4, EN11, EN13	
			Below-grade walls	R-7.5 c.i.	EN5, EN11, EN13	
	Floors		Mass	R-14.6 c.i.	EN6, EN11, EN13	
			Steel-framed	R-38	EN7, EN11, EN13	
	Slabs		Unheated	R-15 for 24 in.	EN8, EN11, EN13	
	Doors		Swinging	U-0.50	EN9, EN13	
			Non-swinging	U-0.50	EN10, EN13	
	Vertical Fenestration		Total fenestration to gross wall area ratio	40% Max	EN15, EN17–18	
			Thermal transmittance (all types and orientations)	U-0.29	EN14	
			SHGC (all types and orientations)	SHGC-0.34	EN14, EN23–24	
			Visible transmittance	VT-0.69	EN14, EN25	
			Exterior sun control (S, E, and W only)	Projection factor > 0.5	EN16, EN21–22 EN26–31, DL5–6, DL20	
	Skylights		Area (percent of roof area)	3% maximum	DL13–16	
			Thermal transmittance (all types)	0.60	DL18	
			SHGC (all types)	SHCG-0.40	DL19	
Lighting/Daylighting	Daylighting		Design the building to maximize access to natural light through sidelighting and toplighting: · Staff areas (exam rooms, nurse stations, offices, and corridors) · Public spaces (waiting and reception)	Diagnostic and treatment block: shape the building footprint such that the area within 15 ft of the perimeter exceeds 40% of the floorplate	DL1–20	
				Inpatient units: ensure that 75% of the occupied space not including patient rooms lies within 20 ft of the perimeter	DL1–20	
	Interior Finishes		Daylighted room interior surface average reflectance	88% on ceilings and walls above 7 ft 50% on walls below 7 ft	EL1, DL14	
	Interior Lighting		LPD	1.0 W/ft^2 or space-by-space method using values in Table 5-9 in EL13	EL13–31, DL1–19	
			Light source system efficacy (linear fluorescent and HID)	90 mean lumens/watt minimum	EL2, EL3	
			Light source system efficacy (all other sources)	50 mean lumens/watt minimum	EL4, EL5	
			Lighting controls (general)	Manual on, auto-off all zones except: no auto-off in 24-h patient care areas (patient rooms, nurses station, etc.)	EL7–11, EL15–32, DL16	
			Daylight-harvesting dimming controls	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	EL12, DL16	
HVAC	Critical Care Areas	Central Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
			DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
			Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
			Economizer	Humid zones A: Not required Dry zones B: Yes Marine zones C: Yes	HV9	
			Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
			Zone airflow setback	Yes	HV1, HV23	

Climate Zone 4 Recommendation Table
for Small Hospitals and Healthcare Facilities *(Continued)*

		Item	Component	Recommendation	How-to Tips in Chapter 5	✓
HVAC (cont.)	Non-Critical Care Areas	Central VAV Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
			DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
			Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
			Economizer	Humid zones A: Not required Dry zones B: Yes Marine zones C: Yes	HV9	
			Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
			Space temperature setback	Yes	HV17, HV22	
		WSHP System	WSHP < 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.5 COP at 68°F	HV2, HV5, HV6	
			WSHP ≥ 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.2 COP at 68°F	HV2, HV5, HV6	
			Water pumps	VFD and NEMA premium efficiency	HV19, HV20	
			Cooling towers/fluid cooler	VFD on fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV2, HV5, HV6, HV20	
			Economizer	Comply with Standard 90.1*	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness Marine zones C: 50% total effectiveness	HV4, HV10	
			WSHP fans	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
		Fan-Coil and Chiller System	Air-cooled chiller efficiency	10.0 EER, 11.5 IPLV	HV3, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV3, HV5, HV6, HV20	
			Economizer	Humid zones A: Not required Dry zones B: Water-side economizer Marine zones C: Water-side economizer	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness Marine zones C: 50% total effectiveness	HV4, HV10	
			Fan-coil units	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
	Ducts and Dampers		Outdoor air damper	Motorized	HV8	
			Duct seal class	Supply and ducts located outdoors = Seal Class A Return and exhaust = Seal Class B	HV13	
			Insulation level	R-6	HV12	
SWH	Service Water Heating		Gas storage (>75 kBtu/h)	90% E_t	WH1–5	
			Gas instantaneous	0.81 EF or 81% E_t	WH1–5	
			Electric (storage or instantaneous)	EF > 0.99–0.0012 × Volume	WH1–5	
			Pipe insulation (d < 1.5 in. / d ≥ 1.5 in.)	1 in./1.5 in.	WH6	

*Note: If the table contains "Comply with Standard 90.1" for a component, the user must meet the more stringent of either the applicable edition of Standard 90.1 or the local code requirements.



Zone 5

Arizona

Apache
Coconino
Navajo

California

Lassen
Modoc
Nevada
Plumas
Sierra
Siskiyou

Colorado

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

Connecticut

All counties

Idaho

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

Illinois

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

Indiana

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

Iowa

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

Kansas

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

Maryland

Garrett

Massachusetts

All counties

Michigan

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

Missouri

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

Nebraska

All counties

Nevada

All counties except:
Clark

New Hampshire

Cheshire
Hillsborough
Rockingham
Strafford

New Jersey

Bergen
Hunterdon
Mercer
Morris
Passaic
Somerset
Sussex
Warren

New Mexico

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

New York

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

North Carolina

Alleghany
Ashe
Avery
Mitchell
Watauga
Yancey

Ohio

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

Oregon

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

Pennsylvania

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

Rhode Island

All counties

South Dakota

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

Utah

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

Washington

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

Wyoming

Goshen
Platte

West Virginia

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

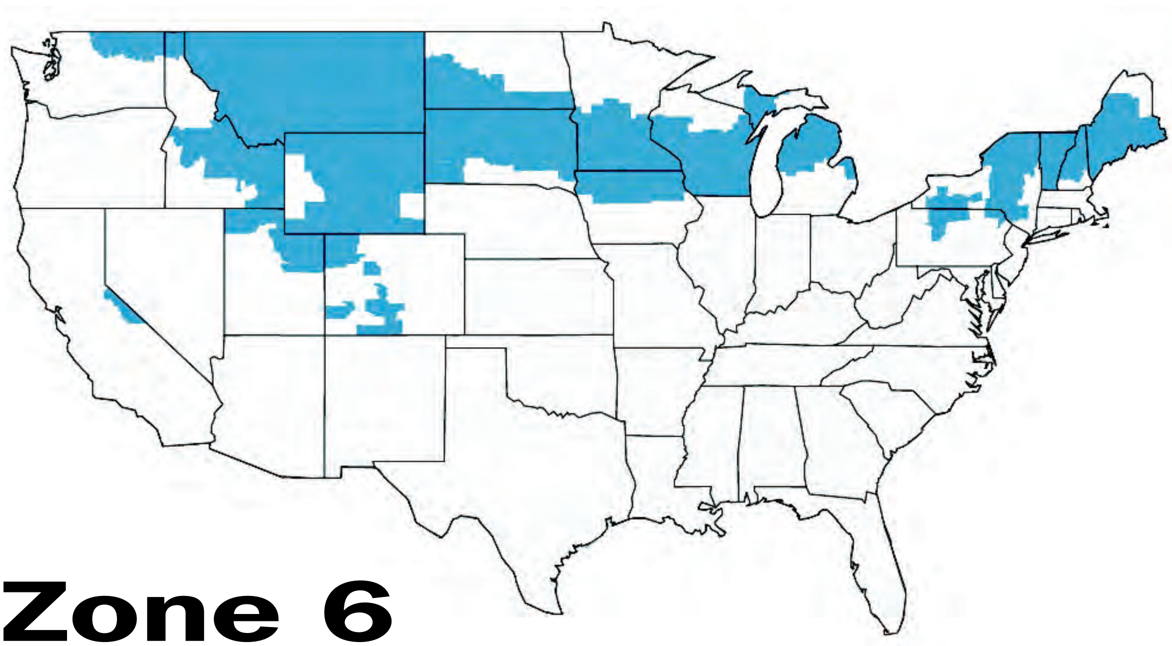
Climate Zone 5 Recommendation Table for Small Hospitals and Healthcare Facilities

	Item	Component	Recommendation	How-to Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-30 c.i.	EN2, EN11, EN13	
		SRI	Comply with Standard 90.1*	EN1	
	Walls	Mass (HC > 7 Btu/ft^2)	R-13.3 c.i.	EN3, EN11, EN13	
		Steel-framed	R-13 + R-15.6 c.i.	EN4, EN11, EN13	
		Below-grade walls	R-7.5 c.i.	EN5, EN11, EN13	
	Floors	Mass	R-16.7 c.i.	EN6, EN11, EN13	
		Steel-framed	R-38	EN7, EN11, EN13	
	Slabs	Unheated	R-15 for 24 in.	EN8, EN11, EN13	
	Doors	Swinging	U-0.50	EN9, EN13	
		Non-swinging	U-0.50	EN10, EN13	
	Vertical Fenestration	Total fenestration to gross wall area ratio	40% Max	EN15, EN17–18	
		Thermal transmittance (all types and orientations)	U-0.29	EN14	
		SHGC (all types and orientations)	SHGC-0.34	EN14, EN23–24	
		Visible transmittance	VT-0.69	EN14, EN25	
		Exterior sun control (S, E, and W only)	Projection factor > 0.5	EN16, EN21–22, EN26–31, DL5–6, DL20	
	Skylights	Area (percent of roof area)	3% maximum	DL13–16	
		Thermal transmittance (all types)	0.60	DL18	
		SHGC (all types)	SHCG-0.40	DL19	
Lighting/Daylighting	Daylighting	Design the building to maximize access to natural light through sidelighting and toplighting: · Staff areas (exam rooms, nurse stations, offices, and corridors) · Public spaces (waiting and reception)	Diagnostic and treatment block: shape the building footprint such that the area within 15 ft of the perimeter exceeds 40% of the floorplate	DL1–20	
			Inpatient units: ensure that 75% of the occupied space not including patient rooms lies within 20 ft of the perimeter	DL1–20	
	Interior Finishes	Daylighted room interior surface average reflectance	88% on ceilings and walls above 7 ft 50% on walls below 7 ft	EL1, DL14	
	Interior Lighting	LPD	1.0 W/ft^2 or space-by-space method using values in Table 5-9 in EL13	EL13–31, DL1–19	
		Light source system efficacy (linear fluorescent and HID)	90 mean lumens/watt minimum	EL2, EL3	
		Light source system efficacy (all other sources)	50 mean lumens/watt minimum	EL4, EL5	
		Lighting controls (general)	Manual on, auto-off all zones except: no auto-off in 24-h patient care areas (patient rooms, nurses station, etc.)	EL7–11, EL15–32, DL16	
		Daylight-harvesting dimming controls	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	EL12, DL16	
HVAC	Critical Care Areas: Central Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
		DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
		Air-cooled chiller efficiency	9.6 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
		Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
		Cooling towers	VFD on tower fans	HV19	
		Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
		Economizer	Yes	HV9	
		Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
		Zone airflow setback	Yes	HV1, HV23	

Climate Zone 5 Recommendation Table for Small Hospitals and Healthcare Facilities *(Continued)*

	Item		Component	Recommendation	How-to Tips in Chapter 5	✓
HVAC (cont.)	Non-Critical Care Areas	Central VAV Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	HV1, HV5, HV6	
			DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	HV1, HV5, HV6	
			Air-cooled chiller efficiency	9.6 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
			Economizer	Yes	HV9	
			Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
			Space temperature setback	Yes	HV17, HV22	
		WSHP System	WSHP < 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.5 COP at 68°F	HV2, HV5, HV6	
			WSHP ≥ 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.2 COP at 68°F	HV2, HV5, HV6	
			Water pumps	VFD and NEMA premium efficiency	HV19, HV20	
			Cooling towers/fluid cooler	VFD on fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV2, HV5, HV6, HV20	
			Economizer	Comply with Standard 90.1*	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness Marine zones C: 50% total effectiveness	HV4, HV10	
			WSHP fans	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
		Fan-Coil and Chiller System	Air-cooled chiller efficiency	9.6 EER, 11.5 IPLV	HV3, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV3, HV5, HV6, HV20	
			Economizer	Water-side economizer	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness Marine zones C: 50% total effectiveness	HV4, HV10	
			Fan-coil units	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
	Ducts and Dampers		Outdoor air damper	Motorized	HV8	
			Duct seal class	Supply and ducts located outdoors = Seal Class A Return and exhaust = Seal Class B	HV13	
			Insulation level	R-6	HV12	
SWH	Service Water Heating		Gas storage (>75 kBtu/h)	90% E_t	WH1–5	
			Gas instantaneous	0.81 EF or 81% E_t	WH1–5	
			Electric (storage or instantaneous)	EF > 0.99–0.0012 × Volume	WH1–5	
			Pipe insulation (d < 1.5 in. / d ≥ 1.5 in.)	1 in./1.5 in.	WH6	

*Note: If the table contains "Comply with Standard 90.1" for a component, the user must meet the more stringent of either the applicable edition of Standard 90.1 or the local code requirements.



Zone 6

California

- Alpine
- Mono

Colorado

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

Idaho

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

Iowa

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

Maine

- *All counties except:*
- Aroostook

Michigan

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

Minnesota

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

Montana

- All counties

New Hampshire

- Belknap
- Carroll
- Coos
- Grafton
- Merrimack
- Sullivan

New York

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

North Dakota

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

Pennsylvania

- Cameron
- Clearfield
- Elk
- McKean
- Potter
- Susquehanna
- Tioga
- Wayne

South Dakota

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

Utah

- Box Elder
- Cache
- Carbon
- Daggett
- Duchesne
- Morgan
- Rich
- Summit
- Uintah
- Wasatch

Vermont

- All counties

Washington

- Ferry
- Okanogan
- Pend Oreille
- Stevens

Wisconsin

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

Wyoming

- *All counties except:*
- Goshen
- Platte
- Lincoln
- Sublette
- Teton

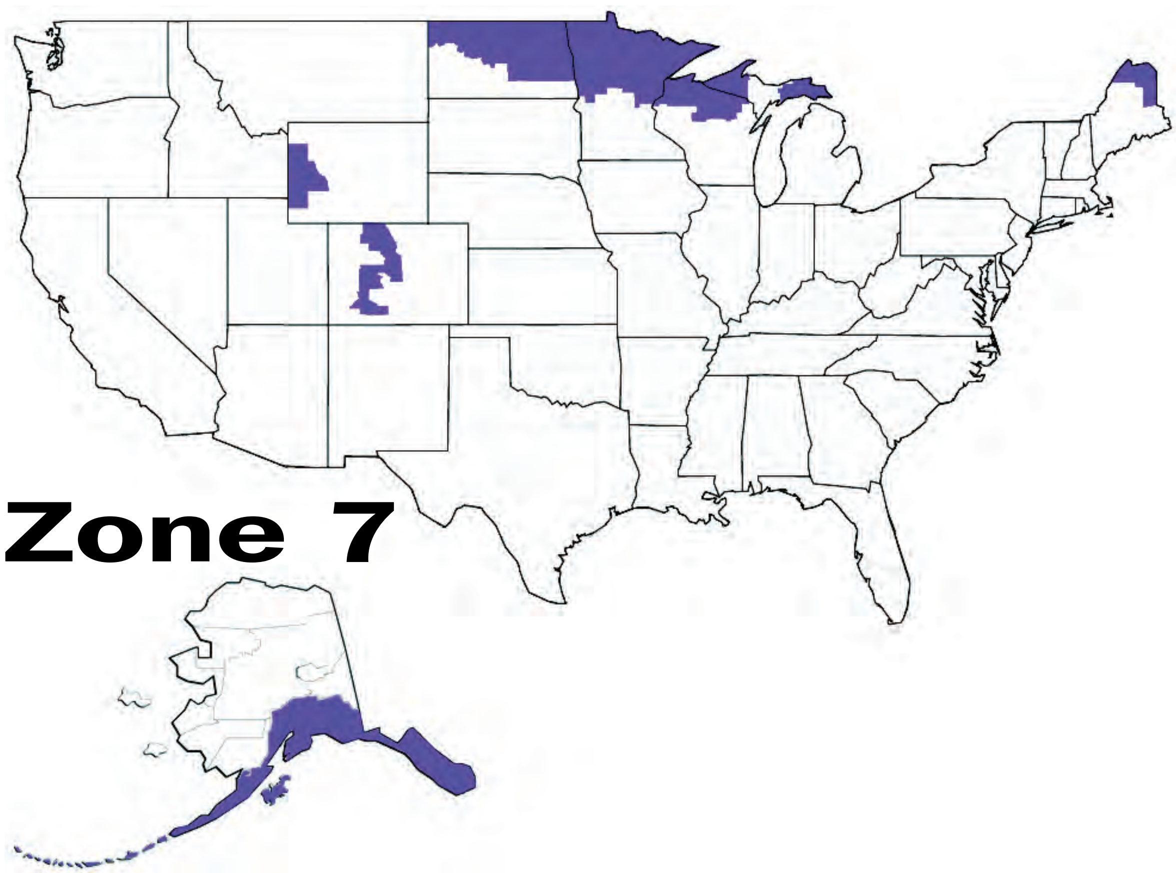
Climate Zone 6 Recommendation Table for Small Hospitals and Healthcare Facilities

	Item	Component	Recommendation	How-to Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-30 c.i.	EN2, EN11, EN13	
		SRI	Comply with Standard 90.1*	EN1	
	Walls	Mass (HC > 7 Btu/ft^2)	R-19.5 c.i.	EN3, EN11, EN13	
		Steel-framed	R-13 + R-18.8 c.i.	EN4, EN11, EN13	
		Below-grade walls	R-12.5 c.i.	EN5, EN11, EN13	
	Floors	Mass	R-19.5 c.i.	EN6, EN11, EN13	
		Steel-framed	R-49	EN7, EN11, EN13	
	Slabs	Unheated	R-20 for 24 in.	EN8, EN11, EN13	
	Doors	Swinging	U-0.50	EN9, EN13	
		Non-swinging	U-0.50	EN10, EN13	
	Vertical Fenestration	Total fenestration to gross wall area ratio	40% Max	EN15, EN17–18	
		Thermal transmittance (all types and orientations)	U-0.29	EN14	
		SHGC (all types and orientations)	SHGC-0.34	EN14, EN23–24	
		Visible transmittance	VT-0.69	EN14, EN25	
		Exterior sun control (S, E, and W only)	Projection factor > 0.5	EN16, EN21–22, EN26–31, DL5–6, DL20	
	Skylights	Area (percent of roof area)	3% maximum	DL13–16	
		Thermal transmittance (all types)	0.60	DL18	
		SHGC (all types)	SHCG-0.40	DL19	
Lighting/Daylighting	Daylighting	Design the building to maximize access to natural light through sidelighting and toplighting: · Staff areas (exam rooms, nurse stations, offices, and corridors) · Public spaces (waiting and reception)	Diagnostic and treatment block: shape the building footprint such that the area within 15 ft of the perimeter exceeds 40% of the floorplate	DL1–20	
			Inpatient units: ensure that 75% of the occupied space not including patient rooms lies within 20 ft of the perimeter	DL1–20	
	Interior Finishes	Daylighted room interior surface average reflectance	88% on ceilings and walls above 7 ft 50% on walls below 7 ft	EL1, DL14	
	Interior Lighting	LPD	1.0 W/ft^2 or space-by-space method using values in Table 5-9 in EL13	EL13–31, DL1–19	
		Light source system efficacy (linear fluorescent and HID)	90 mean lumens/watt minimum	EL2, EL3	
		Light source system efficacy (all other sources)	50 mean lumens/watt minimum	EL4, EL5	
		Lighting controls (general)	Manual on, auto-off all zones except: no auto-off in 24-h patient care areas (patient rooms, nurses station, etc.)	EL7–11, EL15–32, DL16	
		Daylight-harvesting dimming controls	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	EL12, DL16	
HVAC	Critical Care Areas — Central Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
		DX air conditioner (≥ 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
		Air-cooled chiller efficiency	9.6 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
		Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
		Cooling towers	VFD on tower fans	HV19	
		Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
		Economizer	Yes	HV9	
		Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
		Zone airflow setback	Yes	HV1, HV23	

Climate Zone 6 Recommendation Table for Small Hospitals and Healthcare Facilities *(Continued)*

		Item	Component	Recommendation	How-to Tips in Chapter 5	✓
HVAC (cont.)	Non-Critical Care Areas	Central VAV Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
			DX air conditioner (≥ 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
			Air-cooled chiller efficiency	9.6 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
			Economizer	Yes	HV9	
			Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
			Space temperature setback	Yes	HV17, HV22	
		WSHP System	WSHP < 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.5 COP at 68°F	HV2, HV5, HV6	
			WSHP ≥ 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.2 COP at 68°F	HV2, HV5, HV6	
			Water pumps	VFD and NEMA premium efficiency	HV19, HV20	
			Cooling towers/fluid cooler	VFD on fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV2, HV5, HV6, HV20	
			Economizer	Comply with Standard 90.1*	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness	HV4, HV10	
			WSHP fans	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
		Fan-Coil and Chiller System	Air-cooled chiller efficiency	9.6 EER, 11.5 IPLV	HV3, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV3, HV5, HV6, HV20	
			Economizer	Water-side economizer	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness	HV4, HV10	
			Fan-coil units	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
	Ducts and Dampers		Outdoor air damper	Motorized	HV8	
			Duct seal class	Supply and ducts located outdoors = Seal Class A Return and exhaust = Seal Class B	HV13	
			Insulation level	R-6	HV12	
SWH	Service Water Heating		Gas storage (>75 kBtu/h)	90% E_t	WH1–5	
			Gas instantaneous	0.81 EF or 81% E_t	WH1–5	
			Electric (storage or instantaneous)	EF > 0.99–0.0012 × Volume	WH1–5	
			Pipe insulation (d < 1.5 in. / d ≥ 1.5 in.)	1 in./1.5 in.	WH6	

*Note: If the table contains “Comply with Standard 90.1” for a component, the user must meet the more stringent of either the applicable edition of Standard 90.1 or the local code requirements.



Zone 7

Alaska

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

Colorado

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

Maine

Aroostook

Michigan

Baraga
Chippewa
Gogebic
Houghton
Iron
Keweenaw
Luce
Mackinac
Ontonagon
Schoolcraft

Minnesota

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

North Dakota

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

Wisconsin

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

Wyoming

Lincoln
Sublette
Teton

Climate Zone 7 Recommendation Table for Small Hospitals and Healthcare Facilities

	Item	Component	Recommendation	How-to Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-35 c.i.	EN2, EN11, EN13	
		SRI	Comply with Standard 90.1*	EN1	
	Walls	Mass (HC > 7 Btu/ft^2)	R-19.5 c.i.	EN3, EN11, EN13	
		Steel-framed	R-13 + R-18.8 c.i.	EN4, EN11, EN13	
		Below-grade walls	R-15 c.i.	EN5, EN11, EN13	
	Floors	Mass	R-20.9 c.i.	EN6, EN11, EN13	
		Steel-framed	R-60	EN7, EN11, EN13	
	Slabs	Unheated	R-20 for 24 in.	EN8, EN11, EN13	
	Doors	Swinging	U-0.50	EN9, EN13	
		Non-swinging	U-0.50	EN10, EN13	
	Vertical Fenestration	Total fenestration to gross wall area ratio	40% Max	EN15, EN17–18	
		Thermal transmittance (all types and orientations)	U-0.29	EN14	
		SHGC (all types and orientations)	SHGC-0.34	EN14, EN23–24	
		Visible transmittance	VT-0.69	EN14, EN25	
		Exterior sun control (S, E, and W only)	Projection factor > 0.5	EN16, EN21–22 EN26–31, DL5–6, DL20	
	Skylights	Area (percent of roof area)	3% maximum	DL13–16	
		Thermal transmittance (all types)	0.60	DL18	
		SHGC (all types)	Comply with Standard 90.1*	DL19	
Lighting/Daylighting	Daylighting	Design the building to maximize access to natural light through sidelighting and toplighting: · Staff areas (exam rooms, nurse stations, offices, and corridors) · Public spaces (waiting and reception)	Diagnostic and treatment block: shape the building footprint such that the area within 15 ft of the perimeter exceeds 40% of the floorplate	DL1–20	
			Inpatient units: ensure that 75% of the occupied space not including patient rooms lies within 20 ft of the perimeter	DL1–20	
	Interior Finishes	Daylighted room interior surface average reflectance	88% on ceilings and walls above 7 ft 50% on walls below 7 ft	EL1, DL14	
	Interior Lighting	LPD	1.0 W/ft^2 or space-by-space method using values in Table 5-9 in EL13	EL13–31, DL1–19	
		Light source system efficacy (linear fluorescent and HID)	90 mean lumens/watt minimum	EL2, EL3	
		Light source system efficacy (all other sources)	50 mean lumens/watt minimum	EL4, EL5	
		Lighting controls (general)	Manual on, auto-off all zones except: no auto-off in 24-h patient care areas (patient rooms, nurses station, etc.)	EL7–11, EL15–32, DL16	
		Daylight-harvesting dimming controls	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	EL12, DL16	
HVAC	Critical Care Areas — Central Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
		DX air conditioner (≥ 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
		Air-cooled chiller efficiency	9.6 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
		Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
		Cooling towers	VFD on tower fans	HV19	
		Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
		Economizer	Yes	HV9	
		Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
		Zone airflow setback	Yes	HV1, HV23	

Climate Zone 7 Recommendation Table for Small Hospitals and Healthcare Facilities *(Continued)*

	Item		Component	Recommendation	How-to Tips in Chapter 5	✓
HVAC (cont.)	Non-Critical Care Areas	Central VAV Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
			DX air conditioner (≥ 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
			Air-cooled chiller efficiency	9.6 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
			Economizer	Yes	HV9	
			Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
			Space temperature setback	Yes	HV17, HV22	
		WSHP System	WSHP < 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.5 COP at 68°F	HV2, HV5, HV6	
			WSHP ≥ 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.2 COP at 68°F	HV2, HV5, HV6	
			Water pumps	VFD and NEMA premium efficiency	HV19, HV20	
			Cooling towers/fluid cooler	VFD on fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV2, HV5, HV6, HV20	
			Economizer	Comply with Standard 90.1*	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness	HV4, HV10	
			WSHP fans	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
		Fan-Coil and Chiller System	Air-cooled chiller efficiency	9.6 EER, 11.5 IPLV	HV3, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV3, HV5, HV6, HV20	
			Economizer	Water-side economizer	HV9	
			Exhaust-air energy recovery in DOAS	Humid zones A: 50% total effectiveness Dry zones B: 50% sensible effectiveness	HV4, HV10	
			Fan-coil units	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
	Ducts and Dampers		Outdoor air damper	Motorized	HV8	
			Duct seal class	Supply and ducts located outdoors = Seal Class A Return and exhaust = Seal Class B	HV13	
			Insulation level	R-6	HV12	
SWH	Service Water Heating		Gas storage (>75 kBtu/h)	90% E_t	WH1–5	
			Gas instantaneous	0.81 EF or 81% E_t	WH1–5	
			Electric (storage or instantaneous)	EF > 0.99–0.0012 × Volume	WH1–5	
			Pipe insulation (d < 1.5 in. / d ≥ 1.5 in.)	1 in./1.5 in.	WH6	

*Note: If the table contains "Comply with Standard 90.1" for a component, the user must meet the more stringent of either the applicable edition of Standard 90.1 or the local code requirements.

Alaska

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

Climate Zone 8 Recommendation Table for Small Hospitals and Healthcare Facilities

	Item	Component	Recommendation	How-To Tips in Chapter 5	✓
Envelope	Roof	Insulation entirely above deck	R-35 c.i.	EN2, EN11, EN13	
		SRI	Comply with Standard 90.1*	EN1	
	Walls	Mass (HC > 7 Btu/ft^2)	R-25.0 c.i.	EN3, EN11, EN13	
		Steel-framed	R-13 + R-21.6 c.i.	EN4, EN11, EN13	
		Below-grade walls	R-17.5 c.i.	EN5, EN11, EN13	
	Floors	Mass	R-23 c.i.	EN6, EN11, EN13	
		Steel-framed	R-60	EN7, EN11, EN13	
	Slabs	Unheated	R-20 for 48 in.	EN8, EN11, EN13	
	Doors	Swinging	U-0.50	EN9, EN13	
		Non-swinging	U-0.50	EN10, EN13	
	Vertical Fenestration	Total fenestration to gross wall area ratio	40% Max	EN15, EN17–18	
		Thermal transmittance (all types and orientations)	U-0.20	EN14	
		SHGC (all types and orientations)	SHGC-0.40	EN14, EN23–24	
		Visible transmittance	VT-0.65	EN14, EN25	
		Exterior sun control (S, E, and W only)	Projection factor > 0.5	EN16, EN21–22, EN26–31, DL5–6, DL20	
Lighting/Daylighting	Skylights	Area (percent of roof area)	3% maximum	DL13–16	
		Thermal transmittance (all types)	0.60	DL18	
		SHGC (all types)	Comply with Standard 90.1*	DL19	
	Daylighting	Design the building to maximize access to natural light through sidelighting and toplighting: · Staff areas (exam rooms, nurse stations, offices, and corridors) · Public spaces (waiting and reception)	Diagnostic and treatment block: shape the building footprint such that the area within 15 feet of the perimeter exceeds 40% of the floorplate	DL1–20	
			Inpatient units: ensure that 75% of the occupied space (not including patient rooms) lies within 20 feet of the perimeter	DL1–20	
	Interior Finishes	Daylighted room interior surface average reflectance	88% on ceilings and walls above 7ft 50% on walls below 7ft	EL1, DL14	
	Interior Lighting	LPD	1.0 W/ft^2 or space-by-space method using values in Table 5-9 in EL13	EL13–31, DL1–19	
		Light source system efficacy (linear fluorescent and HID)	90 mean lumens/watt minimum	EL2, EL3	
		Light source system efficacy (all other sources)	50 mean lumens/watt minimum	EL4, EL5	
		Lighting controls—general	Manual on, auto-off all zones except: no auto-off in 24-h patient care areas (patient rooms, nurses station, etc.)	EL7–11, EL15–32, DL16	
		Daylight-harvesting dimming controls	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	EL12, DL16	
HVAC	Critical Care Areas — Central Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
		DX air conditioner (≥ 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
		Air-cooled chiller efficiency	9.6 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
		Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
		Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
		Cooling towers	VFD on tower fans	HV19	
		Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
		Economizer	Yes	HV9	
		Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
		Zone airflow setback	Yes	HV1, HV23	

Climate Zone 8 Recommendation Table for Small Hospitals and Healthcare Facilities *(Continued)*

		Item	Component	Recommendation	How-To Tips in Chapter 5	✓
HVAC (cont.)	Non-Critical Care Areas	Central VAV Air-Handling System	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
			DX air conditioner (≥ 760 kBtu/h)	Comply with Standard 90.1*	HV1, HV5, HV6	
			Air-cooled chiller efficiency	9.6 EER/11.5 IPLV	HV1, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV1, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV1, HV5, HV6, HV20	
			Economizer	Yes	HV9	
			Fans	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14, HV21	
			Space temperature setback	Yes	HV17, HV22	
		WSHP System	WSHP < 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.5 COP at 68°F	HV2, HV5, HV6	
			WSHP ≥ 65 kBtu/h	Cooling: 12 EER at 86°F; Heating: 4.2 COP at 68°F	HV2, HV5, HV6	
			Water pumps	VFD and NEMA premium efficiency	HV19, HV20	
			Cooling towers/fluid cooler	VFD on fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV2, HV5, HV6, HV20	
			Economizer	Comply with Standard 90.1*	HV9	
			Exhaust-air energy recovery in DOAS	50% sensible effectiveness	HV4, HV10	
			WSHP fans	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
		Fan-Coil and Chiller System	Air-cooled chiller efficiency	9.6 EER, 11.5 IPLV	HV3, HV5, HV6, HV19	
			Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3, HV5, HV6, HV19	
			Chilled-water pumps	VFD and NEMA premium efficiency	HV19	
			Cooling towers	VFD on tower fans	HV19	
			Gas boiler	90% E_c at peak design heating water temperature	HV3, HV5, HV6, HV20	
			Economizer	Water-side economizer	HV9	
			Exhaust-air energy recovery in DOAS	50% sensible effectiveness	HV4, HV10	
			Fan-coil units	0.4 W/cfm	HV7, HV11	
			Other fans (DOAS, exhaust)	bhp ≤ supply cfm x 0.0012+A, NEMA premium efficiency motors	HV7, HV11, HV14	
			Space temperature setback	Yes	HV17, HV22	
	Ducts and Dampers		Outdoor air damper	Motorized	HV8	
			Duct seal class	Supply and ducts located outdoors = Seal Class A Return and exhaust = Seal Class B	HV13	
			Insulation level	R-6	HV12	
SWH	Service Water Heating		Gas storage (>75 kBtu/h)	90% E_t	WH1–5	
			Gas instantaneous	0.81 EF or 81% E_t	WH1–5	
			Electric (storage or instantaneous)	EF > 0.99–0.0012 × Volume	WH1–5	
			Pipe insulation (d < 1.5 in. / d ≥ 1.5 in.)	1 in./1.5 in.	WH6	

*Note: If the table contains "Comply with Standard 90.1" for a component, the user must meet the more stringent of either the applicable edition of Standard 90.1 or the local code requirements.

Technology Examples and Case Studies 4

The case studies in this chapter illustrate techniques and methods that are discussed in this Guide. They are presented in order of climate zone, from warmest to coldest. Energy numbers are provided to benchmark these buildings against future buildings; however, all these case studies pre-date the publication of the Guide and were not developed using the recommendations in Chapter 3. These facilities may or may not have achieved the 30% energy savings level if they had been constructed entirely according to the recommendations in this Guide. Readers are encouraged to view additional case studies at www.ashrae.org/aedg, as well as submit additional case studies. Case studies provide the motivation and the examples for others to follow.

CLIMATE ZONE 2—PETER AND PAULA FASSEAS CANCER CLINIC AT UNIVERSITY MEDICAL CENTER

TUCSON, AZ

The Peter and Paula Fasseas Cancer Clinic at University Medical Center is a comprehensive cancer center located in the desert climate of Tucson, Arizona. Designed by CO Architects, the two-story, 82,000 ft^2 facility was completed in 2007 at a total cost of roughly $22 million. A number of energy-efficiency measures were incorporated into the design.

The building construction is metal frame with R-19 insulation 16 in. on center (o.c.) with an overall U-factor of 0.114. The roof has R-30 insulation and an overall U-factor of 0.32. Double-pane low-emissivity metal frame windows with thermal break were used in the facility.

The majority of the clinic's lighting consists of T-8 fluorescent lamps. Centralized control panels automatically turn off the lighting in public spaces during non-business hours when these spaces are unoccupied. Intermittently occupied rooms such as shops, workrooms, consulting rooms, and storage areas are equipped with individual occupancy sensors so these spaces are lighted only when occupied. Low-wattage light emitting diode (LED) exit signs are used throughout the facility and multi-level light switching is employed where appropriate.

The centralized panels also control the on/off for exterior lighting by astronomical time clock and/or photocell to ensure that the lights do not operate during daylight hours. All exterior lighting is "dark-sky" compliant, which means that unnecessary uplighting is eliminated in order to reduce light pollution and energy waste.

THE PETER AND PAULA FASSEAS CANCER CLINIC AT UNIVERSITY MEDICAL CENTER	
Energy Savings Measure	**Description of Element**
Envelope	
Walls	Metal frame, R-19 insulation, 16 in. o.c. Overall U-factor of 0.114.
Roof	R-30 insulation. Overall U-factor of 0.032.
Vertical Glazing	Double-pane low-e windows with thermal break and metal frame.
Lighting	
Lighting Design	T-8 fluorescent lighting. Low-wattage LED exit signs.
Controls	Occupancy sensors for public areas and intermittently occupied spaces. Multi-level light switching.
HVAC	
Equipment	VAV rooftop packaged units with terminal reheat using hot water; minimum efficiencies of 8.2 EER, 7.5 IPLV with VFD. Premium efficiency electric motors. 100% air-side economizer.
Controls	Zone demand for supply air temperature.
Service Water Heating	85% thermal efficiency boiler.
Bonus/Additional Savings	
Water Use Reduction	Automatic, low-flow toilets and faucets. Condensate and storm water drainage discharged to the landscape.
Exterior Lighting	Astronomical time clock programming and/or photocell control. Dark-sky compliant.
Energy Use Characteristics	
Total Cost per Square Foot	$200/ft^2.

Data and photographs provided by Arup North America Limited and CO Architects.

The HVAC is handled by rooftop packaged air-conditioning units with terminal reheat using heating hot water that have minimum efficiencies of 8.2 EER and 7.5 IPLV. The variable-air-volume (VAV) units incorporate integrated air-side economizers, which allows for the introduction of 100% outside air when ambient weather conditions permit, thereby reducing the demand on the equipment cooling load and energy consumption. The HVAC systems can reduce the outside air volume to the required minimum. Each zone has individual temperature, and the system controls are able to reset the supply air temperature by 25% of supply room temperature difference. The 85% thermal efficiency heating hot water boiler exceeds the minimum efficiency requirements by 5%. All electric motors over 1 hp are premium efficiency.

A number of water conservation measures were also installed at the facility. Condensate from the packaged rooftop units and storm water drainage is discharged to the landscape arroyo. The sinks in the lavatories are provided with 0.5 gpm flow restrictors and electronic sensor faucets. All toilets and urinals are low flow (1.6 and 1.0 gallons per flush) with battery-operated electronic sensors. The majority of the other sinks in the facilities have 2.2 gpm flow rates and also employ electronic sensor faucets.

Figure 4-1. The Peter and Paula Fasseas Cancer Clinic at University Medical Center building exterior.

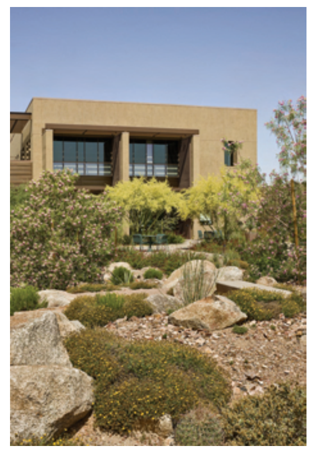


Figure 4-2. Landscape view.

Photographs copyright Robert Canfield Photography.

Figure 4-3. Exterior lighting.

CLIMATE ZONE 2—CHEYENNE ONE MEDICAL OFFICE BUILDING

WEBSTER, TX

Located within the Houston region, the Cheyenne One Medical Office Building is a 48,000 ft^2, three-story facility that accommodates adult medicine. Designed and built by Jacob White Construction Company in 2007, the building also includes a pharmacy and a local bank on its ground floor. The primary goals of the project were to maintain consistent indoor conditions while controlling operating costs. Despite the lack of any government incentives, the projected paybacks of approximately 4.5 years on the overall "green building" enhancements convinced the owner to proceed with the designed elements. The building's actual energy usage is 50% to 55% less than a comparable standard office building with fewer operating hour cycles.

The exterior walls are 6 in. steel stud infill framing with 3 in. of foam sheathing that provides an R-23 wall assembly. The open cell foam limits the air infiltration rates to approximately 0.01 cfm/ft^2. The south and west faces are cement plaster walls with punched glazing openings while the east and north faces are curtainwall constructs.

The building glazing consists of thermally broken aluminum frame systems with a U-factor of 0.33 and SHGC of 0.15. All south- and west-facing glazing have sunscreens

CHEYENNE ONE MEDICAL OFFICE BUILDING	
Energy Savings Measure	**Description of Element**
Envelope	
Walls	R-23 assembly with 3-in. foam sheathing.
Roof	R-70 assembly with insulation and 9-in. deep green roof.
Vertical Glazing	Thermally broken aluminum frame systems. U-factor of 0.33 and SHGC of 0.15.
Daylighting	
Window Design	South- and west-facing sunscreens.
Lighting	
Lighting Power Density	LPD of 1.0 W/ft^2. 2x4 fixtures using super T-8 lamps and CFL.
Controls	Occupancy sensors and dual-level switching.
HVAC	
Equipment	Multi-stage air-cooled chiller and outdoor air unit. VFD. Space heat with electric heat strips at VAV boxes.
Chiller Efficiency	9.6 EER, COP of 2.81.
System Controls	
Measurement and Verification	DDC system with web-accessible real-time operating and performance data. Carbon dioxide (CO_2) monitoring.
Bonus/Additional Savings	
Green Roof Evaporative Cooling	14,566 ft^2 green roof alleviating up to 60 tons of cooling per month (12.26 kBtu/ft^2 per month).
Energy Use Characteristics	
Estimated Annual Energy Index Savings	22.1 kBtu/ft^2/yr (building). 8.28 kBtu/ft^2/yr (green roof).
Actual Energy Index	63 kBtu/ ft^2/yr.
Estimated Annual Cost Savings	\$0.66/ft^2/yr (building). \$0.11/ft^2/yr (green roof).
Initial Investment Premium	\$1.60/ft^2/yr over 10 years.
Total Cost per Square Foot	\$250/ft^2 (including land).

Data and photographs provided by Jacob White Construction Co.

to provide daylighting control. The sunscreens provide shading as well as reflect light onto the internal ceiling and deeper into the occupied spaces.

The building's overall LPD is approximately 1.0 W/ft^2. Direct/indirect 2 × 4 super T-8 fluorescent fixtures are used along with compact fluorescent lamp (CFL) downlights. Occupancy sensors were placed in infrequently used spaces while dual-level controls (switching) are used in more frequently occupied spaces.

The HVAC system is a 250 ton roof-mounted multi-stage chiller and an outdoor air unit. The chiller has an operating efficiency of 9.6 EER (or COP of 2.81). Variable-frequency drives (VFDs) on all air handlers and large supply fans modulate the speed of the fans to match the demand cooling/heating loads, therefore minimizing fan energy requirements. Space heating is provided at exterior-zone-only VAV boxes through electric heat strips. Carbon dioxide monitoring is provided for the entire building.

The building has a 14,566 ft^2 green roof representing 92% of the roof surface. The 9 in. deep green roof together with the construction and insulation provide a calculated R-value of 70 and alleviate as much as 60 tons of cooling per month (or 12.26 kBtu/ft^2 per month).

The direct digital control (DDC) system provides real-time web-accessible operating data and performance data logging for all systems. Additionally, data points have been added to allow the ability to monitor temperature performances/impacts of the green roof.

Photographs copyright Jacob White Construction Co.

Figure 4-4. The Cheyenne One Medical Office Building exterior with shading.

Figure 4-5. Rooftop chiller.

Figure 4-6. Direct versus indirect lighting.

CLIMATE ZONE 3—CONTRA COSTA REGIONAL MEDICAL CENTER AMBULATORY CARE FACILITY

MARTINEZ, CA

The Contra Costa Regional Medical Center Ambulatory Care Facility is a three-story building with 59,000 ft^2 of total conditioned floor area located in the San Francisco Bay area. The ambulatory care facility includes specialty clinics, diagnostic imaging, an outpatient pharmacy, a satellite lab, and a surgical services suite that opened in 2003. Designed by Anshen + Allen Architects, the building is two identical wings joined by a center entry pavilion.

Energy performance modeling was used to predict annual energy performance and was also required for compliance with the utility provider's incentive program. The simulated building energy usage was 35% better than a California Title 24 base building. The 20-year life-cycle costs and simple payback periods, taking into account potential incentives, were calculated for each of the energy efficiency design measures. The total annual projected savings were $43,100 with a payback of 3.2 years.

The design goals were to use daylighting to provide high-quality light and views, to limit the use of electric lighting, and to reduce peak cooling loads. To achieve the design goal, the building envelope features an R-5.6 composite curtainwall construction and an R-19.2 composite roof construction. The building glazing is low-e, high visual light transmittance glazing with a U-value of 0.31 and SHGC of 0.36.

CONTRA COSTA REGIONAL MEDICAL CENTER AMBULATORY CARE FACILITY	
Energy Savings Measure	**Description of Element**
Envelope	
Walls	R-5.6 composite curtainwall assembly.
Roof	R-19.2 composite roof assembly.
Vertical glazing	Low-e and high visual transmittance glazing. Overall U-factor of 0.31 and SHGC of 0.36.
Daylighting	
Window Design	Custom-designed overhang sunshades.
Daylighting Design	3% window-to-wall ratio (WWR) with floor-to-ceiling glazing and high ceilings in perimeter spaces.
Lighting	
Lighting Power Density	Overall LPD of 1.1 W/ft^2.
Lighting Design	High-efficiency T-8 linear fluorescent lamps and F-26 CFLs
Controls	Switchable ballasts in perimeter areas and lobbies for daylighting; occupancy sensors in all offices, staff, and service spaces.
HVAC	
Equipment	Water-cooled DX units with VAV reheat. VFD-controlled supply fans on DX units.
Boilers	High-efficiency condensing boilers.
Cooling Tower	High-efficiency induced draft cooling towers. VFD-controlled pumps, fans, and chillers.
System Controls	
Temperature	Demand ventilation control (DVC) system.
Energy Use Characteristics	
Simulated Site Energy Use Intensity	46 kBtu/ft^2/yr (building only without process).
Annual Energy Savings	$43,100 (electricity and natural gas). Payback of 3.2 years. 20-year life-cycle costing (LCC) savings of $2,716,000.
Project Cost	$267/ft^2.

Data and photographs provided by Anshen + Allen Architects.

The public circulation and waiting areas as well as all patient and exam rooms are located on the perimeter of the building. These perimeter spaces have floor-to-ceiling glazing that provide ample daylighting and exterior views. To increase the penetration of daylighting, the ceiling height incrementally steps up from 9 ft in the interior zones to 10 ft in most perimeter zones or to 20 ft in the entry pavilion of the building. Custom-designed overhang sunshades are used along the floor-to-ceiling curtainwall to reduce heat gain and glare.

The overall LPD is 1.1 W/ft^2. The electrical lighting throughout the building is provided by high-efficiency T-8 linear fluorescent lamps and F-26 CFLs. Occupancy sensors are used in all offices, staff spaces, and service spaces, while daylighting controls with switchable ballasts are installed in all perimeter spaces.

The HVAC systems are designed to comply with the strict California code requirements that dictate air change rates and pressurization levels and demand 100% outdoor air in specific areas. The HVAC system consists of water-cooled direct expansion (Dx) units with VAV hot water reheat and VFD controlled supply fans mounted on top of the DX units. To minimize fan energy, the ductwork is designed for a low-pressure drop. Cooling is provided by high efficiency induced draft cooling towers. High-efficiency condensing boilers provide heat for both space heating and hot water. VFD-controlled pumps are used for heating hot water and for condenser water.

Photographs copyright Robert Canfield.

Figure 4-7. The Contra Costa Regional Medical Center Ambulatory Care Facility exterior view.

Figure 4-8. Public waiting areas with floor-to-ceiling glazing.

CLIMATE ZONE 3—RIVERSIDE MEDICAL CLINIC

RIVERSIDE, CA

The Riverside Medical Clinic is a three-story, 129,000 ft^2 facility located in southern California. Designed and built by Erdman Company, the facility provides adult medicine and primary care services. The owner took advantage of the Riverside Public Utility Incentive program and had a goal of a maximum eight-year return on investment prior to the incentive for the energy-saving strategies.

The final construction included steel stud walls with R-14 continuous insulation (c.i.) and a reflective roof membrane with R-20 insulation. High-performance vertical glazing was installed with an overall U-factor of 0.48 and SHGC of 0.19. Overhangs used in the window design control daylighting. These strategies reduced heat loss by more than 40%.

The overall building LPD was reduced to 0.94 W/ft^2 with 46 W 2 × 4 fluorescent fixtures using super T-8 lamps and with CFLs. While occupancy sensors were evaluated for infrequently occupied spaces, they were installed only in larger spaces with multiple fixtures as this was determined to be the most economical approach.

RIVERSIDE MEDICAL CLINIC	
Energy Savings Measure	**Description of Element**
Envelope	
Walls	R-14 c.i. (outside of steel studs).
Roof	R-20 insulation. Reflective roof membrane.
Vertical Glazing	High performance. Overall U-factor of 0.48 and SHGC of 0.19.
Daylighting	
Window Design	Overhangs.
Lighting	
Lighting Power Density	Overall LPD of 0.94 W/ft^2.
Electric Lighting Design	46 W 2 × 4 fixtures using super T-8 lamps. CFLs.
Controls	Occupancy sensors.
HVAC	
Equipment	Three 75 ton VAV rooftop units. Evaporative cooled condensing. VFD supply and relief fan motor control.
Efficiency	12.6 EER.
Space Heating Hot Water System	Two 97% thermal efficiency boilers.
Service Water Heating	92% efficiency domestic hot water heater.
System Controls	
Measurement and Verification	DDC system. Web-accessible real-time electric and solar hot water use data. Glass art sculpture indicating real-time energy use and carbon savings.
Bonus/Additional Savings	
Renewable Energy	1,200 ft^2 solar hot water system.
Energy Use Characteristics	
Estimated Annual Energy Index Savings	25.4 $kBtu/ft^2/yr$.
Estimated Annual Cost Savings	$\$0.25/ft^2/yr$.
Initial Investment Premium	$\$2.00/ft^2/yr$.
Total Cost per Square Foot	$\$209/ft^2/yr$.

Data, photographs, and copyright provided by Cogdell Spencer ERDMAN.

Taking advantage of the dry climate, the HVAC system uses three 75 ton rooftop units that utilize an evaporative cooling process. This increases the overall efficiency cooling capacity from 9.7 EER to 12.6 EER, thereby allowing the three 75 ton units to replace three 90 ton units. Premium efficiency motors and VFDs on the large supply and relief air fan motors modulate the fan speed to match the cooling/heating loads and minimize required energy. The space heating hot water system employs two 97% thermal efficiency (low water temperature design) condensing hot water boilers.

The service water heating system supplies over 96,000 gallons per year using a high-efficiency (92%) domestic hot water heater that is augmented by a 1,200 ft^2 solar hot water system.

To ensure that energy savings features continued to performed after initial construction and installation, a commissioning plan was employed that included detailed installation checklists and function testing. A DDC system was installed that provides performance data. The system is web accessible and provides real-time data. The clinic also installed a glass and light sculpture that draws attention to the facility's energy savings (see Figure 4-11). The sculpture, designed by artist Steve Feren, has 7 ft high columns that indicate electric use, solar hot water use, and estimated carbon savings.

Figure 4-9. Solar panels at the Riverside Medical Clinic.

Photographs copyright Cogdell Spencer ERDMAN.

Figure 4-10. Exterior view.

Sculpture photograph provided by Kevin Little, copyright Informing Ecological Design, LLC.

Figure 4-11. Glass and light sculpture that draws attention to real-time energy savings.

CLIMATE ZONE 5—DANA-FARBER/BRIGHAM AND WOMEN'S CANCER CENTER

MILFORD, MA

The Dana-Farber/Brigham and Women's Cancer Center is a two-story 54,000 ft^2 facility located next to the main campus of the Milford Regional Medical Center near Boston, MA. Completed in January 2008, the center provides comprehensive cancer services, including radiation therapy, imaging, medical oncology, and laboratory testing. The facility was designed by Steffian Bradley Architects following the guidance in the Green Guide for Health Care, available at www.gghc.org. Total construction cost was $20 million.

An interior LPD of 1.08 W/ft^2 was achieved by careful design using a task/ambient approach to provide recommended light levels without over-lighting. Highly efficient fluorescent, compact fluorescent, and metal halide light sources were employed in luminaires. Multi-level switching and dimming schemes, along with separately controlled task lights, were used in administrative and patient care areas to allow occupants to tune the lighting levels to their specific needs.

Lighting energy savings are also derived from the use of extensive vertical sidelighting and daylight photosensors. Daylighting was used in the main lobbies, infusion bays, and patient community spaces. Dual-sided automatic electronic window shades provide glare control.

A VAV rooftop system with full economizer capability provides the heating, cooling, and ventilation for the center. Enthalpy controls on the economizer enable the system to lock out the economizer if the outdoor temperature and humidity exceed the return air temperature and humidity setpoints.

Individual rooms are heated, cooled, and ventilated via VAV boxes with hot water reheat. Primary air from the rooftop units is ducted to the inlet of the VAV boxes and

DANA-FARBER/BRIGHAM AND WOMEN'S CANCER CENTER	
Energy Savings Measure	**Description of Element**
Envelope	
Opaque Components	R-30 roof, R-13 walls.
Vertical Glazing	Low-emissivity windows.
Lighting	
Lighting Power Density	1.02 W/ft^2.
Electric Lighting Design	Direct/indirect fluorescent with T-5Ho lamps. Compact fluorescent and metal halide downlights.
Controls	Multi-level switching and dimming.
Daylighting	
Window Design	Vertical sidelighting.
Daylighting Design	Daylight photosensors and automatic electronic window shades.
HVAC	
Equipment	VAV rooftop system with economizer. VAV boxes with hot water reheat. Hot water ceiling radiant panels. VFDs and premium-efficiency motors.
Boilers	Gas-fired 85% thermal efficiency.
System Controls	
Measurement and Verification	DDC building automation.
Temperature Control	Room by room, zoned system.
Energy Use Characteristics	
Total Cost per Square Foot	$370/ft^2.

Data and photographs provided by Steffian Bradley Architects.

distributed to each space via a fully ducted low-velocity supply air system. Space sensors maintain each room at 75°F cooling and 72°F heating. Exterior rooms are also heated by hot water ceiling radiant panels. The radiant panels are controlled from the same room sensor as the VAV box so that the radiant panels will not energize if the VAV box is in cooling mode. Critical areas (i.e., for MRI, CT-Scan, linear accelerator, etc.) employ "computer room" type air conditioning units with associated outdoor-air-cooled condensing units.

Hot water for the reheat coils and unitary heating equipment is provided by high-efficiency (85%) fully modulating gas-fired hot water boilers. The main hot water circulating pumps use VFDs and all equipment is equipped with premium efficiency motors.

The building is controlled by a fully automatic direct digital building automation system (BAS). All HVAC equipment is started, stopped, and monitored by the BAS and all setpoints are adjustable.

Photographs copyright Robert Benson.

Figure 4-12. The Dana-Farber/Brigham and Women's Cancer Center building exterior.

Figure 4-13. Daylighting in the lobby area.

Figure 4-14. Patient area.

CLIMATE ZONE 6—THE HEART DOCTORS HEART & VASCULAR INSTITUTE

RAPID CITY, SD

The Heart Doctors Heart and Vascular Institute is a two-story 32,000 ft^2 medical office building located in Climate Zone 6. The full-scope diagnostic testing cardiovascular lab was designed and built by Erdman Company. Completed in 2006, the facility provides diagnostic tests that include echocardiography, arterial and vascular ultrasound, exercise stress testing, cardiac nuclear imaging, tilt table testing, and cardiac event monitoring. The design took advantage of the energy storage rate and other incentives offered by the local power utility, with the main economic criterion of a maximum 10-year rate of return on investment prior to any incentives for the first-cost premiums for the energy-saving strategies. In addition, the HVAC system qualified for the federal commercial energy tax deduction.

The facility was constructed with 6 in. metal stud walls with R-19 batt insulation and a roof with R-20 insulation. The vertical glazing installed has a center of glass U-factor of 0.29 and an SHGC of 0.28. The building was designed to maximize the interior daylighting in the building using windows in each patient exam room and skylights in the building interior.

The overall building LPD was designed to 1.12 W/ft^2 using 64 W 2 × 4 fluorescent fixtures with T-8 lamps. Throughout the building, lighting is controlled via a building energy management system.

THE HEART DOCTORS HEART & VASCULAR INSTITUTE	
Energy Savings Measure	**Description of Element**
Envelope	
Walls	6 in. metal studs with R-19 batt insulation.
Roof	R-20.
Vertical Glazing	Center of glass U-factor of 0.29, SHGC of 0.28.
Daylighting	
Windows	In patient exam rooms.
Skylights	In building interior.
Lighting	
Lighting Power Density	1.12 W/ft^2. 64 W 2x4 fixtures.
Electric Lighting Design	64 W 2x4 fixtures using T-8 lamps (includes parking lot lights).
Controls	Building energy management system.
HVAC	
Equipment	Water-to-water GSHP. Heat pump chiller with ice storage tank. Four-pipe fan-coils. Dedicated outdoor air unit with energy recovery.
Humidification	Humidifier control to minimize electrical demand load.
Service Water Heating	Preheat incoming water with waste heat from heat pumps.
Energy Use Characteristics	
Estimated Annual Energy Index Savings	17.1 kBtu/ft^2/yr.
Actual Energy Index	47 kBtu/ft^2/yr (2008 calendar year).
Estimated Annual Cost Savings	\$0.37/ft^2/yr.
Initial Investment Premium	\$4.30/ft^2/yr.
Total Cost per Square Foot	\$192/ft^2/yr.
Mechanical Cost per Square Foot	\$23/ft^2/yr.

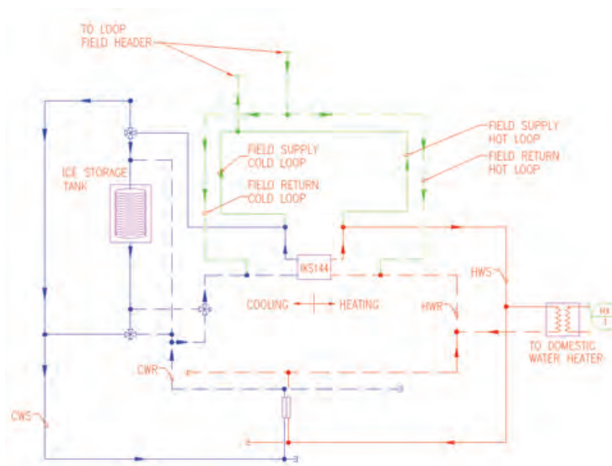
Data and photographs provided by Cogdell Spencer ERDMAN.

The primary mechanical system is a four-piped water-to-water ground source heat pump (GSHP). Four 15-ton heat pumps supply the building's heating and cooling requirements using the ground as an energy source. Hot water (110°F) and chilled water (44°F) is distributed to fan-coils via a four-pipe system. An underground loop field, consisting of 68 vertical bore holes 200 ft deep, was installed for the required heat transfer. When building load conditions require heating in some areas and cooling in others, the heat pumps take excess heat from the zones requiring cooling to satisfy zones requiring heat.

The building also utilizes thermal storage to supplement the cooling load in the summer months. The thermal storage consists of an underground tank that stores ice. The heat pumps generate the chilled water (28°F) during off-peak periods to make ice. During the day the chilled-water is diverted through the coils in the ice storage tank to help maintain the chilled water temperature. The ice storage helped to reduce the size of the installed heat pump equipment and also moves energy use to the more cost-effective off-peak periods.

The outdoor air requirements are met by the use of an energy recovery ventilator (ERV). The ERV takes the building's exhaust air and preconditions the incoming fresh air via a desiccant wheel. The desiccant wheel transfers both temperature and humidity between the exhaust airstream and the supply airstream. The result is a reduction in ventilation heating and cooling load and operating cost.

The high-efficiency (92%) service water heating system uses the building heating how water to preheat the incoming water via a brazed plate heat exchanger. This energy savings feature uses excess heat that would otherwise be expelled to the ground loop.



Photographs copyright Cogdell Spencer ERDMAN.

Figure 4-15. Cooling and heating system diagram.

Figure 4-16. The Heart Doctors Heart & Vascular Institute exterior.

Figure 4-17. Heat pumps.

CLIMATE ZONE 6—PATRICK H. DOLLARD DISCOVERY HEALTH CENTER

HARRIS, NY

Built by the Center for Discovery, the Patrick H. Dollard Discovery Health Center is a two-story 28,000 ft^2 diagnostic and treatment center located in rural upstate New York. Completed in 2003, the facility provides medical services to the Center for Discovery, a school and nonprofit agency for children and adults with profound neurological and developmental impairments.

Built with the goal of comprehensive sustainable design, the facility was located on an abandoned industrial chicken farm so as to avoid using prime farmland for the site. The LEED 2.0 certified facility received the 2004 Society for Healthcare Engineering (ASHE) Vista Award for Sustainable Use of Materials and Natural Resources.

The building was sited to allow for the use of solar heating in the winter and to maximize the use of natural daylight and was designed with a narrow footprint and a glass-terraced wall on the northern end of the building. All occupied and medical treatment spaces have windows and bris soleils shading devices to reduce direct solar gains. The reflective metal roof reduces heat buildup.

Heating and cooling needs are provided via a GSHP system that reduces the electric demand to 6.2% of a comparable base model. Forty geothermal wells extending down 400 ft draw water from the site and pass it through heat pumps that raise the temperature in winter and cool it slighting in summer. The water is then circulated through two separate loops, one for air and one for radiant floor heat. Supplemental grid-source electricity is provided with wind power.

Due to a lack of municipal water supply, a reduction in the use of potable water was required. To that end, a long planar shed roof was included in the design to collect rain for graywater use; it recharges the local aquifer with any runoff. Low-flow plumbing fixtures are also employed to decrease water usage at the facility.

Overall, the building is 48% more energy efficient than a building built to be minimally compliant with ASHRAE/IESNA Standard 90.1-1999.

PATRICK H. DOLLARD DISCOVERY HEALTH CENTER	
Energy Savings Measure	**Description of Element**
Daylighting	
Windows	Sidelighting in occupied and medical treatment spaces.
Shading	Bris soleils.
HVAC	
Equipment	GSHP two-loop system with forty geothermal well borefield. Radiant floor heat.
Bonus/Additional Savings	
Water Use Reduction	Rainwater collection. Low-flow plumbing fixtures.
Energy Use Characteristics	
Total Cost per Square Foot	$200/ft^2.

Data and photographs provided by Robert Guenther, Perkins + Will Architects; Project completed by G5 Architects prior to joining Perkins + Will.

Figure 4-19. The Patrick H. Dollard Discovery Health Center exterior view.

Figure 4-20. Glass-terraced wall with shading.

Figure 4-20. Interior daylighted space.

Photographs copyright Robin Guenther Perkins+Will.

How to Implement Recommendations 5

Recommendations are contained in the individual tables in Chapter 3, "Recommendations by Climate." The following information is intended to provide guidance on good practices for implementing the recommendations as well as cautions to avoid known problems in energy-efficient construction. The sections are divided into quality assurance and commissioning, envelope, lighting, daylighting, HVAC, service water heating, and additional savings. The bonus savings section includes areas for additional savings—these are good practice items that, if implemented, will achieve additional savings above the 30% level.

QUALITY ASSURANCE AND COMMISSIONING

Quality and performance are the result of high intention, sincere effort, intelligent direction, and skilled execution. Deficiencies in the building envelope and mechanical and electrical systems have a wide range of consequences, including elevated energy use or underperformance of the energy efficiency strategies. These deficiencies are commonly a result of design flaws, construction defects, malfunctioning equipment, or deferred maintenance. Fortunately, a quality assurance process known as *commissioning* (Cx) can detect and remedy these types of deficiencies.

As facilities search for higher efficiency through innovation, new applications, and complex controls, the risk of underperformance and the potential for more deficiencies increases. That increases the need and value for Cx for the higher-performing facilities. Lawrence Berkeley National Laboratory (LBNL) published a report on the cost-effectiveness of commissioning commercial buildings, both existing and new construction (Mills and Friedman 2004). The 28 new construction buildings in the study had a median Cx cost of $1.00/ft^2 (0.6% of total construction costs) yielding an average payback of 4.8 years. Cx is one of the most cost-effective means to improving energy efficiency. The report states that "the most cost-effective results occurred in the more energy-intensive facilities, such as hospitals and labs" (Mills et al. 2004). The study found 3305 deficiencies in the new construction projects. Cx can play a significant role in national energy savings, delivering a potential savings of $18 billon per year.

Success of the Cx process requires leadership and oversight. The individual responsible to provide that is the commissioning agent (CxA). CxA qualifications should include an in-depth knowledge of mechanical and electrical systems design and operation as well as general construction experience. The individual represents the owner's interests in helping the team deliver a successful building project. The CxA can be completely independent from the project team companies or a capable member of the contractor, architect, or engineering firms. The level of independence is a decision that the owner needs to make.

Commissioning needs to be an integral part of the design and construction process in order to reach the energy performance goals a building requires. The following are brief descriptions of the steps in the building design and construction Cx process. More detailed information can be found in ASHRAE's Guideline 0 and Guideline 1.1. A sample of the

QUALITY ASSURANCE: IN-HOUSE OR THIRD PARTY?

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

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

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

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

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

Once the design phase is completed, the party that is independent of the design and construction team fulfils the QA role to ensure that the goals, strategies, and recommendations are actually installed and achieved. This Guide provides recommendations to ensure that the goals, strategies, and actions selected are properly executed during the later stages of the building life-cycle in Chapter 5 under "Quality Assurance."

scope of services for the commissioning process might include a responsibility matrix, which can be found in Appendix C.

Owners, occupants, and the delivery team benefit equally from the QA process. More complex building systems require a greater level of effort than what is required for simpler buildings. Small healthcare facilities covered by this Guide have a range of complexity that is not always related to the size of the facility but focuses instead on the systems types and control functions these facilities utilize.

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

Good Design Practice

QA1 Design and Construction Team

Selection of the design and construction team members is critical to a project's success. Owners need to understand how team dynamics can play a role in the building's resulting performance. Owners should evaluate qualifications of candidates, past performance, cost of services, and availability of the candidates in making their selection. Owners need to be clear in their expectations of how team members should interact. It should be clear that all members should work together to further team goals. The first step is to define members' roles and responsibilities. This includes defining deliverables at each phase during the design and commissioning processes.

QA2 Selection of Quality Assurance Provider

Quality assurance is a systematic process of identifying the Owner's Project Requirements (OPR), operational needs, and Basis of Design (BoD) to ensure that the building performs accordingly. The selection of a QA provider should include the same evaluation process the owner would use to select other team members. Qualifications in providing QA services, past performance of projects, cost of services, and availability of the candidate are some of the parameters an owner should investigate and consider in making a selection. Owners may select a member of the design or construction team as the QA provider. Commissioning requires in-depth technical knowledge of the building envelope and of mechanical, electrical, and plumbing systems as well as operational and construction experience.

QA3 Owner's Project Requirements and Basis of Design

Having a shared vision plays an important role in setting expectations and motivations among team members. The design team should assist the owner in documenting these goals and expectations. The Cx industry refers to such documentation as the Owner's Project Requirements (OPR). The requirements are from the owner's perspective on how the building project will influence their business and what metrics will gauge the success. The expectations should include level of quality, budgets, and project schedule. Sustainability goals, including energy-efficiency strategies, are also commonly part of the OPR. For example, an OPR would include strategies and recommendations selected from this Guide (see Table 2-1 and Chapters 3 and 5).

The OPR forms the foundation of the team's tasks by defining project and design goals, measurable performance criteria, owner directives, budgets, schedules, and supporting information into a single, concise document. Development of the OPR document requires input from all key facility users and operators. It is critical to align the complexity of the systems with the capacity and capability of the facility staff.

The next step is for the design team members to document how their design responds to the OPR information. This document is the Basis of Design (BoD). It records the standards and regulations, calculations, design criteria, decisions and assumptions, and the system descriptions. The narrative must clearly articulate the specific operating parameters required for the systems to form the correct basis for later quality measurements. Essentially, it is the engineering background information that is not provided in the construction documents that map out how the A&E end up with their designs. For example, it would state key criteria such as future expansion and redundancy considerations. It should include important criteria such as what code, standard, or guideline is being followed for the various engineered systems, including ventilation and energy. It provides a good place to document owner input needed for engineered systems such as identifying what electrical loads are to be on emergency power.

QA4 *Quality Assurance Plan*

Make sure there is a QA plan that is appropriate for the project and owner. It needs to outline the associated tasks, deliverables, responsibilities, lines of communication, and schedule. This is the CxA's responsibility to develop and maintain. Be sure all of the activities are accounted for in the budget and the owner understands and approves as well as understands the expected benefits for each activity.

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

QA5 *Design Review*

A second pair of eyes provided by the CxA/QA provider gives a fresh perspective that allows identification of issues and opportunities to improve the quality of the construction documents with verification that the OPR are being met. Issues identified can be more easily corrected early in the project, providing potential savings in construction costs and reducing risk to the team and owner.

QA6 *Defining Quality Assurance at Pre-Bid*

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

QA7 *Verifying Building Envelope Construction*

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

QA8 *Verifying Electrical and HVAC Systems Design and Construction*

Performance of electrical and HVAC systems are key elements of this Guide. How systems are designed as well as installed affect how efficiently they will perform. Collaboration between the entire design team is needed to optimize the energy efficiency of the facility. Natural daylight and artificial lighting will impact the heating and cooling loads from both a systems capacity and hourly operation mode. The design reviews should pay close attention to this area. Proper installation is just as important as proper design. Making sure the installing contractor's foremen understand the owner's goals, the QA process, and the installation details is a key factor to system performance success. A significant part of this process is a careful and thorough review of product submittals to ensure compliance with the design. It is in everyone's best interest to install the components correctly and completely the first time. Trying to inspect quality into a project is time consuming, costly, and usually doesn't result in quality. It's much better to ensure all team members are aligned with the QA process and goals. Certainly, observations and inspections during construction are necessary. The timing is critical to ensure that problems are identified at the beginning of each system installation. That minimizes the number of changes (time and cost) and leaves time for corrections.

QA9 ***Performance Testing***

Performance testing of systems is essential to ensure that all the commissioned systems are functioning properly in all modes of operation. That is a prerequisite for the owner to realize the energy savings that can be expected from the strategies and recommendations contained in this Guide. Unlike most appliances these days, none of the mechanical/electrical systems in a new facility are "plug and play." If the team has executed the Cx plan and is aligned with the QA goals, the performance testing will occur quickly and only minor but important issues will need to be resolved. Owners with operation and maintenance (O&M) personnel can use the functional testing process as a training tool to educate their staff on how the systems operate as well as for system orientation prior to training.

QA10 ***Establish Building Operation and Maintenance Program***

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

QA11 ***Monitor Post-Occupancy Performance***

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

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

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Mills, E., H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haasl, and M.A. Piette. 2004. The cost-effectiveness of commercial buildings commissioning: A meta-analysis of energy and non-energy impacts in existing buildings and new construction in the United States. LBNL Report No.56637. Lawrence Berkeley National Laboratory, Berkeley, CA.

ENVELOPE

Opaque Envelope Components

Good Design Practice

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

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

The solar reflectance and thermal emissivity property values represent initial conditions as determined by a laboratory accredited by the Cool Roof Rating Council (CRRC). An SRI can be determined by the following equations:

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

where

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

and

α = solar absorptance = 1 – solar reflectance

ε = thermal emissivity

These equations were derived from ASTM E1980 assuming a medium wind speed. Note that cool roofs are not a substitute for the appropriate amount of insulation.

Table 5-1. Examples of Cool Roofs

Category	Product	Reflectance	Emissivity	SRI
Single-ply	White polyvinyl chloride (PVC)	0.86	0.86	107
	White chlorinated polyethylene (CPE)	0.86	0.88	108
	White chlorosulfonated polyethylene (CPSE)	0.85	0.87	106
	White thermoplastic polyolefin (TSO)	0.77	0.87	95
Liquid-applied	White elastomeric, polyurethane, acrylic coating	0.71	0.86	86
	White paint (on metal or concrete)	0.71	0.85	86
Metal panels	Factory-coated white finish	0.90	0.87	113

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

The insulation entirely above deck should be continuous insulation (c.i.) rigid boards. Continuous insulation is important because no framing members are present that would introduce thermal bridges or short circuits to bypass the insulation. When two layers of c.i. are used in this construction, the board edges should be staggered to reduce the potential for convection losses or thermal bridging. If an inverted or protected membrane roof system is used, at least one layer of insulation is placed above the membrane and a maximum of one layer is placed beneath the membrane.

EN3 *Walls, Mass* (Climate Zones: all)

Mass walls are defined as those with a heat capacity exceeding 7 Btu/ft^2·°F. Insulation may be placed either on the inside or the outside of the masonry wall. When insulation is placed on the exterior, rigid c.i. is recommended. When insulation is placed on the interior, a furring or framing system may be used, provided the total wall assembly has a U-factor that is less than or equal to the appropriate climate zone construction listed in Appendix A. See Figure 5-1.

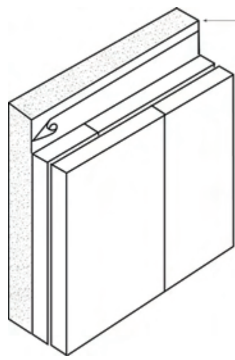

Figure 5-1. (EN3) Example mass wall assembly.

The greatest advantages of mass can be obtained when insulation is placed on its exterior. In this case, the mass absorbs heat from the interior spaces that is later released in the evenings when the buildings are not occupied. The thermal mass of a building (typically contained in the building envelope) absorbs heat during the day and reduces the magnitude of indoor air temperature swings, reduces peak cooling loads, and transfers some of the absorbed heat into the night hours. The cooling load can then be covered by passive cooling techniques (natural ventilation) when the outdoor conditions are more favorable. An unoccupied building can also be pre-cooled during the night by natural or mechanical ventilation to reduce the cooling energy use. This same effect reduces heating load as well.

Thermal mass also has a positive effect on thermal comfort. High-mass buildings attenuate interior air and wall temperature variations and sustain a stable overall thermal environment. This increases thermal comfort, particularly during mild seasons (spring and fall), during large air temperature changes (high solar gain), and in areas with large day-night temperature swings.

A designer should keep in mind that the occupant will be the final determinant on the extent of the usability of any building system, including thermal mass. Changing the use of internal spaces and surfaces can drastically reduce the effectiveness of thermal storage. The final use of the space must be considered when making the heating and cooling load calculations and incorporating possible energy savings from thermal mass effects.

EN4 *Walls, Steel Framed* (Climate Zones: all)

Cold-formed steel framing members are thermal bridges to the cavity insulation. Adding exterior foam sheathing as c.i. is the preferred method to upgrade the wall thermal performance because it will increase the overall wall thermal performance and tends to minimize the impact of the thermal bridging.

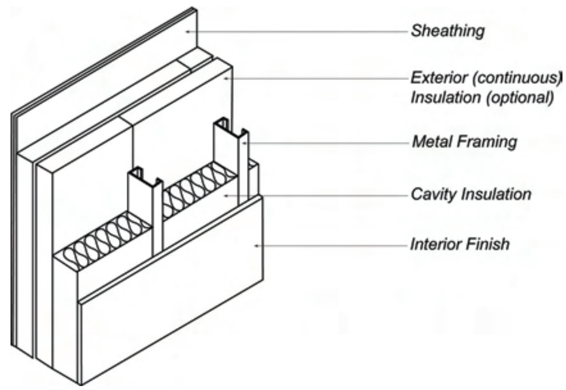

Figure 5-2. (EN4) Example of a steel-framed wall assembly.

Alternative combinations of cavity insulation and sheathing in thicker steel-framed walls can be used, provided that the proposed total wall assembly has a U-factor that is less than or equal to the U-factor for the appropriate climate zone construction listed in Appendix A. Batt insulation installed in cold-formed steel-framed wall assemblies is to be ordered as "full width batts" and installation is normally by friction fit. Batt insulation should fill the entire cavity and not be cut short. See Figure 5-2.

EN5 ***Below-Grade Walls*** **(Climate Zones: all)**

Insulation, when recommended, may be placed either on the inside or the outside of the below-grade wall. If placed on the exterior of the wall, rigid c.i. is recommended. If placed on the interior of the wall, a furring or framing system is recommended, provided the total wall assembly has a C-factor that is less than or equal to the appropriate climate zone construction listed in Appendix A.

EN6 ***Floors—Mass*** **(Climate Zones: all)**

Insulation should be continuous and either integral to or above the slab. This can be achieved by placing high-density extruded polystyrene above the slab with either plywood or a thin layer of concrete on top. Placing insulation below the deck is not recommended due to losses through any concrete support columns or through the slab perimeter.

Exception: Buildings or zones within buildings that have durable floors for heavy machinery or equipment could place insulation below the deck.

EN7 ***Floors—Metal Joist or Wood Joist/Wood Frame*** **(Climate Zones: all)**

Insulation should be installed parallel to the framing members and in intimate contact with the flooring system supported by the framing member in order to avoid the potential thermal short-circuiting associated with open or exposed air spaces. Non-rigid insulation should be supported from below, no less frequently than 24 in.

EN8 ***Slab-on-Grade Floors, Unheated*** **(Climate Zones: ❹ ❺ ❻ ❼ ❽)**

Rigid c.i. should be used around the perimeter of the slab and should reach the depth listed in the recommendation or to the bottom of the footing, whichever is less.

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

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

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

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

Options

EN11 *Alternative Constructions* (Climate Zones: all)

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

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

Cautions

The design of building envelopes for durability, indoor environmental quality, and energy conservation should not create conditions of accelerated deterioration or reduced thermal performance or problems associated with moisture, air infiltration, or termites.

The following cautions should be incorporated into the design and construction of the building.

EN12 *Slab Edge Insulation* (Climate Zones: all)

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

EN13 *Air Infiltration Control* (Climate Zones: all)

The building envelope should be designed and constructed with a continuous air barrier system to control air leakage into or out of the conditioned space and should extend over all surfaces of the building envelope (at the lowest floor, exterior walls, and ceiling or roof). An air barrier system should also be provided for interior separations between conditioned space and space designed to maintain temperature or humidity levels that differ from those in the conditioned space by more than 50% of the difference between the conditioned space and design ambient conditions. If possible, a blower door should be used to depressurize the building to find leaks in the infiltration barrier. The air barrier system should have the following characteristics.

- It should be continuous, with all joints made airtight.
- Air barrier materials used in frame walls should have an air permeability not to exceed 0.004 cfm/ft^2 under a pressure differential of 0.3 in. H_2O (1.57 lb/ft^2) when tested in accordance with ASTM E 2178.
- The system should be able to withstand positive and negative combined design wind, fan, and stack pressures on the envelope without damage or displacement and should transfer the load to the structure. It should not displace adjacent materials under full load.
- It should be durable or maintainable.
- The air barrier material of an envelope assembly should be joined in an airtight and flexible manner to the air barrier material of adjacent assemblies, allowing for the

relative movement of these assemblies and components due to thermal and moisture variations, creep, and structural deflection.

- Connections should be made between:
    a. Foundation and walls
    b. Walls and windows or doors
    c. Different wall systems
    d. Wall and roof
    e. Wall and roof over unconditioned space
    f. Walls, floors, and roof across construction, control, and expansion joints
    g. Walls, floors, and roof to utility, pipe, and duct penetrations
- All penetrations of the air barrier system and paths of air infiltration/exfiltration should be made airtight.

Vertical Fenestration

Good Design Practice

EN14 ***Vertical Fenestration Descriptions*** **(Climate Zones: all)**

Fenestration refers to the light-transmitting areas of a wall or roof, mainly windows and skylights but also including glass doors, glass block walls, and translucent plastic panels. Vertical fenestration includes sloped glazing if it has a slope equal to or more than 60° from the horizontal. If it slopes less than 60° from the horizontal, the fenestration falls in the skylight category. This means clerestories, roof monitors, and other such fenestration fall in the vertical category.

The recommendations for vertical fenestration are listed in Chapter 3 by climate zone. To be useful and consistent, the U-factors for windows should be measured over the entire window assembly, not just the center of glass. Look for a label that denotes the window rating is certified by the National Fenestration Rating Council (NFRC). The selection of high-performance window products should be considered separately for each orientation of the building and for daylighting and viewing functions.

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

To meet the SHGC recommendations for vertical fenestration in Chapter 3, use the SHGC multipliers for permanent projections as provided in Table 5.5.4.4.1 in ASHRAE/IESNA 90.1-2007. These multipliers allow for a higher SHGC for vertical fenestration with overhangs. For an overhang on south-facing windows with a projection factor greater than 0.5, the recommended SHGC can be increased by the multipliers in Table 5-3.

Table 5-2. Vertical Fenestration Descriptions

U-Factor	SHGC	VT	Class and Coating	Gas	Spacer	Frame
0.43	0.26	0.63	Double low-e coating, low solar gain (LSG2)	Argon	Standard	Unbroken Aluminum
0.29	0.34	0.69	Double low-e coating, medium solar gain (MSG)	Argon	Insulating	Fiberglass
0.20	0.40	0.65	Triple low-e coating, high solar gain (HSG)	Argon	Insulating	Fiberglass

Table 5-3. Projection Factor Multipliers for South-Facing Windows

Projection Factor	Multiplier
> 0.5 – 0.6	1.06
> 0.6 – 0.7	1.11
> 0.7 – 0.8	1.16
> 0.8 – 0.9	1.20
> 0.9 – 1.0	1.23

For example, the recommended SHGC in Climate Zone 1 is 0.26. For an overhang with a projection factor of 0.7 on a south-facing window, a SHGC of 0.289 is acceptable (0.26 × 1.11 = 0.289).

EN15 *Window-to-Wall Ratio* (Climate Zones: all)

The window-to-wall ratio (WWR) is the percentage resulting from dividing the total glazed area of the building by the total exterior wall area. For any given WWR selected between 20% and 40%, the recommended values for U-factor and SHGC contribute toward the 30% savings target of the entire building. A reduction in the overall WWR will also save energy, especially if glazing is significantly reduced on the east and west facades. Reducing glazing on east and west facades for energy reduction should be done while maintaining consistency with needs for view, daylighting, and passive solar strategies.

Window Design Guidelines for Thermal Conditions

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

EN16 *Unwanted Solar Heat Gain is Most Effectively Controlled on the Outside of the Building* (Climate Zones: all)

Significantly greater energy savings are realized when sun penetration is blocked before it enters the windows. Horizontal overhangs at the top of the windows are most effective for south-facing facades and must continue beyond the width of the windows to adequately shade them (see Figure 5-3). Vertical fins oriented slightly north are most effective for east- and west-facing facades. Consider louvered or perforated sun control devices, especially in primarily overcast and colder climates, to prevent a totally dark appearance in those environments. See DL20 for more information on shading strategies.

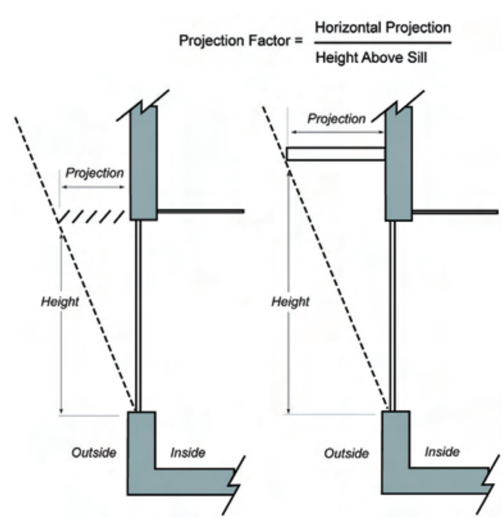

Figure 5-3. (EN16) Windows with overhang.

EN17 *Operable versus Fixed Windows* (Climate Zones: all)

Operable windows play a significant role in healthcare design in embracing the core idea of indoor to outdoor connection and reaching out to the outdoor environment and nature.

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

Operable Clerestory Windows for Free Nighttime Cooling (Night Flush). In some cases operable windows may be used to remove thermal loads that have accumulated over the course of daytime and are stored in the building by cross-ventilating the building after business hours. Occupancy types best suited are administrative work areas, public spaces, and in some cases exam rooms. To allow for this to happen, the following conditions are required:

- Footprint: narrow floorplate and open-plan layout
- Operable windows
- Solid slabs/exposed ceiling slabs in concrete structures

EN18 *Continuous Insulation to Avoid Thermal Breaks* (Climate Zones: all)

Windows that are installed out of the plane of the wall insulation are one common source of envelope thermal breaks or breaches. Figure 5-4a shows an example of this construction. Installing the fenestration outside of the plane of the wall insulation defeats the thermal break in the window frame. In cold climates this causes condensation and

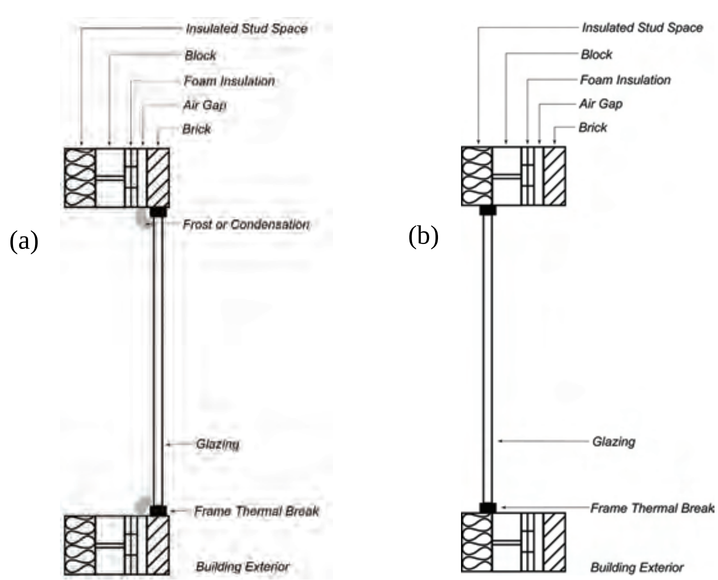

Figure 5-4. (EN18) Thermal break (a) at window frame and (b) in window frame aligned with wall insulation.

frosting. The normal solution is not to rebuild the wall but to blow hot air against the window to increase the interior surface temperature of the frame and glazing, which increases the temperature difference across the glazing and reduces the interior film coefficient from 0.68 to 0.25.

Fenestration should be installed to align the frame thermal break with the wall thermal barrier (as shown in Figure 5-4b). This will minimize thermal bridging of the framing due to fenestration projecting beyond the insulating layers in the wall.

Warm Climates

EN19 ***Building Form and Window Orientation*** **(Climate Zones: ❶ ❷ ❸)**

In warm climates, south-facing glass can be more easily shielded and can result in less solar heat gain and glare than can east- and west-facing glass. During early massing studies and pre-design, preference should be given to site layouts that permit elongating the building in the east-west direction and that permit orienting more windows to the north and south. A good design strategy avoids areas of glass that do not contribute to the view from the building or to the daylighting of the space. If possible, configure the building to maximize north- and south-facing walls and glass by elongating the floor plan. Since sun control devices are less effective on the east and west facades, the solar penetration through the east- and west-facing glazing should be minimized. This can be done by reducing the area of glazing or, if the glass is needed for view or egress, by reducing the SHGC, or by utilizing automated operable shading systems. For buildings where a predominantly east-west exposure is unavoidable, more aggressive energy conservation measures will be required in other building components to achieve an overall 30% energy savings. See DL5 and DL6 for more information on building orientation and shape as they relate to daylighting strategies.

EN20 ***Glazing*** **(Climate Zones: ❶ ❷ ❸)**

For north- and south-facing windows, select windows with a low SHGC and an appropriate visible transmittance (VT); see EN14. Certain window coatings, called *selective low-e*, transmit the visible portions of the solar spectrum selectively, rejecting the non-visible infrared sections. These glass and coating selections can provide a balance between VT and solar heat gain. Window manufacturers market special “solar low-e” windows for warm climates. All values are for the entire fenestration assembly, in compliance with NFRC procedures, and are not simply center-of-glass values. For warm climates, a low SHGC is much more important for low energy use than the window assembly U-factor. Windows with low SHGC values will tend to have a low center-of-glass U-factor because they are designed to reduce the conduction of the solar heat gain absorbed on the outer layer of glass through to the inside of the window.

EN21 ***Obstructions and Plantings*** **(Climate Zones: all)**

Adjacent taller buildings and trees, shrubs, or other plantings effectively shade glass on south, east, and west facades. For south-facing windows, remember that the sun is higher in the sky during the summer, so shading plants should be located high above the windows to effectively shade the glass. Also, be careful to not block south light that is being counted on for daylighting. While the shading effect of plants can reduce energy consumption, it doesn’t impact equipment size. The sizing of HVAC equipment relies on the SHGC of the glass and shading system only. The glazing of fully shaded windows can be selected with higher SHGC ratings without increasing energy use.

The solar reflections from adjacent buildings with reflective surfaces (metal, windows, or especially reflective curtain walls) should be considered in the design. Such reflections may modify shading strategies, especially on the north facade.

Cold Climates

EN22 *Window Orientation* (Climate Zones: ❹ ❺ ❻ ❼ ❽)

Only the south glass receives much sunlight during the cold winter months. If possible, maximize south-facing windows by elongating the floor plan in the east-west direction and relocate windows to the south face. Careful configuration of overhangs or other simple solar control devices will allow for passive heating when desired but prevent unwanted glare and solar overheating in the warmer months. To improve performance, operable shading systems should be employed that achieve superior daylight harvesting and passive solar gains and also operate more effectively when facing east and west directions. Unless such operable shading systems are used, glass facing east and west should be significantly limited. Areas of glazing facing north should be optimized for daylighting and view and focus on strong U-factors to minimize heat loss and maintain thermal comfort by considering triple glazing to eliminate drafts and discomfort. During early massing studies and pre-design, preference should be given to sites that permit elongating the building in the east-west direction and that permit orienting more windows to the south. See DL5 and DL6 for more information on building orientation and shape as they relate to daylighting strategies.

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

Passive solar energy-saving strategies should be limited to non-permanently occupied spaces such as lobbies and circulation areas, unless those strategies are designed so that the occupants are not affected by direct beam radiation. Consider light-colored blinds, blinds within the fenestration, light shelves, or silkscreen ceramic coating (frit) to control solar heat gain. In spaces where glare is not an issue, the usefulness of the solar heat gain collected by these windows can be increased by using hard massive and darker colored floor surfaces such as tile or concrete in the locations where the transmitted sunlight will fall. These floor surfaces absorb the transmitted solar heat gain and release it slowly over time, providing a more gradual heating of the structure. Consider higher SHGC and low-e glazing with optimally designed exterior overhangs.

EN24 *Glazing* (Climate Zones: ❹ ❺ ❻ ❼ ❽)

Higher SHGCs are allowed in colder regions, but continuous horizontal overhangs are still necessary to block the high summer sun angles.

Window Design Guidelines for Daylighting

Good Design Practice

EN25 *Visual Transmittance* (Climate Zones: all)

Utilizing daylight in place of electrical lighting significantly reduces the internal loads and saves cost on lighting and cooling power. In the US, it is estimated that 10% of the total energy generated in 24 hours is consumed by electrical lighting during daytime. The higher the visible transmittance (VT), the more energy can be saved.

The amount of light transmitted in the visible range affects the view through the window, glare, and daylight harvesting. For the effective utilization of daylight, high VT glazing types (0.60 to 0.70) should be used in all occupied spaces.

High VT's are preferred in predominantly overcast climates. VTs below 0.50 appear noticeably tinted and dim to occupants and may degrade luminous quality. However, lower VTs may be required to prevent glare, especially on the east and west facades or for higher WWRs. Lower VTs may also be appropriate for other conditions of low sun angles or light-colored ground cover (such as snow or sand), but adjustable blinds should be used to handle intermittent glare conditions that are variable.

High continuous windows are more effective than individual ("punched") or vertical slot windows for distributing light deeper into the space and provide greater visual comfort for the occupants. Try to expand the top of windows to the ceiling line for daylighting but locate the bottom of windows no higher than 30 in. above the floor (for view). Daylighting can be achieved with higher WWRs, which can lead to higher heating and cooling loads.

EN26 ***Separating Views and Daylight*** **(Climate Zones: all)**

In some cases, daylight harvesting and glare control are not always best served by the same glazing product. Patient rooms in particular require better control of visual comfort levels, which can make it necessary to separate daylight glazing from view glazing.

The most common strategy is to separate (split) the window horizontally to maximize daylight penetration. For daylight glazing, which is located above the view window, between 6 ft above the floor and the ceiling, high VT glazing should be used. The view windows located below 6 ft do not require such high VTs, so values between 0.50 and 0.60 are acceptable to achieve recommended SHGC values. See DL7–DL12 for more information on vertical glazing strategies.

Windows both for view and for daylighting should primarily be located on the north and south facades. Windows on the east and west should be minimized as they are difficult to protect from overheating and from glare. See DL4–DL6 for more information on building orientation and layout in regards to daylighting.

EN27 ***Color-Neutral Glazing*** **(Climate Zones: all)**

The desirable color qualities of daylighting are best transmitted by spectrally neutral glass types that alter the color spectrum to the smallest possible extent. Avoid tinted glass, in particular bronze- and green-tinted glazing.

EN28 ***Reflectivity of Glass*** **(Climate Zones: all)**

To the greatest extent possible, avoid the use of reflective glass or low-e coating with a highly reflective component. These reduce transparency significantly, especially at acute viewing angles where they impact the quality of the view.

EN29 ***Light-to-Solar-Gain Ratio*** **(Climate Zones: all)**

High-performance and selective low-e glazing permits significantly higher visual transmittance than reflective coatings or tints do. The light-to-solar-gain (LSG) ratio is the criteria for stating the efficacy of the glass, indicating the ability to maximize daylight and views while minimizing solar heat gain. In today's markets a variety of cost-effective glass types are available with high LSG ratios. Ratios over 1.6 are considered good. Any ratio greater than 2.0 is very effective and will contribute to achieving the goal of 30% savings.

EN30 ***High Ceilings*** **(Climate Zones: all)**

More daylight savings will be realized if ceiling heights are raised along the building perimeter. Greater daylight savings can be achieved by increasing ceiling heights to 11 ft or higher and by specifying higher VTs (0.60 to 0.70) for the daylight window than for the view window. North-facing clerestories are more effective than skylights to bring daylight into the building interior.

EN31 ***Light Shelves*** **(Climate Zones: all)**

Consider using interior or exterior light shelves between the daylight window and the view window. These are effective for achieving greater uniformity of daylighting and for extending ambient levels of light onto the ceiling and deeper into the space. Some expertise and analysis will be required to design an effective light shelf.

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LIGHTING

Energy-efficient lighting in the healthcare setting is possible without sacrificing the visual needs and comfort of patients and caregivers. There are also potentially beneficial health effects of exposing patients and staff to daylight in many settings. When properly designed, a positive synergy of energy conservation and improved health is possible.

Electric Lighting

Good Design Practice

EL1 ***Light-Colored Interior Finishes* (Climate Zones: all)**

For electrical lighting to be most efficient, spaces must have light-colored finishes. Ceiling reflectance should be at least 85% for direct lighting schemes and preferably at least 90% for indirect and daylighting schemes. This generally means using high-performance white acoustical tile or high-reflectance white ceiling paint on hard surfaces. For daylighting schemes, the average reflectance of the walls should be at least 50%, and for the portions of the wall adjacent to the daylighting aperture and above 7 ft high it should be 70%. This generally means using light tints for the wall surface, as the lower reflectance typical of doors, trim, and other objects on the walls will reduce the average. Floor surface reflectance should be at least 20%, for which there are many suitable surfaces.

The shape and finish of the ceiling should also be considered. A flat or gradually sloped ceiling is the most efficient; steep sloping ceilings and exposed structures, even if painted white, may have significantly lower reflectance. Lighting systems with indirect components are recommended in some applications, but if the ceiling cavity includes exposed structures or exposed ductwork, a higher percentage of direct light may be required. See DL22 for information on interior finishes for daylighting.

EL2 ***Linear Fluorescent Lamps and Ballasts* (Climate Zones: all)**

T-8 lamps with electronic ballasts are a very commonly specified commercial fluorescent lighting system in the United States. Fluorescent lamps with low mercury content are available from major lamp manufacturers and are the standard for sustainable design projects.

To evaluate the efficacy of the lighting system, consider the mean, or "design," lamp lumens in the lamp manufacturer's specification data. This value is lower than the initial lumens and reflects the depreciated lumen output occurring at 40% of the lamp's rated life, which better characterizes actual performance.

Generally, the lumen output will vary according to the color temperature, color rendering index (CRI), and between standard (RE700), premium (RE800), and high-performance (RE800/HL) lamps. The light source efficacy and LPD requirements in Chapter 3 can be achieved as long as the higher performance versions of T-8 lamps and ballasts are used.

The CRI is a scale measurement identifying a lamp's ability, generally, to adequately reveal color characteristics. The scale maximizes at 100, which indicates the best color-rendering capability. Lamps specified for ambient lighting should have a CRI of 80 or greater to allow for accurate perception of color characteristics. As shown in Table 5-4, "standard" T-8 lamps have lower CRI values than recommended.

High-performance T-8 lamps are defined, for the purpose of this document, as having a lamp efficacy of 90+ lumens per watt, based on mean lumens divided by the cataloged lamp input watts. High-performance T-8s also have a CRI of 82 or higher and no less than 95% lumen maintenance.

Next, select the ballast. The ballast has significant impact on the energy efficiency of the lighting system. Similar to lamp efficacy, lighting system efficacy is a measure of the energy efficiency of the combined lamp and ballast system.

To determine the lighting system efficacy, which is expressed in mean lumens per watt (MLPW), multiply the lamp mean lumens by the number of lamps and the ballast factor (BF), and then divide by the ballast input power (watts). For example, using two standard T-8 lamps and a generic instant start ballast, the system efficacy is

$$\frac{2 \text{ lamps} \times 2660 \text{ mean lumens} \times 0.87 \text{ ballast factor}}{59 \text{ watts}} = 77 \text{ MLPW}$$

Standard "Generic" Instant Start Electronic Ballasts. The most standard instant start ballast is the common and least expensive ballast; the typical input power for a two-lamp normal light level (0.87 BF) is about 59 W. If you do not specify ballast performance, this is likely what the manufacturer will use in the luminaire.

Low Light Output Version of Standard Ballasts. Similar to the standard ballast, this version operates at 0.78 BF and has input power of about 54 W for a two-lamp ballast. The resulting light level is about 10% less than the standard ballast, with a corresponding reduction in input power.

High Light Output Version of Standard Ballasts. Similar to the standard ballast, this version operates at 1.15–1.20 BF and has input power of 74 to 78 W for a two-lamp ballast. The resulting light level is about 32% higher than the standard ballast, with a corresponding increase in ballast input power.

Program Start Ballasts. Available in low power and normal power models, program start ballasts use an additional watt per lamp to perform programmed starting, which makes lamps last longer when frequently switched.

Dimming Ballasts. Electronic ballasts that provide a continuous range of dimming are available in varying ranges from 100%–20% to 100%–1%. Most dimming ballasts require 60 to 66 W for two lamps. Additional power, compared to fixed output ballasts, is used to heat the lamp cathodes to permit proper dimming operation, but some newer high-performance dimming ballasts do have full output MLPW over 90. (MLPW efficacy is less valuable for evaluating dimming ballasts since the lumen output, BF, and corresponding input power vary over the dimming range of the ballast). Another variation is "stepped dimming," which typically provides 2 or 3 levels, such as 50% and 100% or 35%, 65%, and 100%.

Table 5-4. Typical T-8 Lamp Specification Data

Lamp General Description	T-8 Lamp Designation	Lumens		CRI	Color Temp, K
		Initial	Mean		
Standard F32T8	F32T8/RE741/ECO	2800	2660	78	4100
Premium F32T8	F32T8/RE841/ECO	2950	2800	85	4100
High Performance F32T8	F32T8/RE841/HL/ECO	3100	3000	85	4100

Stepped dimming ballasts are typically less expensive than continuous dimming.

High-Performance Electronic Ballasts. A high-performance electronic ballast is defined, for the purpose of this document, as a two-lamp ballast using 55 W or less with a BF of 0.87 (normal light output) or greater. High-performance ballasts are also available for low light output, high light output, and dimming versions.

Table 5-5 shows combinations of various lamps and ballasts (with two-lamp ballasts; values for one-, three-, and four-lamp ballasts will be slightly different). Use this table to select T-8 lamps and ballasts to meet the LPD and efficacy recommendations of Chapter 3. Low-wattage T-8 lamps are available ("energy-saving" 30, 28, or 25 W versions of a 4 ft lamp) but may result in lower light levels or an increased number of fixtures or lamps to achieve recommended light levels. Because of limitations in their use for dimming and other applications, these lower wattage lamps are not considered for these recommendations. In general, specifying "high-performance" electronic ballasts and fluorescent lamps is required to meet the energy-efficiency objectives.

EL3 *Fluorescent T-5 Sources* (Climate Zones: all)

As an alternative to T-8 lamps, T-5 lamps may also be used. T-5 lamps are now available in standard, premium, and high output (HO). An advantage of T-5s is reduced use of natural resources (glass, metal, phosphors) in the lamp, plus the ability to use smaller luminaires than comparable T-8 systems. The standard and premium versions, nominally 28 W, offer at least 90 MLPW with any available ballast. When used in optimally designed luminairies, they offer the highest efficiency available today. T-5HO lamps offer at least 75 MLPW on any ballast, including dimming ballasts. Despite their lower efficacy, their high output may provide better overall performance in some applications. (See Table 5-6.)

Table 5-5. Efficacy Values for Different Lamp/Ballast Combinations (Using Two 32 W T-8 Lamps)

Ballasts	Lamp Selection		
	F32T8 Standard	F32T8 Premium	F32T8 High Performance
Generic Standard Instant Start (59 W, 0.87 BF)	77	80	87
Standard Instant Start Low Light Level (54 W, 0.78 BF)	75	78	85
Standard Instant Start High Light Level (74 w, 1.15 BF)	81	84	92
Standard Program Start Normal Light Level (60 w, 0.88 BF)	78	82	88
Program Start Low Light Level (56 w, 0.78 BF)	73	75	82
Dimming Rapid Start (64 w max, 0.88 BF max)	72	75	81
High-Performance Normal Light Level (55 w, 0.88 BF)	85	90	95
High-Performance Instant Start Low Light Level (48 w, 0.78 BF)	85	88	96
High-Performance Instant Start High Light Level (70 w, 1.15 BF)	86	89	97
High-Performance Dimming, Step and Continuous (54 w, 0.87 BF)	78	81	97

Meets 90 MLPW efficacy criteria (shaded cells)

EL4 ***Compact Fluorescent*** **(Climate Zones: all)**

To achieve the LPD recommendations in Chapter 3, compact fluorescent lamps (CFLs) can be used for a variety of applications such as utility lighting in small spaces, downlighting, accent lighting, and wall-washing. Suitable lamps include twin tube, multiple twin tube, twist tube, and long twin tube lamps. Only pin-based CFLs are included in this group, since a screw-based lamp can be replaced with an incandescent lamp and is therefore not compliant with most energy codes. Suitable luminaires have integral hard-wired electronic ballasts.

Because the efficacy of CFLs is typically less than 60 MLPW, they should not be used for general lighting in most space types. To meet the 50 MLPW efficacy requirements, some CFL-and-ballast combinations must be avoided (see Table 5-7).

EL5 ***Metal Halide*** **(Climate Zones: all)**

To achieve the LPD recommendations in Chapter 3, metal halide lamps may be used for general lighting in large spaces outdoor lighting, and for accent lighting and wall-washing in low wattages. In the metal halide family there are two primary types: ceramic metal halide (CMH) lamps and quartz metal halide (QMH) lamps. Both types are high-intensity discharge lamps in which intense light energy is generated inside an arc tube made either of ceramic or quartz glass. The two types are comparably efficient. CMH lamps have very good color in the warm (3000 K) and neutral (4000 K) ranges; QMH lamps' color rendering quality is mediocre except in high color temperature lamps (5000 K and above). In general, only the improved CRI CMH lamps are recommended for interior applications.

Table 5-6. Typical T-5 Lamp Specification Data

Lamp General Description	T-5 Lamp Designation	Lumens		CRI	Color Temp, K
		Initial	Mean		
Standard F28T5	F28T5/RE841/ECO	2900	2700	85	4100
Premium F28T5	F28T5/RE841/HL/ECO	3050	2900	85	4100
High Output F54T5HO	F54T5/RE841/ HO/ECO	5000	4650	85	4100

Table 5-7. System Efficacy for CFL-Ballast Systems

Lamp Type	Magnetic Ballast and Pre-Heat Lamp (2 Pin Lamps)	Electronic Ballast (4 Pin Lamp) Program Start (instant start)	
5–13 W twin tube	All < 50	57 (13 watt only)	
13–26 W double twin tube	All < 50	13 W	57
		18 W	52
		26 W	53
18–42 W triple and quad twin tube and most twist tube lamps	N/A	18 W	53
		26 W	55
		32 W	55
		42 W	57
2D	28 W < 50	28 W	63
Long twin tube	N/A	18 W	46
		24/27 W	61
		36/39 W	64
		40 W	60

Does not meet efficacy criteria.

Meets 50 MLPW efficacy criteria.

Table 5-8. System Efficacy for Metal Halide Lamp-Ballast Systems

Lamp	Type	Magnetic Ballast	Electronic Ballast (Minimum Efficacy; Some Ballasts Will Be Higher)
20 W CMH	Pulse start	N/A	55
35/39 W CMH	Pulse start	43	53
50 W QMH	Pulse start	33	40
70 W CMH	Pulse start	45	51
100 W CMH	Pulse start	51	60
150 W CMH	Pulse start	59	67
175 W QMH	Probe start	N/A	N/A
	Pulse start	67	72
320 W QMH	Pulse start	71	76
350 W QMH	Pulse start	73	77
400 W QMH	Probe start	N/A	N/A
	Pulse Start	71	82
400 W CMH	Pulse Start	72	87

Does not meet efficacy criteria (shaded cells)

Metal halide lamps may be further categorized into low-wattage (150 W and lower) and high-wattage (higher than 150 watts). All low-wattage lamps are pulse start and can be operated on either magnetic ballasts or more efficient electronic ballasts. High-wattage lamps are available in both probe start (less efficient) and pulse start (more efficient). Recently, electronic ballasts have become practical for indoor use of pulse start metal halides; most ballasts for high-wattage lamps are magnetic. The Energy Independence and Security Act (EISA) of 2007 regulates the type of ballast that may be used in commercial luminaires starting in 2009. The act sets minimum efficiency performance for ballasts for metal halide lamps greater than 150 W and less than 500 W. The effective result of the legislation is that magnetic probe start metal halide systems are rendered obsolete in favor of pulse start and electronic ballast systems.

With metal halide lamps, their apparent high efficacy (from initial rated lumens) is often offset by their high rate of lumen depreciation. Probe start metal halide lamps operated on magnetic ballasts will lose more than 45% of their rated lumen output over life; with pulse start lamps, the losses are about 35% on magnetic ballasts but can be improved to about 20% by using electronic ballasts. Since mean lumens takes lumen depreciation into account, the type of ballast plays a significant role in the efficacy. As a result, a number of lamps and ballasts do not meet the efficacy criteria, as shown in Table 5-8 (not a comprehensive list).

Caution: Metal halide lamps require a warm-up and re-strike time of up to 15 minutes if turned off during operations. Therefore a supplemental emergency source is required that will provide light during the re-strike time when used in applications requiring emergency standby power. In addition, metal halide lamp performance is affected by the position of the lamp arc tube. When the lamp is operated in a position other than the rated position, the output will be reduced. This is known as the *tilt factor*. Lamps applied in a manner where tilt factor reduces output will have reduced efficacy that may fall outside the recommendations.

EL6 *Exit Signs* (Climate Zones: all)

Use light-emitting diode (LED) exit signs or other sources that use less than 5 W per face. The selected exit sign and source should provide the proper luminance to meet all building and fire code requirements.

EL7 *General Lighting Control Strategies* (Climate Zones: all)

To maximize the energy performance of a facility, lighting control strategies should be adopted to optimize how lights are turned on, when and how lights are turned off, and the output level of the lights whenever they are operating. The optimum electric light level in a given space is dependent on the task or activity in the space, the user's personal preference or desired aesthetic, and the amount of daylight in the space. Typically, the highest potential for lighting energy savings in a hospital is to adjust the lighting to optimum levels whenever the lights are turned on.

One example of this approach is the common need for relatively high illuminance levels in a space for housekeeping and maintenance where lower light levels would be appropriate for typical operation or patient care. In this application, having the higher level of illumination separately controlled by a manual ON-time interval OFF switch, instead of setting the room lighting at the higher level all the time, will save energy. Another prime light control strategy for most public spaces, corridors, waiting rooms, etc. is daylighting control, where electric light levels are automatically adjusted to supplement the available daylight in a space throughout the day.

EL8 *Occupancy-Based Control* (Climate Zones: all)

Use occupancy sensors in all exam and treatment rooms as well as in staff support spaces for nutritional care, medication areas, clean and soiled utility rooms, offices, mechanical rooms, restrooms, and storage rooms. The greatest energy savings and occupancy satisfaction are achieved with manual ON/automatic OFF occupancy sensor scheme (also referred to as *vacancy sensing*). This avoids unnecessary operation when electric lights are not needed, reduces the frequency of switching, and maximizes lamp life compared to automatic ON schemes. In every application the occupant should not be able to override the automatic OFF setting, even if it is set for manual ON. A manual OFF or separate switching capability is also useful for multi-level lighting schemes where a higher light level is only needed periodically. Unless otherwise recommended, occupancy sensors should be set for medium to high sensitivity and a 15-minute time delay (the optimum time to achieve energy savings without excessive loss of lamp life). Review the manufacturer's data for proper placement and coverage.

In high-performance integrated lighting control systems, motion sensors can also be used in spaces that have little if any traffic during late-night hours. If light levels are automatically set back late at night, motion sensors can be used to raise light levels in public corridors, waiting rooms, and other spaces whenever someone approaches and occupies the space.

The two primary types of occupancy sensor technologies are passive infrared (PIR) and ultrasonic. PIR sensors can see only in a line-of-sight and should not be used in rooms where the user cannot see the sensor (e.g., storage areas with multiple aisles, restrooms with stalls). Ultrasonic sensors can be disrupted by high airflow and should not be used near air duct outlets. Dual-technology sensors combine the sensor technologies; these should be considered for spaces larger than 150 ft^2 or those with objects or partitions that could affect the performance of PIR sensors. Sensors can also incorporate auxiliary relays that can interface between lighting and other building systems.

Caution: Occupancy sensors should not be used with high-intensity discharge (HID) lamps because of warm-up and re-strike times.

Programmed start ballasts are recommended for fluorescent lamps and CFLs if frequent on-off cycles are expected. (Some standard ballasts and all dimming ballasts are programmed start for some lamp types.)

EL9 *Wall Control—Dimming and Switching* (Climate Zones: all)

In patient care spaces, the controls for switching and dimming of the lighting system (and motorized window shades if provided) should be readily accessible by patients, their families, and support staff. In spaces with several lighting zones and where multiple control locations are desired, the number of conventional 120V/277V switches and multi-gang switch locations can become cumbersome and confusing to the patient, family members, and care-giving staff. In these applications, low-voltage multifunction wall controls with appropriate labeling should be considered.

In non-patient-care areas, the controls should be located where they are easily accessible and understandable by the care-giving staff. In general use spaces, lighting should be controlled by a time-of-day scheduling system or occupancy sensors. Wall controls should be provided for manual override. These manual controls should be placed in remote locations for use by the staff only.

EL10 *Patient Control* (Climate Zones: all)

Practical patient control of lighting and window shades should be integrated to the patient's pillow speaker or other bedside remote control. In most areas, giving the patient the capability to control light levels and window shades to enhance their comfort is beneficial. It also reduces the patient's dependency to call a nurse to make adjustments to the environment, enhancing the nurse's productivity.

EL11 *Time Clock Control* (Climate Zones: all)

Interior Lighting. In some general purpose spaces, retail and dining areas, and even administration office areas, time-of-day scheduling controls can be used to ensure that lights are on when desired and reduced or turned off after hours when not required. (Refer to EL8 for how occupancy sensors can be used with time clock controls to raise light levels whenever someone approaches or occupies the space.)

In spaces that have significant daylighting, such as an entry lobby, time-of-day scheduling can be used to reduce the output or turn off some interior lights during the day.

Exterior Lighting. Use an astronomical time switch with an exterior photocell for all exterior lighting. Turn off exterior lighting not designated for security purposes when the building is unoccupied. This system can be programmed to control lighting related to the daily sunrise and sunset for the geographic location of your building. This not only eliminates the need to make seasonal adjustments to your time clock controls but also maximizes the energy saved with time clock control (lights are never turned on too early or left on longer than needed). Astronomical time switches can retain programming and the time setting during loss of power for at least 10 hours. If a building energy management system is being used to control and monitor mechanical and electrical energy use, it can also be used to schedule and manage outdoor lighting energy use.

EL12 *Daylight Harvesting Control* (Climate Zones: all)

In atriums, lobbies, waiting rooms, corridors, open-office and administration areas, and other appropriate spaces where the design team has brought quality daylight into the space, automated daylight harvesting controls can be used to regulate the output of electric lights to optimize the quality of the visual environment while saving significant amounts of energy. Step dimming systems can be applied where abrupt incremental changes in ambient electric light levels will not be a distraction to the occupants in the space. In spaces where adjustments in electric light levels should be transparent to the occupants, continuous dimming systems should be applied.

Daylight harvesting controls may be considered in patient room applications, especially for the lighting zones nearest the windows. Lighting power reductions during daylight hours have been as high as 87% in this application (Brown et al. 2005). However, patient control of their environment is an overriding priority, and automatic controls should not override the ability to manually control the lights. This makes the potential energy savings challenging to quantify. See DL25–27 for additional information on daylighting control strategies.

EL13 *Electrical Lighting Design* (Climate Zones: all)

The 1.0 W/ft^2 LPD (shown in the recommendation tables in Chapter 3) represents an average LPD for the entire building. Alternatively, individual spaces may have higher

Table 5-9. Space-by-Space Lighting Power Density Recommendations

Space	How-to Tips	Recommended LPD W/ft^2	Control Scheme*
Patient room	EL14–EL15	0.7	ML/DL
Nurse station	EL16–EL17	1.0	ML/DL
Surgery/operating room	EL18–EL19	2.0	ML
PACU/recovery/non-invasive treatment	EL20–EL21	0.8	ML
Treatment/procedure room	EL22–EL23	2.0	ML/ DL
Exam room	EL24	1.2	ML/OC/DL
LDR/obstetrics	EL25–EL26	0.6	ML
Radiology	EL27–EL28	0.8	ML
Lab/pharmacy	EL29	1.2	SW/OC
Work room/supply room	EL16–EL17	1.2	ML/OC
Individual office	EL30–EL31	0.9	ML/OC/DL
Conference room	EL30–EL31	1.2	ML/OC/DL
Corridor (24-hour care)	EL16–EL17	0.7	ML/DL/LS
Corridor (non-care)	EL16–EL17	0.7	TC/OC/DL/LS
Lobby	EL31	0.9	TC/OC/DL/LS
Physical therapy		0.9	ML/TC/OC/DL
Laundry		0.6	TC/OC
Lounge/waiting	EL31	0.8	TC/OC/DL/LS
Food prep		1.2	TC/OC

* ML – Multi-level or dimming; SW – Manual switch; TC – Astronomic time schedule; OC – Occupancy/vacancy sensor; DL – Daylight harvesting; LS – Light level setback.

power densities if they are offset by lower power densities in other areas. In this space-by-space method, calculate an overall lighting power allowance for the entire project by adding the products of the individual space type areas and their respective LPD recommendation as shown in Table 5-9. (For spaces not listed in Table 5-9, use the appropriate entry in the ASHRAE/IESNA Standard 90.1 space-by-space power density table, Table 9.4.5.).

EL14 *Lighting for the Patient Room* (Climate Zones: all)

The private hospital patient room must accommodate a multitude of medical tasks. The patient room lighting design must reconcile multiple lighting needs as simply and economically as possible. The patient, the patient's family, doctor, nurse, and housekeeping personnel may each require different illuminance levels for various tasks.

A long-term design trend is to give the patient room the aura of a home or hotel bedroom, so it is desired that the luminaires are not overly "institutional" in appearance. Decorative luminaires such as wall sconces are welcome but should be controlled separately from other lighting for the patient and examination. Use luminaires with high efficacy sources and limited power and light output.

The room lighting should accommodate reading at the normal reading position, for the patient sitting up in bed, as well as for visitors and caregiving staff. Consideration should be given to the patient lying in the supine position on the bed being exposed to the luminance of lights in the ceiling in their direct line of sight, as this makes them vulnerable to glare. A wall-mounted indirect light located at the head of the patient bed is a proven approach for low-glare general light.

Additionally, lighting for staff examination of the patients is needed. This illumination should be as shadow-free as possible and have a color quality that enables accurate observation of all tissue surfaces. Whether fixed or portable, the examination lighting should be confined to the bed area and intuitively controlled by the nursing staff.

A source of local low-level illuminance is needed during the night to allow the nurse and patient to navigate the room during normal sleeping hours. There is a potential conflict between the light needed for observation by the nursing staff and the patient's need for darkness at night to accommodate sleep. A low-wattage shielded LED night light located between the bed and the door is a good choice.

The patient bathroom should be adequately illuminated to avoid falls caused from wet floors.The vanity area should be illuminated so the face is properly modeled. This is often accomplished with a luminaire mounted to the wall either flanking or above the mirror. (See Figure 5-5.)

EL15 ***Lighting Control for the Patient Room*** **(Climate Zones: all)**

Lighting controls should be located for the patient, visitors, and the nursing staff. Multiple light-level switching or dimming controls should be positioned at the entrance to patient rooms to create a comfortable visual environment per the patient's preference or as needed for the task at hand.

For observing patients, local low-level lighting is needed at night. This light should be switched at the door and include dimming controls. Light control should also be considered to enable the staff to immediately bring all lights in the patient room on to full output in a medical code emergency.

In patient rooms with four or more lighting zones and where multiple control locations are desired, the number of conventional switches and multi-gang switch locations can become cumbersome and confusing to the patients, their families, and the care-giving staff. In these applications, low-voltage multifunction wall controls with appropriate labeling should be considered.

Patient control of lighting and window shades should be integrated to the patient's pillow speaker or other bedside remote control. Convenient controls for the patient not only empower and relax the patient but also reduce the patient's dependency to call a nurse to make adjustments to lighting and window shades, enhancing the nurse's productivity.

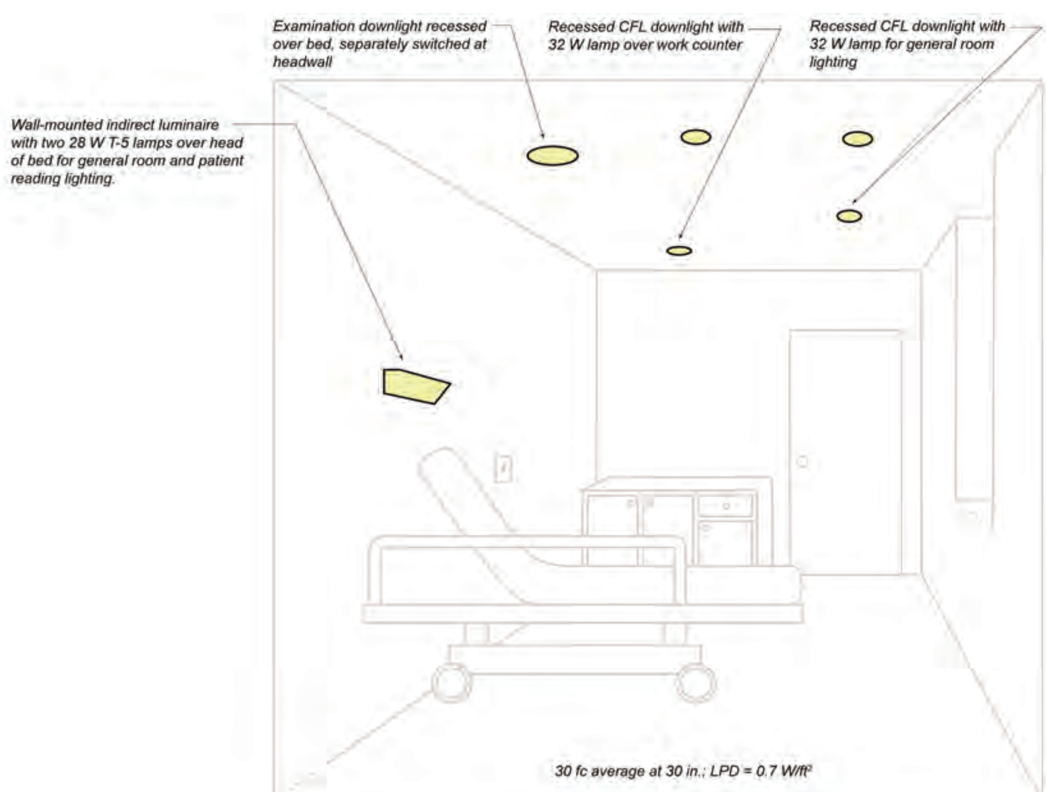

Figure 5-5. (EL14) Patient room lighting plan.

Patient room designs have also improved to provide the patient and staff excellent access to daylight and views. To further optimize energy performance, lighting controls may be considered to take advantage of the daylight provided. Manual dimming controls should be evaluated to enable reduction in electric light output of appropriate light fixtures in response to the daylight available in the space. Automated daylight harvesting controls might be considered for the lighting zone nearest the windows that dim or turn off these lights when ample daylight is present. (See EL12 and DL25–27 for more information on daylight harvesting.)

EL16 *Lighting for Nurse Stations and Care Area Corridor* (Climate Zones: all)

In most cases, patient care is coordinated from a station. Reading, writing, filing, monitoring, care-giving team communication, medication dispensing, and many other care-related functions take place here. Data entry and charting using a computer means that low-glare illuminance should be considered to mitigate reflected glare on the monitor screen. In addition, digital record processes are creating a trend where data entry occurs throughout the care area with distributed work stations in the corridor outside the patient rooms in addition to the nurse station.

The nurse station is used continuously night and day. Attention should be given to the varying demands of lighting for daytime and nighttime. For those walking to and from corridors and the patients' rooms, consider the lighting transitions so they are fully coordinated under both day and night conditions to avoid continuous retinal re-adaptation.

During sleeping hours, high levels of illumination in the corridor may trespass into the patient room when nurses enter the room. Therefore, it is suggested that the corridor lighting be adjustable to allow a "night" setting with reduced illuminance. (See Figure 5-6.)

Cautions: In general, recessed downlights are too inefficient to provide the necessary illumination in corridors. However, recessed downlights that use CFLs may be appropriate for supplemental light in applications where a low-brightness appearance is desired or as a task light in a specific area.

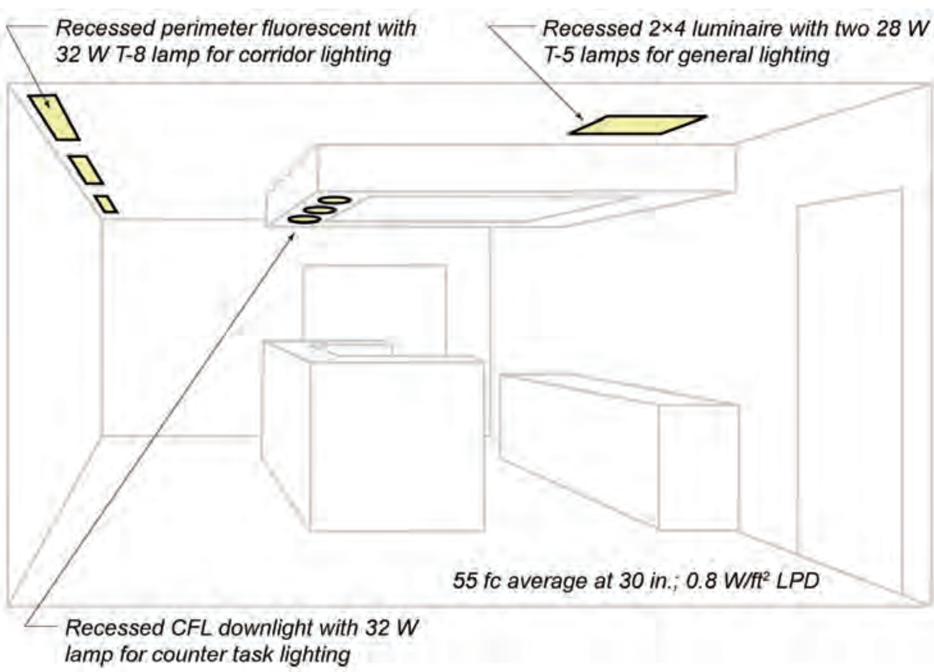

Figure 5-6. (EL15) Nurse station lighting plan.

The corridors should have an emergency lighting system that can produce at least 1 footcandle (fc), on average, along the path of egress. The controls must operate the intended lights during a power outage regardless of normal control setting. This may require an automatic transfer relay that bypasses normal controls.

Switching of the lighting system in corridors should be readily accessible only to the staff.

Avoid overlighting with inefficient task lighting at work counters. Typical linear fluorescent luminaires may overlight the task area when mounted less than 36 in. from the surface. Lights mounted under wall cabinets and transaction counters are often obstructed by objects in the work area.

EL17 *Lighting Control for Nurse Stations and Care Area Corridor* (Climate Zones: all)

The nursing staff frequently make trips from their work stations to patient rooms; lighting level transitions from the work stations to corridors and patient rooms should be coordinated under both daytime and nighttime conditions. Wall control dimming or multiple-level switching control should be provided to balance near- and far-field luminance levels.

Corridor lighting should be equipped with manual dimming or multi-level switches to allow a "night" setting with reduced illuminance. In corridors, lighting controls should *not* be readily accessible to the general public.

Adjacent medication areas should have multiple-level switching or dimming control to provide at least two light levels, one for general work and one for medication preparation. This space is also a prime candidate for occupancy-based controls.

In general, switching in 24-hour patient care areas should not use an automatic time-of-day control system; however, controls using occupancy sensors may be effective. In non-24-hour care settings, automatic time-of-day control with local manual override is appropriate. In addition, provide automatic daylight harvesting controls with dimming or multi-level switching in corridors having windows, skylights, or other forms of natural lighting.

EL18 *Lighting for Surgical Suite* (Climate Zones: all)

Operating room lighting is perhaps the most important lighting in the hospital. Various tasks take place here and lighting needs are different for the surgical team, the nurse, the anesthesiologist, and other staff. Because of the variety of surgical procedures, the general lighting should suit the varying visual requirements of the surgeon and staff. A uniformly distributed, multi-level, adjustable illuminance should be provided using recessed shielded luminaires, with a quality prismatic lens that gives diffused, low-glare light. The general room lighting should be able to provide at least 100 fc uniformly throughout the surgical field.

Color appearance should not noticeably change when viewed under the surgical task light or the general room illuminance. This is best achieved by matching the spectral power distributions of these two light sources, but usually it is only practical to match their color temperatures. For example, if the main surgical light has a color temperature of 4100 K, then the general room illuminance should be provided by sources with a similar color temperature.

The proliferation of minimally invasive surgical techniques using a variety of different remote vision scopes, as well as implementation of digital imaging and patient telemetry, has led to greater use of heads-up video display monitors, usually liquid crystal display (LCD) flat panels. It is not uncommon to have several display monitors viewable from the surgical table. The combination of heads-up and heads-down tasks creates challenges for maintaining a glare-free and comfortable visual environment. It is important to properly balance the room surfaces' reflectance and luminance to prevent disruptive veiling reflections on the monitors and visual discomfort from high contrast ratios. The capability to control the luminance of perimeter wall surfaces by varying the general ambient light during the surgical procedure is an important feature. (See Figure 5-7.)

The surgical task light must provide a variable range with high levels of illuminance—more than 1000 footcandles—in a small area with little or no shadows. It must also be adjustable, both in beam size and position, to accommodate the multiple viewing needs and positions of the various members of the surgical team. The task lighting system usually is comprised of two to three specialty luminaires suspended from the ceiling over the surgical table. These lights commonly use high-output quartz halogen sources with special dichroic reflectors to manage the color temperature and radiated energy of the light. The latest solid-state LED lighting technology offers promise of more energy efficiency and even better shadow-free light distribution, with less radiated heat. (See Figure 5-7.)

EL19 *Lighting Control for Surgical Suite* (Climate Zones: all)

General and ambient lighting fixtures should incorporate dimmers or multi-level switching controls. High light levels are required to clean and set up these spaces. During procedures, especially when video screens or microscopes are introduced, physicians and technicians desire lower ambient light levels for a clear view of video images. Controls should be conveniently provided to make adjustments to the perimeter and ambient lighting that match the specific requirements of each procedure and the preferences of the surgical team.

EL20 *Lighting for PACU/Recovery Rooms* (Climate Zones: all)

The post anesthetic care unit (PACU) recovery room is where the patient is placed after a surgery. Its lighting needs are also applicable for pre-operative holding and induction rooms. This space has to accommodate careful examination and monitoring of the patient and, on occasion, an emergency procedure if the patient's condition requires.

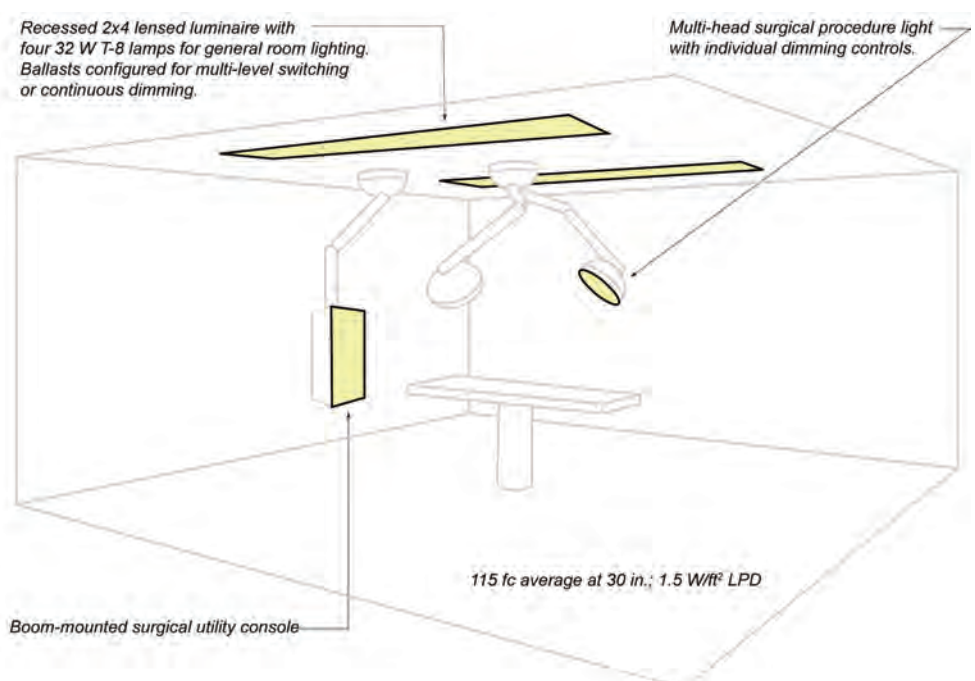

Figure 5-7. (EL18) Operating room lighting plan.

As patients regain consciousness, they will be sensitive to intense brightness, especially since they are typically supine in the bed. Therefore, the general lighting approach should be subdued, with the capability to quickly raise the illuminance in case staff needs to work. A multi-level scheme with dimming, stepped switching, or multiple light sources should be considered.

The presence of daylight in the area, while not necessary, can be pleasant for the patient's comfort as long as direct glare from glazing is avoided. (See Figure 5-8.)

EL21 ***Lighting Control for PACU/Recovery Rooms*** **(Climate Zones: all)**

Wallbox dimming or dual-level controls should be adopted for PACU/recovery rooms so that lights can be dimmed for patient comfort and increased for critical tasks when needed. Lowered ambient light levels also may be desired for some emergency procedures (such as when using a laryngoscope). Individual light controls should be provided at locations that are conveniently located for the staff to use.

EL22 ***Lighting for Non-Surgical Treatment Procedure Rooms*** **(Climate Zones: all)**

Rooms for non-invasive treatments and procedures, commonly seen in the emergency department as well as in other outpatient care environments, pose complex demands on the lighting because of the wide variety of activities that may take place. General lighting for examining patients should be as shadow-free as practicable and have a color quality that enables accurate diagnosis of all tissue surfaces. When the patient is being examined, the uniformity and level of illuminance are important. The ability to reduce the general illuminance to a subdued level is also desirable for patient comfort in some common situations.

Repair of lacerations and treatment of wounds is frequently performed in such rooms. This meticulous work has similar illumination needs as surgery. Although the tasks are typically smaller and procedures are not quite as long and demanding as surgery, they still require the use of a specialized task light similar to that in the operating

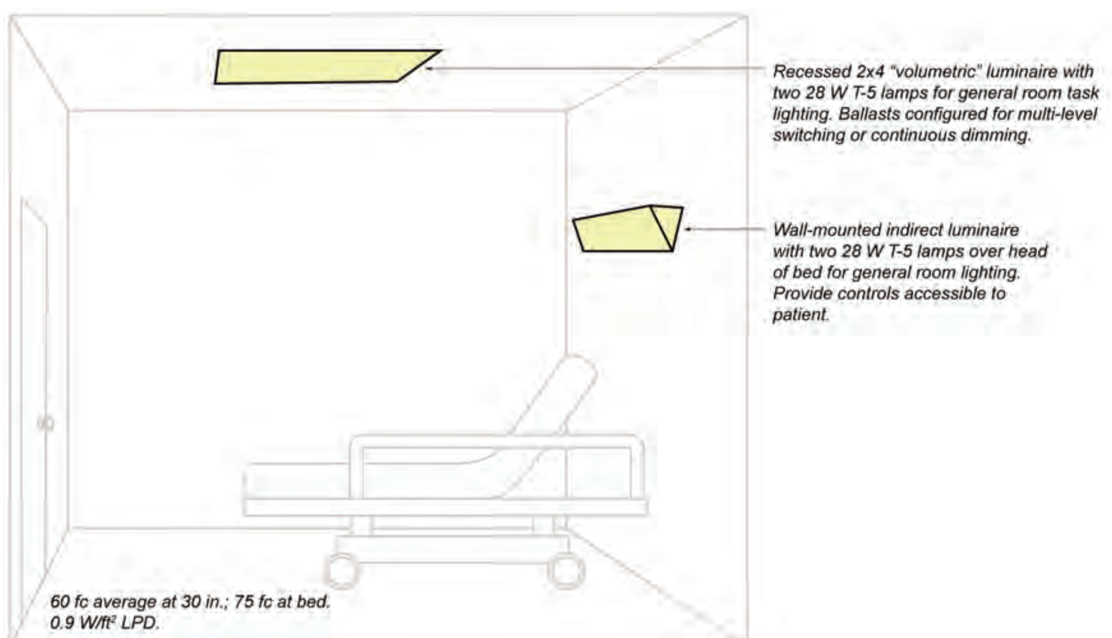

Figure 5-8. (EL20) PACU lighting plan.

room. Whether fixed or portable, the specialized task lighting should be located in the bed area and controllable by the nursing staff. .(See Figure 5-9.)

EL23 *Lighting Control for Non-Surgical Treatment Procedure Rooms* (Climate Zones: all)

In non-surgical treatment areas as well as in rooms for dialysis, chemotherapy, and other infusion treatments, etc., manual dimming or multi-level switching light controls should be provided for the staff to adjust light levels to relax patients before and during these procedures. When possible, patients should be able to control the lights and window shades to personal preferences to reduce stress and make them as comfortable as possible. Handheld remote controls or infrared control integrated into a television remote control are options that should be considered to allow patients to control their environments during these long procedures.

EL24 *Lighting for Exam Rooms* (Climate Zones: all)

Exam rooms are spaces for general examination and diagnosis. General lighting for examining patients should be as shadow-free as practical and have a color quality that enables accurate diagnosis of all tissue surfaces. The uniformity and level of illuminance are also important. (See Figure 5-10.)

EL25 *Lighting Control for Exam Rooms* (Climate Zones: all)

When in rooms waiting to be examined, patients might be suffering from migraine headaches and other conditions, making them very sensitive to light. Multi-level switching or dimming to reduce the general illuminance to a subdued level is desirable for their comfort while waiting to meet with the doctor or nursing staff. Occupancy/vacancy sensors are also ideal in this application. In exam rooms with windows, automatic daylighting controls with dimming or step dimming capabilities will also reduce energy consumption.

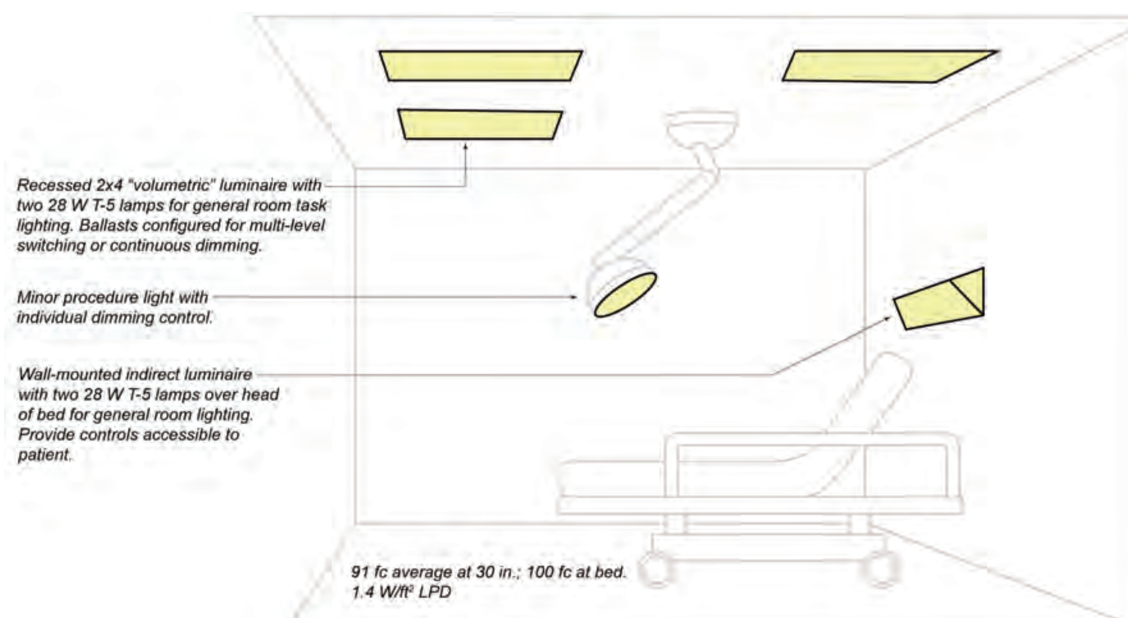

Figure 5-9. (EL22) Non-surgical treatment room lighting plan.

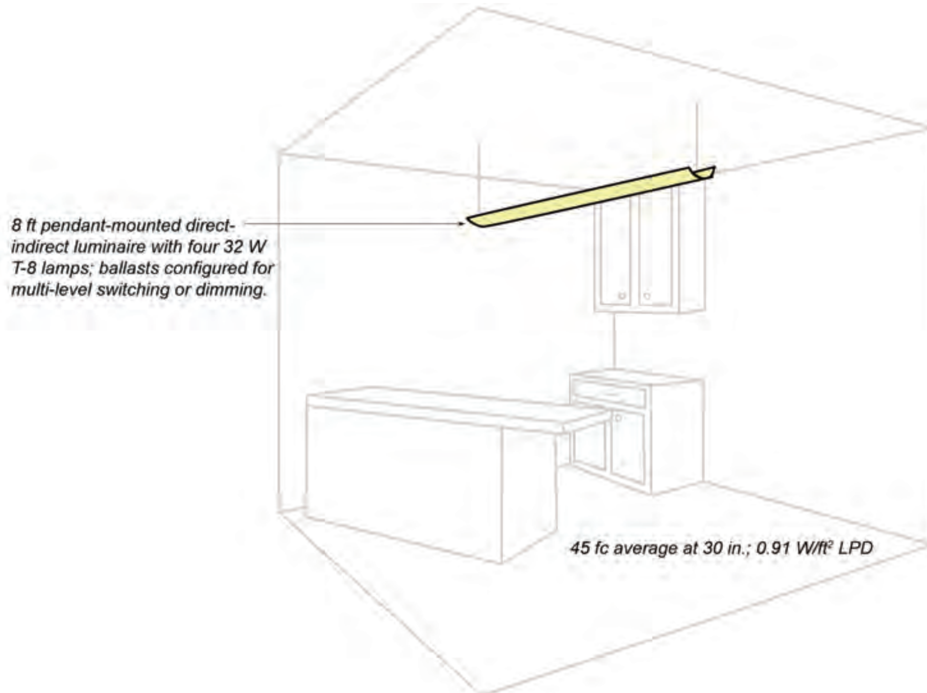

Figure 5-10. (EL24) Exam room lighting plan.

EL26 *Lighting for the Obstetrics Suite* (Climate Zones: all)

A recent trend has been the use of multi-purpose rooms for observation, labor, and delivery during routine births. Sometimes, the newborn is even kept in the same room as the mother after delivery instead of in a separate nursery. These rooms are commonly referred to as labor, delivery, and recovery (LDR) rooms and may also include postpartum stay (LDRP). Such rooms frequently have a home- or hotel-like atmosphere and use a specially designed birthing bed.

After birth, the infant is typically kept in a nursery for observation. Nursery lighting should allow the easy examination of infants in cribs and incubators. The general lighting should not be kept at high levels because infants may be vulnerable to retinopathy (damage to the retina from overexposure to light). Luminaires for general lighting should be selected and/or installed so that the luminance, as seen from the normal bassinet position, is not uncomfortable or harmful to the infant patient. Variable indirect ambient lighting is desirable for this type of space.

Special care nurseries (SCNs) or neonatal intensive care units (NICUs) are used for premature or ailing infants. Flexible lighting levels are needed in these areas. The staff may prefer subdued light for some periods yet need high levels for tasks during emergencies or treatment. Parents often visit the rooms to feed or hold their infants. Dimming, or zones of individualized control, should be provided for the activities. Also, spaces with exposure to daylight may help improve healing time and deter depression. (See Figure 5-11.)

EL27 *Lighting Control for the Obstetrics Suite* (Climate Zones: all)

Today's birthing rooms are intended to have a "home-like" atmosphere. To compliment the furnishing and room finishes, manual wallbox dimming controls should be provided for patients, visitors, and staff to adjust the general ambient lighting to create an environment that is as comfortable and relaxed as possible. Wall controls should be

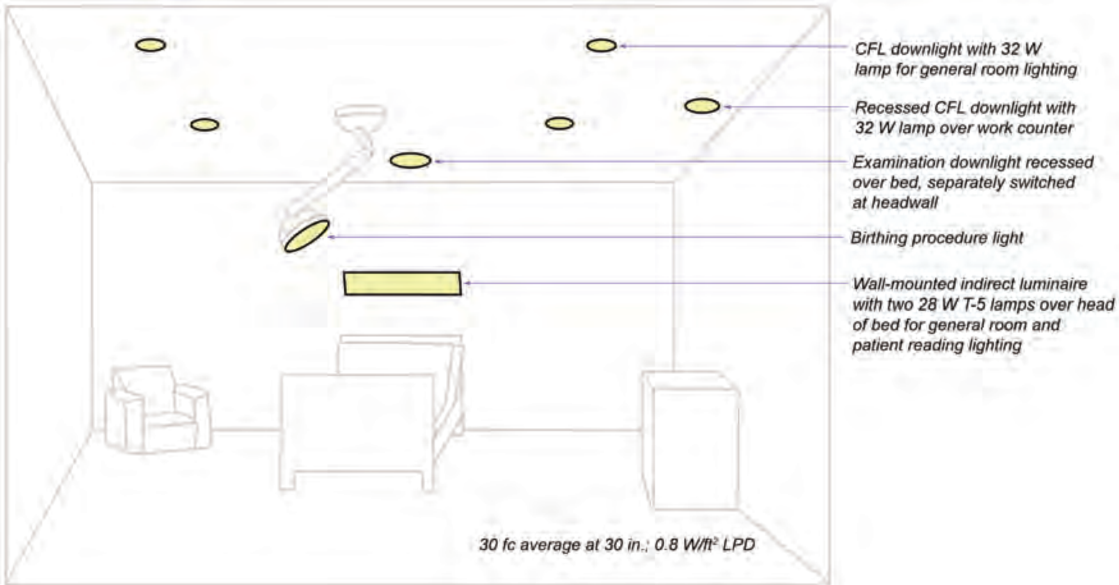

Figure 5-11. (EL26) LDR lighting plan.

conveniently located for staff at the newborn's crib to adjusts lights to low levels to protect infants from retinal overexposure and to bring lights to full output in the event of an emergency.

As in standard patient rooms, manual or automated daylight harvesting controls should be considered for the lighting zone nearest the windows to dim or turn off these lights when ample daylight is present.

EL28 *Lighting for Radiology and Diagnostic Imaging* (Climate Zones: all)

The modern radiographic suite involves a wide variety of visual tasks performed with complex equipment, such as X-ray, fluoroscopy, or ultrasound equipment. The lighting must be planned with care, taking into consideration the personnel and the need to minimize glare, which can disturb patients. Since radiology personnel frequently view video screens or may need to view the patient from an adjacent space through a window, there should be an emphasis on minimizing glare.

Special types of diagnostic imaging, including computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET) imaging, typically require three spaces: a control room, an equipment room, and the scanning room where the patient is handled. The patient is typically observed during the procedure through a window by a staff operator in an adjacent control room. This requires careful balancing of illuminance in the two spaces to maintain visibility, so the lighting in both rooms should be variable or dimmable.

The scanning equipment can be intimidating, and some patients experience claustrophobia during CT, and especially MRI, scans. It helps if the scanning area is visually relaxing. Also, the general lighting should be capable of being subdued to produce an environment comfortable and calming for the patient. Since the patient typically is in a supine position on a gantry, the patient's field of view should be kept free from uncomfortably high luminance or glare.

A special type of treatment using radiation to treat tumors and cancer is known as *radiation therapy* and uses equipment such as clinical linear accelerators, tomotherapy, Gamma Knife, and Cyber Knife. The type of space this equipment requires is similar to that of the other types of special imaging listed above, but because higher doses of

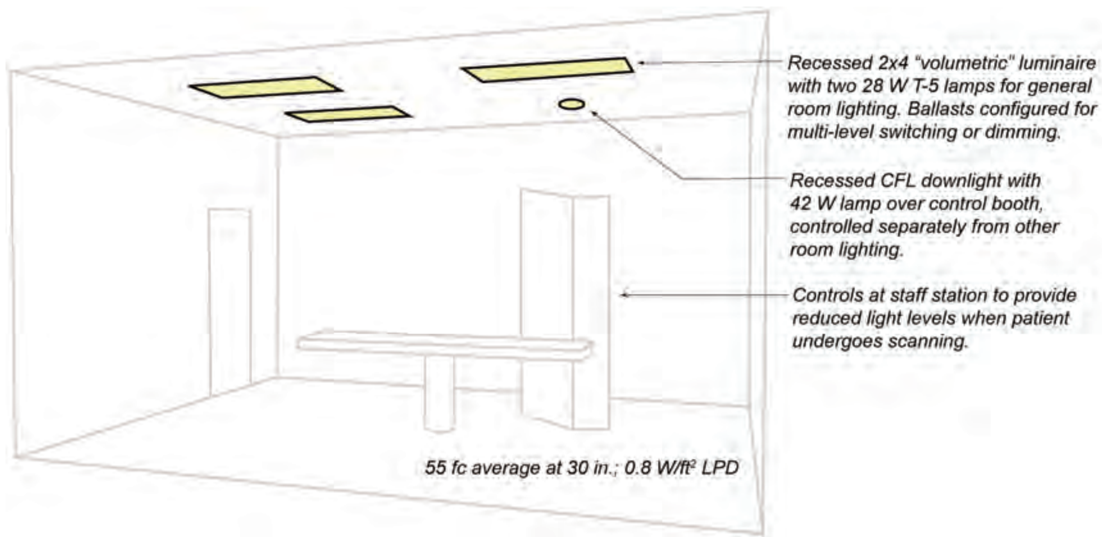

Figure 5-12. (EL28) Imaging (X-ray) suite lighting plan.

radiation are applied, this equipment is kept in special concrete vaults. The visual tasks and conditions are also similar, but given the setting, more emphasis should be given on creating a comforting environment for the patient. (See Figure 5-12.)

EL29 *Lighting Control for Radiology and Diagnostic Imaging* (Climate Zones: all)

Because radiologists and technicians frequently view video and image intensifier screens during radiology and diagnostic imaging procedures, desired illuminance values in these areas range from 20 to 2000 lux. Dimming controls should provide convenient control of the general lighting to enable the medical staff to see fine details much clearer in these video images.

In diagnostic imaging rooms, the general lighting should also be adjustable with a dimming system to create an environment comfortable and calming for the patient.

Lighting control systems may require special direct current output to prevent interference with the imaging equipment and may require controls located outside the scanning area.

EL30 *Lighting for Laboratories and Pharmacies* (Climate Zones: all)

Tests on patient body fluids and tissues are performed in hospital laboratories. Laboratory suites may comprise facilities for chemistry, hematology, microbiology, and nearby support areas (such as blood banks). Here, specialized test equipment and personal computers are in constant use.

Pharmacies have visual tasks similar to those of the laboratories. The use of personal computers, the reading of small print on labels, and the counting and handling of drugs all are demanding visual tasks that require accuracy and avoiding errors. Luminaires providing indirect light, or direct light with shielding, that minimize glare on monitor screens are desirable. It is important to avoid shadowy illumination so that lighting is efficient. A scheme that employs ambient illumination at levels suitable for general reading, say 30 fc, with local task lighting providing 100 fc where accuracy and focus are needed, is an approach that can minimize energy use.

Avoid overlighting with inefficient task lighting at work counters. Typical linear fluorescent luminaires may overlight the task area when mounted less than 36 in. from

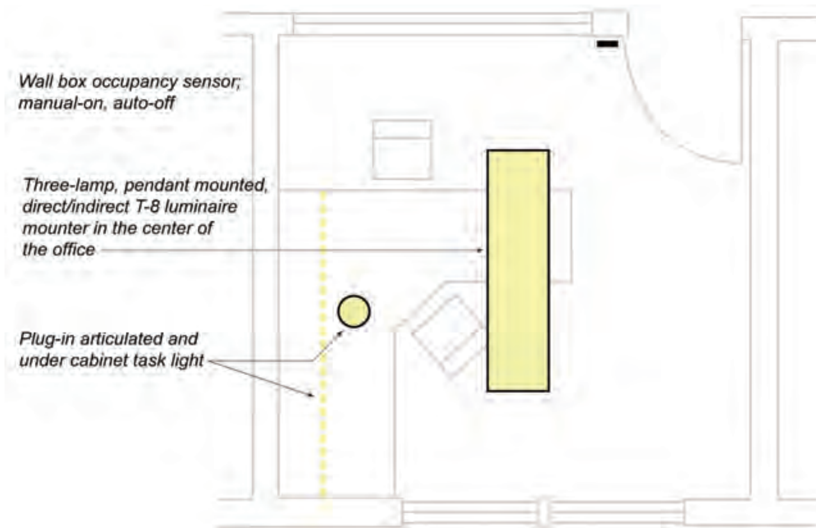

Figure 5-13. (EL31) Small office lighting plan.

the surface. Lights mounted under wall cabinets and transaction counters are often obstructed by objects in the work area.

Lighting should be zoned and manual wall control dimming or switching should be provided to enable laboratory and pharmacy personnel to conveniently adjust appropriate lights to best support the immediate task at hand.

EL31 *Lighting for Individual Offices and Conference Rooms* (Climate Zones: all)

Private offices for administrators, doctors, nursing department heads, etc., are located throughout a healthcare facility. These rooms should be designed the same as offices in any other building. A target lighting power density of 0.9 W/ft^2 is achievable with average illuminance of at least 30 fc and local task illuminance of 50 fc on the desk. This can be achieved with pendant-mounted indirect/direct luminaires or recessed fluorescent. Luminaires should be selected to mitigate glare, especially glare reflected on computer monitor screens. (See Figure 5-13.)

Conference and meeting rooms are also located in different areas of the facility, both in administrative and nursing areas. The visual tasks in a conference room are not dissimilar to those in an enclosed office but might also include the need for audiovisual presentation. This capability invites the use of variable illumination and the use of multiple sets of luminaires to highlight a presentation wall. The target average illuminance is in the range of 30–40 fc. (See Figure 5-14.)

To ensure that lights are on only when needed, occupancy-based controls should be applied to individual private offices. The best performance is achieved with vacancy mode (manual ON/automatic OFF) occupancy sensors. For highest performance in employee comfort, productivity, and energy efficiency, multi-level switching or dimming controls will also allow each staff person to set lights to his or her personal preference. Energy savings from personal controls can range from 15% to 50%.

EL32 *Lighting Control for General Public Spaces—Atriums, Lobbies, Waiting Rooms, Public Corridors* (Climate Zones: all)

In atriums, lobbies, waiting rooms, corridors, and other appropriate spaces where the design team has brought quality daylight into the space, daylight harvesting controls should be considered to regulate the output of electric lights to automatically optimize

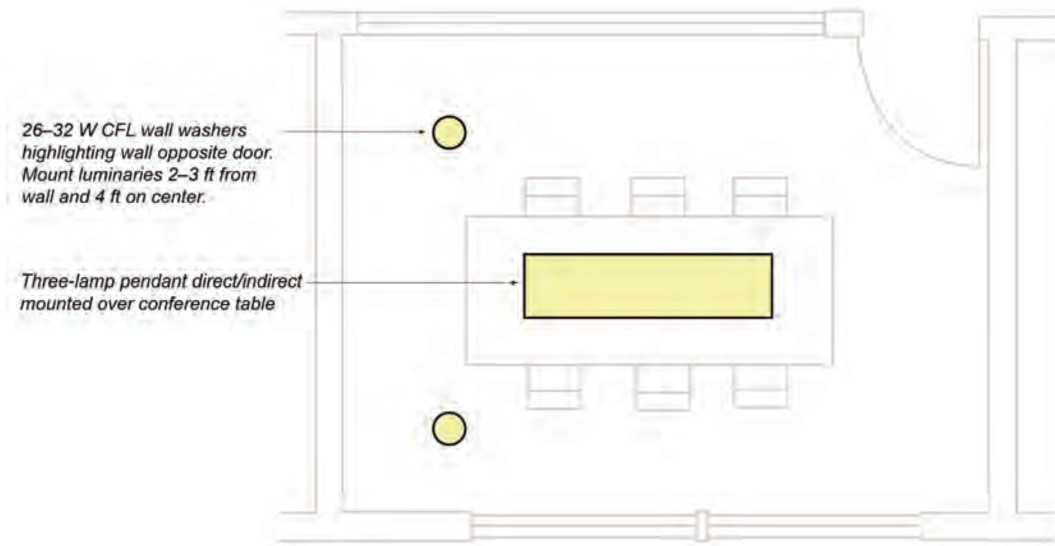

Figure 5-14. (EL31) Conference room lighting plan.

the quality of the visual environment while saving significant amounts of energy. Step dimming systems can be applied where abrupt incremental changes in ambient electric light levels will not be a distraction to the occupants in the space. In spaces where it is desired that adjustments in ambient electric light be transparent to the occupants, continuous dimming systems should be applied.

Where appropriate, time clock controls should also be applied to optimize the on/off times of the lighting in select public areas. Areas should also be identified where a night set-back light level is appropriate, where motion sensors can be used to override the set-back status if staff or visitors enter the space.

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DAYLIGHTING

DL1 *General Principles* (Climate Zones: all)

Daylighting is not limited to specific technologies. Daylighting is based on an integrated approach to design that takes influence at every scale and level of design and during each phase of the design process.

Daylighting strategies drive building shape and form, integrating them well into the design from structural, mechanical, electrical, and architectural standpoints.

Daylighting increases energy performance and impacts building size and costs by downsizing fans, ductwork, and cooling equipment because overall cooling loads are reduced, allowing for trade-offs between the efforts made for daylighting and the sizing of the air-handling and cooling systems.

Providing daylight is fundamental for a healing environment, as it makes a key contribution to energy-efficient and eco-effective healthcare design. While the most valuable asset of daylight is its free availability, the most difficult aspect is its controllability as daylight changes during course of the day. Daylighting is more of an art than a science, and it offers a broad range of technologies that provide glare-free balanced light, sufficient lighting levels, and good visual comfort.

Daylighting will only translate into savings when electrical lighting is dimmed or turned off and is replaced with natural daylight.

Effective daylighting uses natural light to offset electrical lighting loads. When designed correctly, daylighting lowers energy consumption and reduces operating and investment costs:

- Reduced electricity use for lighting and peak electrical demand
- Reduced cooling energy and peak cooling loads
- Reduced fan energy and fan loads
- Reduced maintenance costs associated with lamp replacement
- Reduced HVAC equipment and building size and cost

However, to achieve this reduced cooling, the following criteria must be met:

- High-performance glazing to meet lighting design criteria and block solar radiation
- Effective shading devices, sized to minimize solar radiation during peak cooling times
- Electric lights, through the use of photosensors, automatically dimmed or turned off

The case for daylighting reaches far beyond energy performance alone. Indoor environmental quality not only benefits the patients and their healing process, but also has a significant impact on the performance of the care-giving staff.

Daylight is an essential component for improving patient recovery and for reducing the patient's time of stay. The most underestimated value of daylighting is its ability to increase staff productivity and reduce medical errors. These impacts are difficult to quantify, but the potential for improvement and economical savings is immense and needs to be taken into consideration as serious decision making criteria in the process of healthcare design. These benefits may far outweigh the energy savings and become the significant drivers for daylighting buildings altogether.

The daylighting strategies recommended in this guide have successfully been implemented in buildings before. Most daylighting strategies are generic and apply to healthcare facilities just as they do to other building types. The reason daylighting has been implemented less successfully in healthcare settings is due to programmatic constraints that make it more challenging to locate occupied spaces on the perimeter than it is for other building types. Also, occupancy-specific lighting conditions, as required for patient rooms, reduce opportunities for daylighting to specific space types only. The following tips and strategies are designed to address healthcare-specific opportunities and to overcome these obstacles.

DL2 ***Consider Daylighting Early in the Design Process*** **(Climate Zones: all)**

In small healthcare facilities, the building program and medical planning are the main drivers that establish the shape and the footprint of the building. Planning criteria often result in creating compact, deep floor plates, while daylighting strategies attempt the opposite by articulating and narrowing the floor plate.

The configuration of the building footprint is established early in the design process, definitely freezing the building depth early and locking in all future potential for daylighting—the key factor for anticipating future design upgrades and improvements. A frequent issue with existing buildings is their depth of floor plate, which prevents easy upgrades with daylighting and natural ventilation.

This demonstrates two important aspects. One is the importance of integrating daylight design criteria before the footprint is locked in so that the building can unfold its full energy-saving potential. Another is that medical planning and energy-efficient design are inseparable design criteria, as they both impact the shape and footprint and are integral drivers of the shaping of the "bones" of the building.

Daylight strategies impact the design at different levels of scale in each phase of design and can be characterized in four categories.

Pre-Design. During pre-design, the daylight strategies' focus is on massing studies and the shaping of the floor plate. The goal is to minimize depth and maximize access to windows and daylight by strategically placing light wells, shafts, and atria and orienting fenestration in a predominantly north and south direction. The emphasis is on maximizing the amount of occupied space that has access to windows and on minimizing the distance from the building core to the perimeter. This can create conflict with programmatic and logistical requirements, such as keeping traffic distances short for staff circulation and materials transportation.

Schematic Design. During the schematic design phase, daylight strategies are about interiors, focusing on spatial considerations to optimize daylight penetration and defining ceiling height, layout, and partition wall transparency with clerestory windows for borrowed light. The planning focus is directed toward coordinating space types that require daylight and views and placing them along the perimeter.

Design Development. During the design development phase, the daylighting strategies' focus is on envelope design to optimize quantity and quality of daylight while minimizing solar gains. The interior design focus is on surface reflectivity and optimizing furniture layout to align with visual and thermal comfort requirements.

Construction Documents (CD). Coordination of electrical lighting includes the placement of photo-sensors and occupancy sensors for controlling automated daylight switching and dimmable ballasts.

DL3 *Use Daylighting Analysis Tools to Optimize Design* (Climate Zones: all)

This Guide is designed to help achieve energy savings of 30% without energy modeling, but energy and daylighting modeling programs make evaluating energy-saving trade-offs faster and daylighting designs far more precise.

Annual savings will have to be calculated with an annual whole-building energy simulation tool after the daylighting design tools have been used to determine the foot-candles in the spaces and after the windows have been appropriately sized. Current daylighting analysis tools do not help with heating and cooling loads or other energy uses; they predict only illumination levels and electric lighting use.

DL4 *Space Types, Layout, and Daylight* (Climate Zones: all)

In healthcare facilities, daylight is a key requirement for all occupied spaces. However, the individual lighting needs are different for staff, patients, and the public. The goal is to identify the spaces that best lend themselves to daylight harvesting and saving energy and to recommend layout strategies that allow locating spaces on the perimeter of the building. The potential of energy saving through daylighting varies and depends on program and space types, which can be broadly characterized by the following four categories of occupied spaces.

Patient Rooms and Recovery Areas. Patient rooms by nature require quality views and daylight. In patient rooms, lighting level requirements are typically low and daylight control is driven by the patient's health condition and individual needs. Prioritizing response to patient needs makes the patient room an unreliable space for maximization of daylight, making it unsuitable as a source for daylight harvesting and energy savings.

Diagnostic and Treatment (D&T) Spaces. Typically dominated by planning criteria, such as circulation distance, proximity, and adjacency requirements, operating rooms and procedure rooms are often located at the core of a deep floor plate with no access to views and daylight. Breaking up the D&T block requires careful planning, but locating these spaces on the building perimeter for daylighting and views is feasible without surrendering flexibility, as case studies have shown (Burpee et al. 2009.; Pradinuk 2008).

Staff areas (Exam Rooms, Nurse Stations, and Offices). Locating staff spaces on the building perimeter is essential for staff performance, a design strategy that dovetails with the effort to save energy through reduction of electric light and cooling loads.

Public Spaces (Lobbies, Reception, Waiting Areas, and Transitional Spaces). These spaces provide the best opportunity for high ceilings with high, large-scale fenestration and offer the largest potential for daylight harvesting and energy savings due to their depth and potentially high ceilings.

The following recommendations apply to spaces that are not located on the building perimeter but will allow for additional energy savings if they are designed to follow specific rules.

Internal Corridors. In single-story buildings or on top-level floors, where sidelighting is not available, top lighting should be used to provide daylight for corridors and contiguous spaces. Make sure that nurse stations, which are frequently placed in niches of circulation areas, and waiting areas have access to daylight and views.

Conference Rooms. Conference rooms are densely populated spaces that build up high interior heat loads for only a limited period of time. When located on the perimeter, the interior loads and solar radiation penetrating the perimeter wall accumulate, leading to escalation of peak loads and oversizing of HVAC systems. As a strategy to minimize peak load, conference rooms should be located on north façade perimeters only or inboard, avoiding west-, south-, and east-facing perimeter walls. This approach is supported by prioritizing perimeter space for permanently occupied spaces, which make better use of daylight and views than conference rooms, which remain unoccupied in many cases.

From an energy performance standpoint, public areas and staff spaces are the most beneficial spaces for harvesting daylight, which underscores the importance of locating these spaces on the perimeter, preferably in a north- and south-facing configuration. Although patient rooms in hospitals typically have large fenestration and occupy a significant part of the building perimeter, they can't be considered effective sources for energy savings.

DL5 ***Building Orientation and Daylight*** **(Climate Zones: all)**

Effective daylighting begins with selecting the correct solar orientation of the building and the building's exterior spaces. For most spaces, the vertical facades that provide daylighting should be oriented within 15° of north and south directions. Sidelighted daylighting solutions can also work successfully for other orientations, but they will require a more sophisticated approach to shading solutions, and they would reach beyond the recommendations proposed for accomplishing the goals stipulated in this Guide.

Context and Site. Ensure that apertures are not shaded by adjacent buildings, trees, or by components of the small healthcare facility itself.

DL6 ***Building Shape and Daylight*** **(Climate Zones: all)**

Best daylighting results are achieved through limiting the depth of the floor plate and minimizing the distance between the exterior wall and any interior space. Narrowing the floor plate will in most cases result in introducing courtyards and articulating the footprint for better daylight penetration.

Building Shape and Self-Shading. Optimizing the building shape for daylight translates to balancing the exterior surface exposed to daylight and self-shading the building mass to avoid direct-beam radiation.

Effective daylighting requires a maximum amount of occupied area to be located within minimum distance to the building perimeter.

The following design criteria are recommended for achieving 30% energy savings.

Diagnostic and Treatment Block. Shape the building footprint to allow for all spaces within 15 ft of the perimeter to be equal to or exceed 40% of the total floor plate area.

Inpatient Units. Ensure that 75% of the occupied space, not including patient rooms, is located within 20 ft of the perimeter wall. Where top lighting is not an option, the floor plate should be targeted to achieve a depth of 60 ft.

For sunny climates, designs can be evaluated on a sunny day at the summer solar peak. For overcast sky climates, a typical overcast sky day should be used to evaluate the system. Typically, the glazing-to-floor ratio percentage will increase for overcast sky climates. Daylighting can still work for a small healthcare building in a overcast sky climate, however. Overcast sky climates can produce diffuse skies, which create good daylighting conditions and minimize glare and heat gain.

TECHNOLOGY CASE STUDY
QUEEN OF VALLEY HOSPITAL—TOP LIGHTING AND SIDELIGHTING

The Queen of the Valley Hospital Outpatient Surgery and Procedure Center is a 20,000 ft^2 outpatient clinic located in Napa, California. Designed by Boulder Associates and completed in 2007, the facility makes extensive use of clerestories and sidelighting with light shelves in order to take full advantage of daylighting in the facility.

The facility has four procedure rooms and four surgery suites, each with their own pre-op and recovery areas. All of these areas utilize daylighting features. Figure 5-15a shows the clerestory in one of the recovery halls. Figure 5-15b shows that the nurse station areas also take advantage of daylighting with the use of clerestories and sidelighting that also provides view glass.

See the how-to tips DL8 through DL15 for additional information on sidelighting, clerestories, and rooftop monitors.

(a) (b)

Photographs copyright Solar Eye Communications.

Figure 5-15. The Queen of the Valley Hospital Outpatient Surgery and Procedure Center (a) recovery hall and (b) nurse station.

Daylighting systems need to provide the correct lighting levels. To meet the criteria, daylight modeling and simulation may be required. Daylighting systems should be designed to meet the following criteria.

- In a clear sky condition, to provide sufficient daylight, illuminance levels should achieve a minimum of 25 fc but no more than 250 fc.
- In overcast sky conditions, daylighted spaces should achieve a daylight factor of 2 but no more than 20.

The same criteria for lighting quality and quantity apply to electric lighting and daylighting. When the criteria cannot be met with daylighting, electric lighting will meet the illuminance design criteria. The objectives are to maximize the daylighting and to minimize the electric lighting. To maximize the daylighting without oversizing the fenestration, in-depth analysis may be required.

DL7 ***Window-to-Wall Ratio (WWR)*** **(Climate Zones: all)**

There are two steps to approaching window configuration and sizing. The first is that they should follow interior-driven design criteria such as occupancy type and requirements for view, daylight, and outdoor connectivity. The second step targets peak load and energy use, which limit window size to comply with the mechanical systems target. For small healthcare projects to achieve 30% savings, the overall WWR should not exceed 40%.

DL8 ***Sidelighting: Ceiling and Window Height*** **(Climate Zones: all)**

For good daylighting in cellular-type spaces, a minimum ceiling height of 9 ft is recommended. In public spaces, which extend to greater depth, such as waiting areas and lobbies, ceiling height, at least partially, should be 10 to 12 ft. When daylighting is provided exclusively through sidelighting, it is important to elevate the ceiling on the perimeter and extend glazing to the ceiling. Additional reflectance to increase lighting levels can be achieved by sloping the ceiling up toward the outside wall. (See Figure 5-16a and 5-16b)

DL9 ***Sidelighting: Clerestory Windows*** **(Climate Zones: all)**

In cases where it is not possible to place windows in exterior walls for programmatic or functional reasons, clerestory windows or window bands should be considered for daylighting. Daylight delivered above 7 ft at clerestory level, delivers the highest illuminance level available through sidelighting. (See Figure 5-17.)

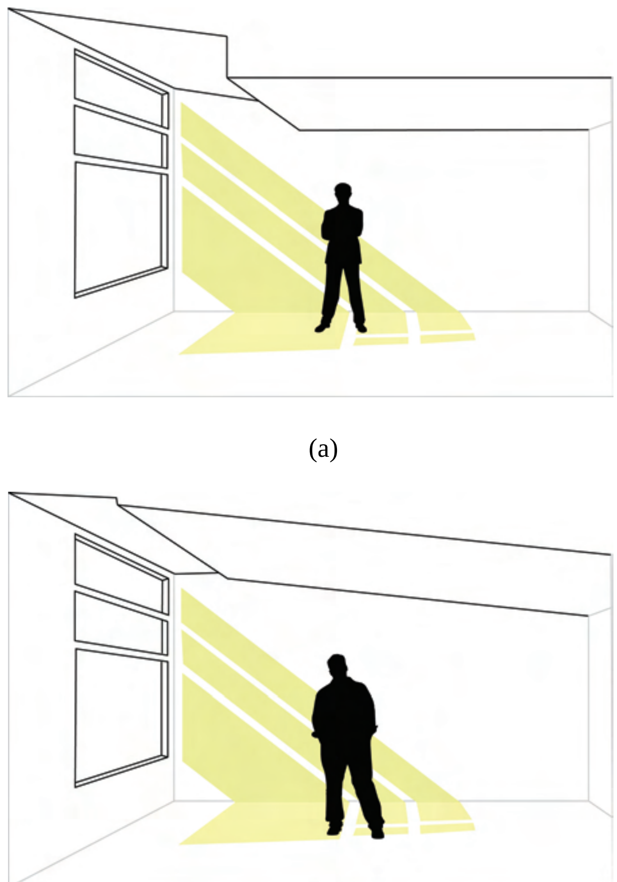
DL10 ***Sidelighting: Borrowed Light*** **(Climate Zones: all)**

Borrowed light is an effective strategy to deliver daylight to corridors that are located behind spaces on the building perimeter: The corridor wall frequently blocks and prevents daylight from entering deeper into the building. The corridor partitioning wall provides significant opportunities to daylight in the corridor through borrowed light. The corridor partitions should be designed with clerestory windows or window bands for perimeter spaces with a depth-to-height ratio no larger than 2.5:1. (See Figure 5-18.)

DL11 ***Sidelighting: Wall-to-Wall Windows*** **(Climate Zones: all)**

Raising the window levels to ceiling level is the first priority for deepening daylight penetration. However, to balance light levels in the room and to mitigate contrast, it is equally important to maximize the window width. By extending the window width from wall to wall, the adjacent partitioning walls receive greater exposure and act as indirect sources of daylight while also achieving greater depth of daylight penetration. (See Figure 5-19.)

Even more daylight and a wider range of view can be gained by making the first 2 to 3 ft of the cellular partitioning walls, where they meet the perimeter wall, transparent.



(a)

(b)

Figure 5-16. (DL8) (a) Raised ceiling at façade and (b) sloped ceiling at façade.

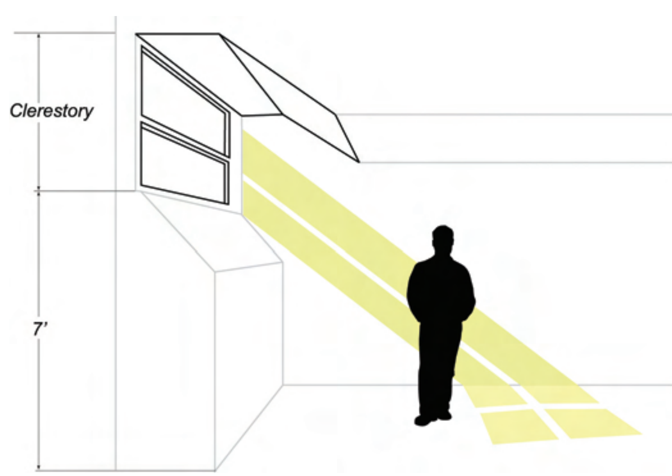


Figure 5-17. (DL9) Clerestory.

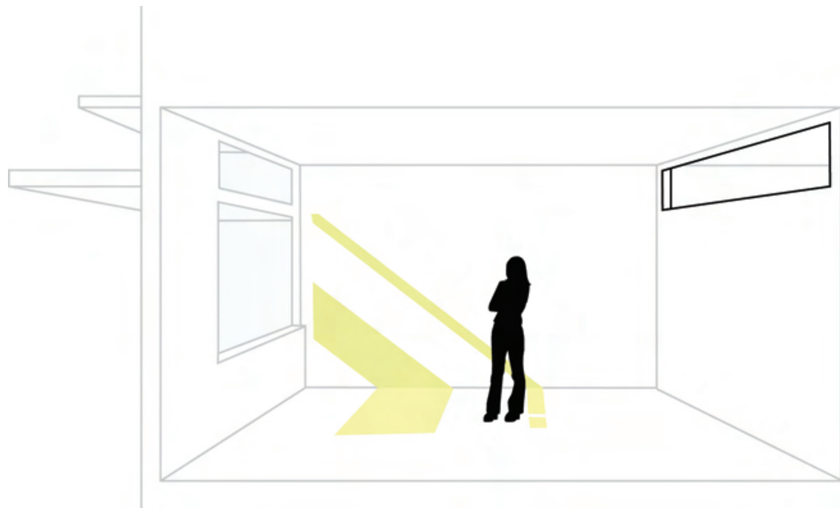


Figure 5-18. (DL10) Borrowed light in corridor.

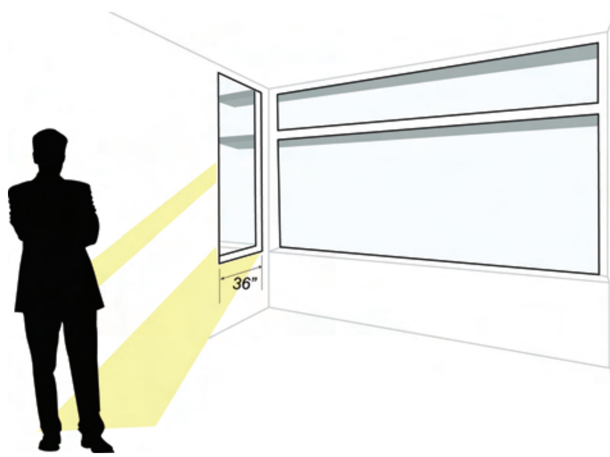


Figure 5-19. (DL11) Maximized window width.

This enlarges the daylighted portion of the room enclosure additionally by 50% to 60% per space. (See Figure 5-20.)

DL12 ***Sidelighting: Punched Windows*** **(Climate Zones: all)**

In cases where window size is limited and “punched” windows can’t be avoided, special care should be taken in placing the aperture to avoid high contrasts and low visual comfort.

To ensure that daylight is maximized and light levels are distributed evenly, the window aperture should align with either of the partitioning walls. This will mitigate contrast differences, maximize the depth of daylight reach, and also make the space appear larger. (See Figure 5-21.)

DL13 *Top Lighting* (Climate Zones: all)

Top lighting draws from zenithal skylight, which makes top lighting the most effective source of daylight. Top lighting therefore requires smaller apertures than sidelighting to achieve the same level of light. In small healthcare facilities, top lighting is recommended for use in occupied spaces that have no access to sidelight. Top lighting is best used in circulation areas and contiguous spaces that are used for nurse stations and waiting areas or lobbies. Top lighting in circulation areas needs careful coordination with overhead ductwork and lighting but does not limit future flexibility as required in program spaces.

Top lighting is a highly effective strategy that not only provides excellent daylight and way finding support but also saves energy for electrical lighting and cooling. The limitation of top lighting is that it can be used in single-story designs only or on the top floors of multi-story designs. Two types of toplighting can be distinguished, as noted in DL14 and DL16.

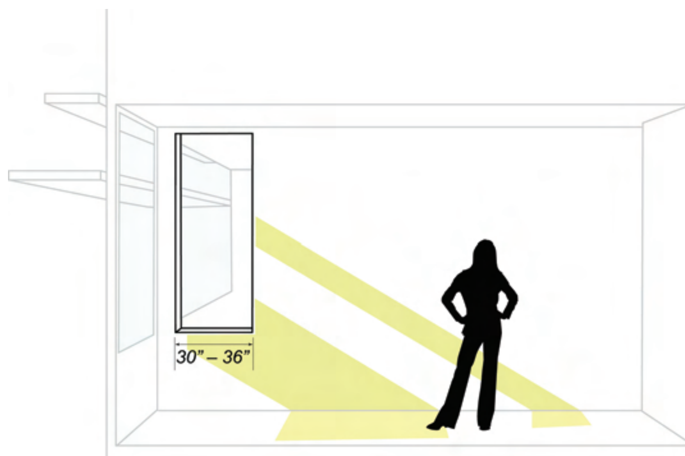


Figure 5-20. (DL11) Transparent partitioning wall.

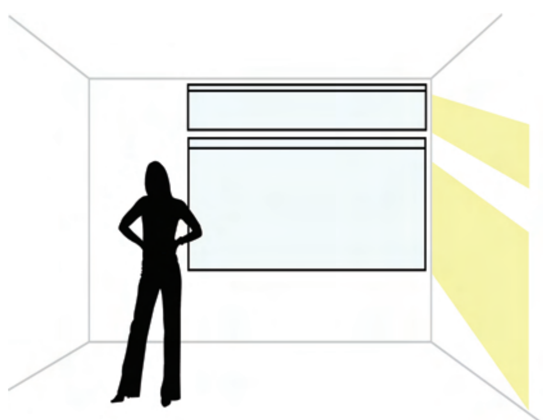


Figure 5-21. (DL12) Punched window placed next to partition wall.

DL14 ***Rooftop Monitors*** **(Climate Zones: all)**

Rooftop monitors are typically the top lighting strategy best suited for healthcare applications. The monitor's vertical glazing delivers excellent quality daylight, and delivers it specifically to the monitor's orientation (which is important for good controlling of the daylight). Roof monitors should not face east or west. South orientation is possible if appropriately sized overhangs are included, but undesired solar heat gain is blocked most effectively when the monitors face north. (See Figure 5-22.)

Fenestration to Floor Area Ratio (FFR) of Rooftop Monitors. A 10% FFR of vertical glazing with a VT in accordance with the values for vertical fenestration in the recommendation tables in Chapter 3 is sufficient to achieve good quality daylight levels and to switch off electrical lighting during daytime in all climates and under partially cloudy sky conditions. When the monitor faces south, the glazing area is typically 25% less than when it faces north to provide the same amount of daylighting.

Rooftop monitors add volume. In spaces using all-air system environments with a cfm rate based on square footage, the added volume should be taken into consideration, as the volume increase can lead to a higher cfm rate and incur higher energy consumption.

DL15 ***Rooftop Monitor Design*** **(Climate Zones: all)**

To help reduce conductive gains and losses, the walls and ceilings of the roof monitor should be insulated and should incorporate appropriate insulation barriers as recommended in EN2 and EN11. Make sure that the colors used within the monitor are light and comply with the minimum reflectances in Table 5-10. White works best. Darker colors will result in a considerable loss of efficiency.

Also consider acoustic issues. If acoustical ceiling material is used, make sure that the reflectance and the acoustical properties are high. Often manufacturers, in presenting the reflectance of an acoustical tile, will specify the reflectance of the paint. Remember to account for reduced reflectance caused by the fissure in the tile. (See Figure 5-22.)

DL16 ***Skylights*** **(Climate Zones: ❹ ❺ ❻ ❼ ❽)**

Skylights are a powerful source of daylight; however, their difficulties with handling solar heat gain, direct beam radiation, and glare in a demanding work environment

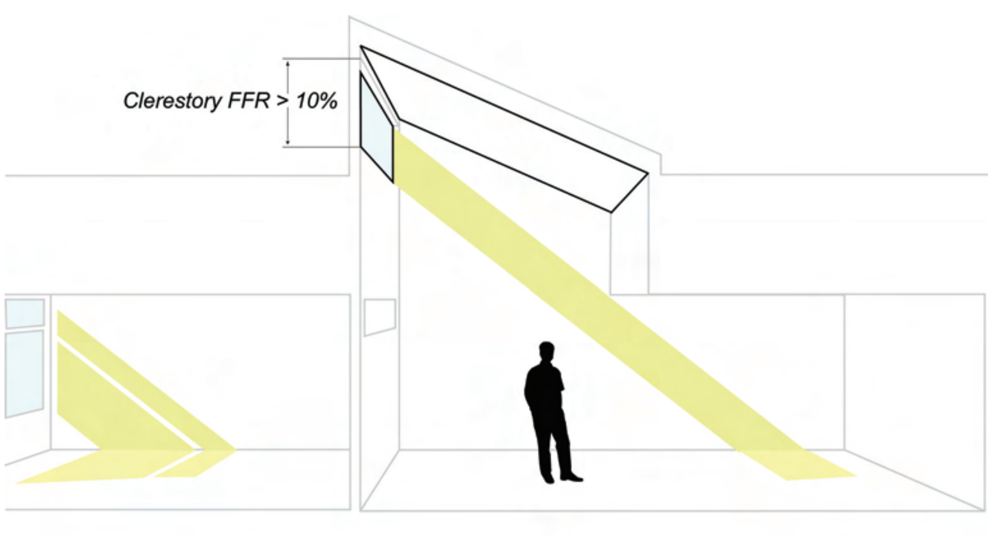


Figure 5-22. (DL14) Rooftop monitor over nurse station.

make their design very challenging. Applications in healthcare facilities should be considered with great care and only if north-facing rooftop monitors are not deemed feasible. In hot climates, north-facing monitors should be used whenever possible.

Work spaces need to be shielded from direct sun. Diffusing skylights can cause glare. Use light-reflecting baffles and/or diffusing glazing to control direct sun. (See Figure 5-23.)

Reduce thermal gain during the cooling season by using skylights with a low overall thermal transmittance (U-factor). Insulate the skylight curb above the roof line with rigid c.i. Shade skylights with exterior/interior sun control devices such as screens, baffles, or fins.

DL17 *Toplighting: Thermal Transmittance* (Climate Zones: ❶ ❷ ❸)

Use north-facing monitors for toplighting whenever possible in hot climates to eliminate excessive solar heat gain and glare. Typically, north-facing monitors have one-sixth the heat gain of skylights.

Reduce thermal gain during the cooling season by using skylights with a low overall thermal transmittance (U-factor). Insulate the skylight curb above the roof line with continuous rigid insulation. Shade skylights with exterior/interior sun control such as screens, baffles, or fins.

DL18 *Top Lighting—Thermal Transmittance* (Climate Zones: ❹ ❺ ❻ ❼ ❽)

In moderate and cooler climates, use either north- or south-facing rooftop monitors for top lighting but not east- or west-facing monitors. East-west glazing adds excessive

Table 5-10. Minimum Reflectance

Location	Minimum Reflectance
Wall segment above 7 ft	70%
Ceiling	70% (preferably 80%–90%)
Light wells	70%
Floors	20%
Furniture	50%
Walls segment below 7 ft	50%

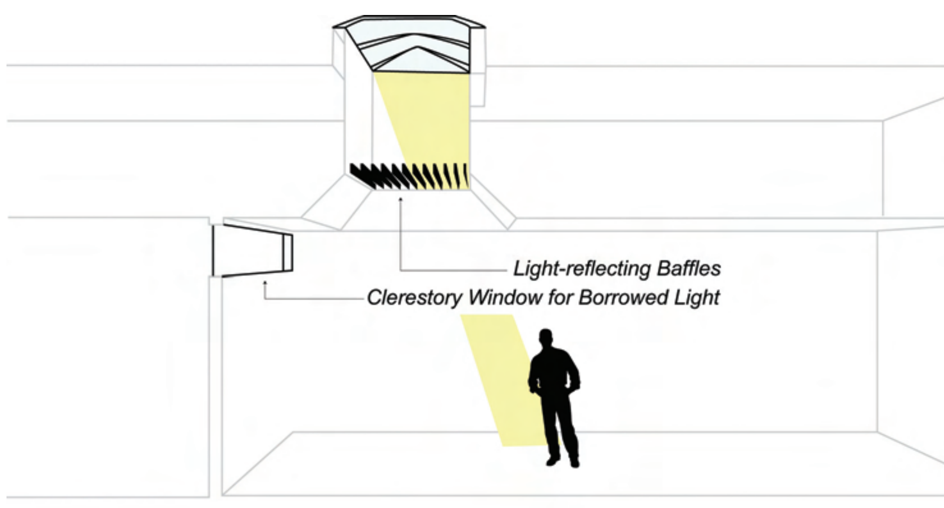


Figure 5-23. (DL16) Roof skylight and space section.

summer heat gain and makes it difficult to control direct solar gain. Monitors with operable glazing may also help provide natural ventilation in temperate seasons when air conditioning is not in use. Typically, north-facing monitors have 1/6 the heat gain of skylights.

Reduce summer heat gain as well as winter heat loss by using skylights with a low overall thermal transmittance. Use a skylight frame that has a thermal break to prevent excessive heat loss/gain and winter moisture condensation on the frame. Insulate the skylight curb above the roof line with rigid c.i.

Shade south-facing rooftop monitors and skylights with exterior/interior sun control devices such as screens, baffles, or fins. As shown in Figure 5-24, splay the skylight opening at 45° to maximize daylight distribution and minimize glare.

DL19 *Toplighting: Use Ceiling Height Differentials* (Climate Zones: all)

Differences in floor-to-floor height offer useful opportunities for daylighting. Differentials in ceiling height as a result of programmatic requirements provide cost-effective opportunities to implement daylight through top lighting. (See Figure 5-25).

DL20 *Shading Systems to Eliminate Direct Beam Radiation* (Climate Zones: all)

Essential for good daylight quality in small healthcare design is the elimination of uncontrolled, direct beam radiation impacting the patient or staff areas. Direct beam radiation causes thermal discomfort and glare, which are critical to avoid in all patient and staff spaces but less critical to avoid for some public spaces and corridors. Strategies should be used that bounce, redirect, and filter sunlight so that direct radiation does not enter the space.

The sun is a moving source of energy with constantly changing directions and intensities of light and heat radiation. When planning the exterior walls, designers face the task of minimizing the solar heat load but maximizing glare-free daylight under permanently changing conditions. The goal is to maximize the light-to-solar-heat-gain ratio for every minute of the day.

Shading systems are designed to reduce solar radiation. However, in most cases they also inadvertently cause loss of valuable daylight. As a result, the electric lights are switched on during the peak time of day, causing cooling load and power consumption to peak and driving HVAC sizing excessively/uncontrollably. This explains why in the process of developing a shading strategy it becomes inevitable to acknowledge and include daylighting as an integral component of the system.

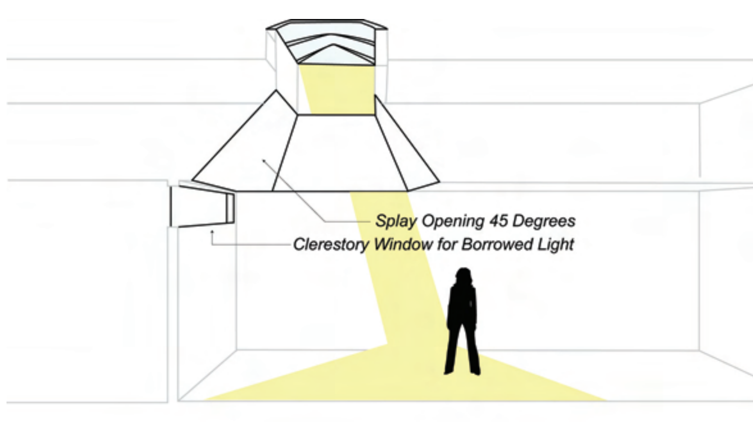


Figure 5-24. (DL18) Roof skylight section.

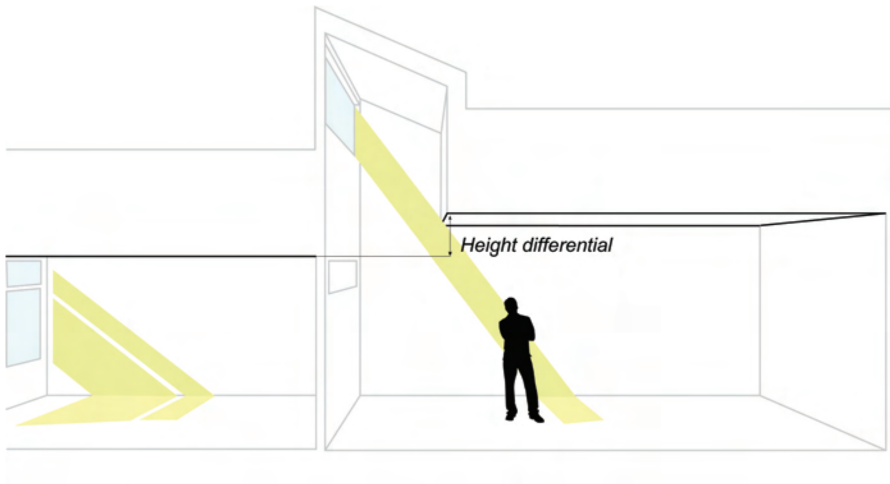


Figure 5-25. (DL19) Top lighting height differential—south-facing.

The effectiveness of shading systems varies widely and depends on the system's ability to adapt to changing conditions. This explains why dynamic systems that operate on demand and track the path of the sun are significantly more successful than static/ fixed systems.

Shading Type Selection. To obtain the best overall performance results, the selection of the right shading type should be based on considerations concerning both heat load and the ability to facilitate daylight and views. There are six shading types to choose from, as discussed in the following.

Fixed External Shading. Solar heat gain is most effectively controlled when penetration is blocked before entering the building. One disadvantage of exterior shading systems can be the accessibility issues for maintaining and cleaning the façade. Fixed devices are designed to perform best at peak hours but work significantly less effectively outside the optimized time range. There are different configurations of exterior shading:

- *Horizontal Devices.* Overhangs, soffits, awnings, and trellises respond well to steep solar angles and work best on south-facing facades. Passive solar gains are possible in winter; however, additional interior shading will be required to counter glare. Projection factor: A projection factor of 0.5 is typical. Overhangs are most effective and economical when located directly above the glass and continues beyond the width of the window. (See figures 5-26a and 5-26b.)
- *Vertical Devices.* Vertical screens or horizontal louvers configured in vertical arrays work when oriented south, west, or east. (See Figure 5-26c)

Dynamic Shading Systems. Dynamic or operable systems are the most effective shading devices available, as they don't have to compromise on one single position for minimizing heat gain and maximizing daylight. The most common technologies used are louvered systems and fabric-based roller shades, which are able to reduce solar heat gain by as much as 80% to 90% while concurrently allowing for daylight and views. Operable systems are motorized and controlled either manually or automatically and can be driven by solar tracking technology.

Exterior Systems. On the exterior, operable systems are less commonly used than fixed systems, due to higher maintenance and vulnerability in windy conditions. Ideally, best applications are found in double-skin façade systems, a rapidly emerging technology, where accessibility is easier and weather protection allows for more lightweight solutions.

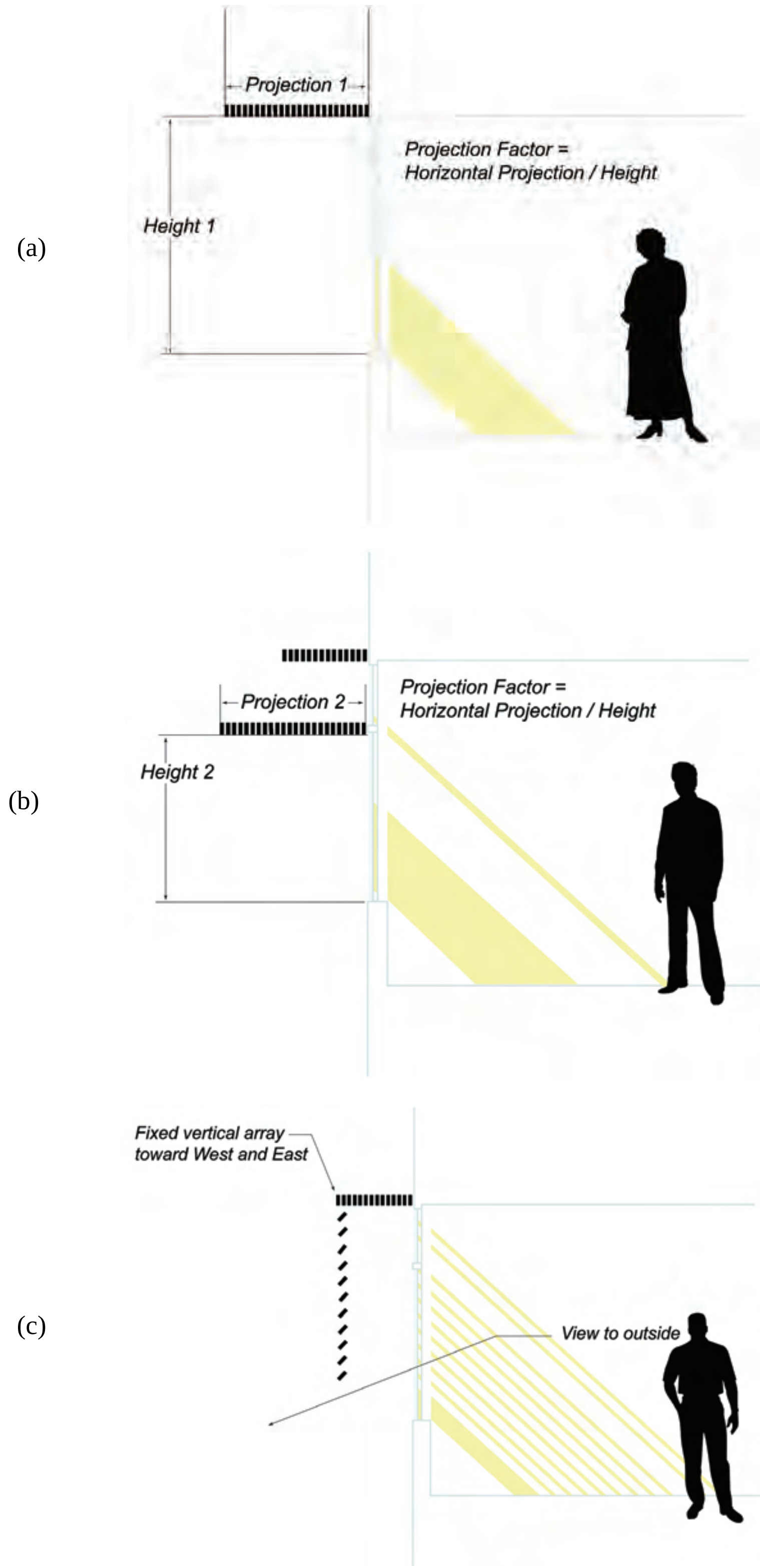


Figure 5-26. (DL20) Fixed external shading in (a and b) horizontal configuration and in (c) vertical configuration.

Interstitial Systems. Integrated with the insulated glazing unit, operable louvers are located between the glass panes. Louvers are rotated, raised, and lowered electrically. This clean, tidy solution with good accessibility lends itself to application in healthcare environments. (See Figure 5-27.)

Internal Shading Systems. Fixed interior shades or operable roller shade systems are typically used for filtering light to mitigate glare or to ensure thermal comfort against direct solar radiation that has escaped the exterior shading devices. Internal shades use fabrics with various levels of transmissivity to reduce heat radiation and provide thermal comfort and glare protection.

Using internal shading alone, without automated daylight control systems, should not be a primary strategy for improving energy performance. They can, however, be used for improving thermal comfort. Interior light shelves can also act as internal shades, but they are not a recommended choice in healthcare facilities due to cleanability issues.

Automated or Manual Operation. The success of daylighted spaces depends on how occupants interact with the daylighting system. This is particularly true for blinds or shades that are available for adjustment by occupants. Occupants are motivated to close the blinds but not to reopen them. If blinds are left closed, the daylighting potential will not be realized. Automated systems will allow user override but can be programmed to reset themselves to their system/performance-based position.

Also, if temporary darkening of a specific space is not functionally required, do not install shades or blinds on the daylighting glass. Unnecessary blinds will result in reduced performance, increased first costs, and higher long-term maintenance expenses.

DL21 *Daylighting Control for Audiovisual Activities* (Climate Zones: all)

If a space requires darkening for audiovisual or other functions, consider motorized roller shades or motorized vertical blinds for apertures that are out of reach. This may seem to result in higher maintenance costs, but such controls can have the opposite effect. The mechanical stress placed on manual operators by the personnel (because of uneven cranking) limits the effective life of these devices to fewer than 10 years. The inconvenience associated with the process also results in a number of these shades being left closed. Motorized shades, which cost more up front, will provide operators with greater ease of operation and result in a better-performing daylighting design. Some motorized devices can also be programmed to reset in the open position at the beginning

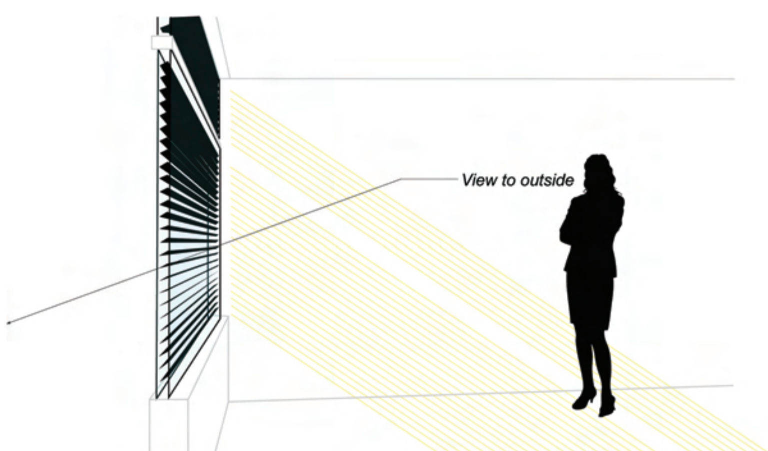


Figure 5-27. (DL20) Operable louvres located between glass panes.

of each day.TV monitors or LCD projectors require that the light level at the specific location of the screen falls in the range of 5 to 7 fc for optimum contrast. Slightly higher levels (7 to 15 fc) should still provide acceptable light levels for the visual aids, but the reduced contrast will make them harder to read.

As an option to shading the daylighting apertures, consider locating the screen or monitor in a part of the room that has less daylight and does not produce glare on the screen.

DL22 ***Interior Finishes for Daylighting*** **(Climate Zones: all)**

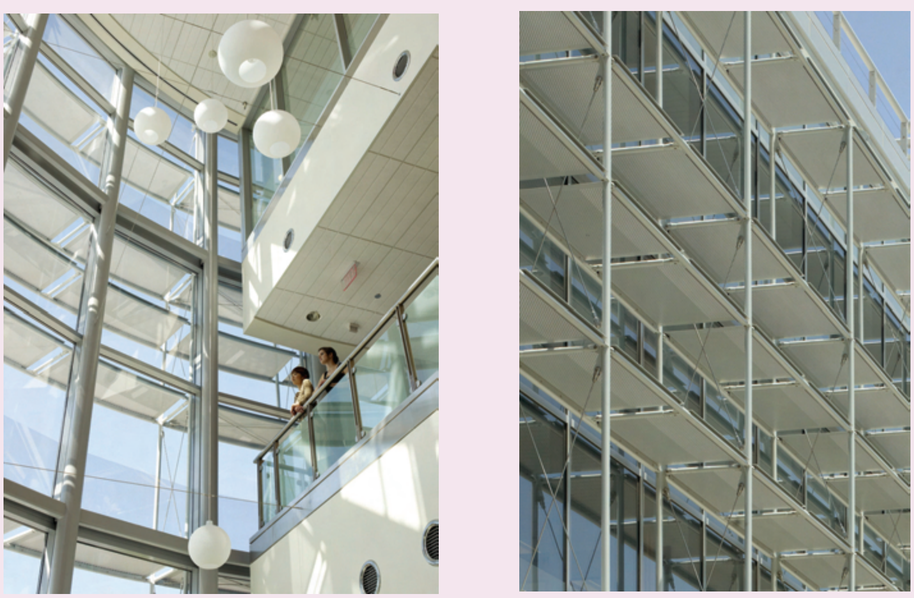
Select light colors (white is best) for interior walls and ceilings to increase light reflectance and reduce lighting and daylighting requirements. Minimum surface reflectances are shown in Table 5-10. The colors of the ceiling, walls, floor, and furniture have a major impact on the effectiveness of the daylighting strategy.

TECHNOLOGY CASE STUDY
VALLEY HEALTH CENTER SUNNYVALE—DAYLIGHT SHADING

The Valley Health Center Sunnyvale is a three-story, 41,000 ft^2 outpatient clinic designed by Anshen + Allen Architects that opened in 2009. Daylighting and high-performance facade design was the primary energy efficiency strategy used in the design of the facility. A well planned and optimized building orientation allowed for maximizing the daylight harvesting while minimizing the entry of solar radiation.

The ceiling height was designed to step up incrementally from a typical height of 9 ft for the interior core spaces to 10 ft at perimeter public spaces and to 38 ft at the three-story entry rotunda. Most of the glazing was located on the southern façade for the most effective daylighting efficiency. In order to take full advantage of the daylighting and views provided there, the patient registration and waiting areas were placed on the southern perimeter of the building.

Due to the high amount of glazing on the southern facade, an effective shading system was needed. Continuous stacked horizontal sunshades were designed using a lightweight suspended tubular steel truss structure that supports the perforated aluminum panel shading devices. The panels block solar radiation, maximize daylight, and mitigate glare (see Figures 5-28a and 5-28b).



(a) (b)

Photographs copyright Cesar Rubio.

Figure 5-28. View of the (a) interior and (b) exterior of continuous stacked horizontal sunshades.

Consider a ceiling tile or surface that has a high reflectivity. Make sure that the ceiling tile reflectance includes the fissures within the acoustical tiles, as these irregularities affect the amount of light absorbed. Do not assume that the color of a tile alone dictates its reflectance. When selecting a tile, specify a minimum reflectivity. Most manufactures will list the reflectance as if it were the paint color reflectance. The Cx provider should verify the reflectance. See EL1 for additional information on interior finishes.

DL23 ***Outdoor Surface Reflectance*** **(Climate Zones: all)**

Consider the reflectance of the roofs, sidewalks, and other surfaces in front of the glazing areas. The use of lighter roofing colors can increase daylighting concentration and in some cases can increase indoor illuminance levels to reduce power consumption for electrical lighting.

High-albedo roofs reflect heat instead of absorbing it to lower the heat load and keep the building cooler. Also, the heat-island effect is diminished, which lowers the environmental temperature, which can support natural ventilation through courtyard fenestration.

Use caution, however, when designing light-colored walkways in front of floor-to-ceiling glazing. Light-colored surfaces will improve daylighting but can also cause unwanted reflections and glare impacting interior spaces.

DL24 ***Calibration and Commissioning*** **(Climate Zones: all)**

Even a few days of occupancy with poorly calibrated controls can lead to permanent overriding of the system and loss of savings. All lighting controls must be calibrated and commissioned after the finishes are completed and the furnishings are in place. Most photosensors require daytime and nighttime calibration sessions. The photosensor manufacturer and the QA provider should be involved in the calibration. Document the calibration and Cx settings and plan for future recalibration as part of the maintenance program.

DL25 ***Dimming Controls*** **(Climate Zones: all)**

In all regularly occupied daylighted spaces such as staff areas, continuously dim rather than switch electric lights in response to daylight to minimize occupant distraction. Specify dimming ballasts that dim to at least 20% of full output, with the ability to turn off when daylighting provides sufficient illuminance. Provide a means and a convenient location to override daylighting controls in spaces that are intentionally darkened to use overhead projectors or slides. The daylighting control system and photosensor should include a 15-minute time delay or other means to avoid cycling caused by rapidly changing sky conditions and a 1-minute fade rate to change the light levels by dimming. Automatic multi-level daylight switching may be used in non-regularly occupied environments such as hallways, storage rooms, restrooms, lounges, and lobbies.

DL26 ***Photosensor Placement and Lighting Layout*** **(Climate Zones: all)**

Correct photosensor placement is essential. Consult daylighting references or work with the photosensor manufacturer for proper location. Mount the photosensors in a location that closely simulates the light level (or can be set by being proportional to the light level) at the work plane. Depending on the daylighting strategy, photosensor controls should be used to dim particular logical groupings of lights. Implement a lighting fixture layout and control wiring plan that complements the daylighting strategy. In sidelighted spaces, locate luminaires in rows parallel to the window wall, and wire each row separately. Because of the strong difference in light that will occur close to the window and away from the window, having this individual control by bank will help balance out the space. In a space that has a skylight, install one photosensor that controls all the perimeter lights and a second that controls all the lights within the skylight well.

DL27 *Photosensor Specifications* (Climate Zones: all)

Photosensors should be specified for the appropriate illuminance range (indoor or outdoor) and must achieve a slow, smooth linear dimming response from the dimming ballasts.

In a *closed-loop* system, the interior photocell responds to the combination of daylight and electric light in the daylighted area. The best location for the photocell is above an unobstructed location such as the middle of the space. If using a lighting system that provides an indirect component, mount the photosensor at the same height as the luminaire or in a location that is not affected by the uplight from the luminaire.

In an *open-loop* system, the photocell responds only to daylight levels but is still calibrated to the desired light level received on the work surface. The best location for the photosensor is inside the skylight well.

DL28 *Select Compatible Light Fixtures* (Climate Zones: all)

First consider the use of indirect lighting fixtures that more closely represent the same effect as daylighting. Indirect lighting spreads light over the ceiling surface, which then reflects the light to the task locations; with the ceiling as the light source, indirect lighting is more uniform and has less glare.

In addition, insist on compatibility between ballast, lamps, and controls. Ensure that the lamps can be dimmed and that the dimming ballasts, sensors, and controls will operate as a system.

References

Burpee, H., J. Loveland, M. Hatten, and S. Price. 2009. High-performance hospital partnerships: Reaching the 2030 challenge and improving the health and healing environment. *ASHE International Conference on Health Facility Planning, Design, and Construction, March 8-11, Phoenix, AZ.*

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HVAC

The mission of healthcare facilities is to provide an environment for healing patients. HVAC systems must support this primary mission and be dependable day to day, hour to hour. The challenge is how to provide reliable systems that meet all of the various healthcare-specific criteria and use less energy. HVAC designers looking at new and innovative ways to save energy in healthcare facilities should consider the following:

- Innovative applications of proven technology
- Dependable equipment
- Appropriate redundancy
- Simple and reliable control sequences
- System complexity that is aligned with facility maintenance capabilities

HVAC design criteria for healthcare facilities vary as much as the medical services provided. The criteria for a hospital operating 24/7 with patients who are incapable of self-preservation are very different than those for a medical office building that operates similarly to a commercial office building.

For in-patient and surgical facilities, the federal government's Centers for Medicare & Medicaid Services (CMS) define regulations if reimbursement is involved. The state health departments are also involved with inspection and compliance. Most states reference AIA's *Guidelines for Design and Construction of Health Care Facilities* (the *Guidelines*), while others have generated their own criteria. A partial list of healthcare facility references for HVAC designers follows.

- *Guidelines for Design and Construction of Health Care Facilities* (AIA 2006)
- *HVAC Design Manual for Hospitals and Clinics* (ASHRAE 2003)
- ANSI/ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality* (ASHRAE 2007a)
- ANSI/ASHRAE/ASHE Standard 170, *Ventilation of Heath Care Facilities* (ASHRAE 2008a)
- ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings* (ASHRAE 2007b)
- *ASHRAE Handbook—Fundamentals* ("Load Calculations" and "Duct Design" chapters) (ASHRAE 2009)
- *ASHRAE Handbook—HVAC Systems and Equipment* (ASHRAE 2008b)
- *ASHRAE Handbook—HVAC Applications* ("Health Care Facilities" chapter) (ASHRAE 2007c)

HVAC systems manage air contaminants through filtration, dilution, air pressure differences between rooms, and in some situations, airflow patterns within rooms. The *Guidelines*, ASHRAE/ASHE Standard 170, the ASHRAE Handbook, and most of the other publications for room design criteria use air exchange rates as a method to ensure appropriate levels of dilution. The criteria list *total* and *outside* air change per hour requirements for typical room types found in healthcare facilities.

The HVAC system is also responsible for maintaining acceptable temperature and relative humidity levels. It is common that the dilution air exchange rates require more air than that needed to maintain the space temperature. To complicate the situation, the air also needs to be dehumidified by overcooling it and causing condensation to occur at the central cooling coil. Constant-volume reheat systems have traditionally been a common approach in these facilities because of their ability to independently control both temperature and humidity. They easily handle these issues and are simple to understand and maintain. Given the high degree of reliability and dependability required in a hospital, and the fact that energy use has historically been a small percentage of the operating budget of healthcare facilities, they were a logical choice.

However, because of the high air change rates and humidity control required in many of the space types found in healthcare facilities, the amount of reheat energy used by these systems is a significant portion of the total energy use. The baseline energy modeling for this Guide shows that reheat represents over 20% of the total energy use of the building, and this occurs in all climate zones (see Figure 5-29). With energy rates increasing, this is becoming a more significant portion of the total operating cost of a facility.

Although many types of HVAC systems could be used in small healthcare facilities, this Guide assumes that one of the following three system types is to be used to reduce energy use compared to the baseline systems (see Chapter 1).

- **HV1:** Multiple-zone, variable-air-volume (VAV) air-handling system (indoor or outdoor) with either direct expansion (DX) cooling or a water chiller and either a hot water coil, indirect gas furnace, or electric resistance in the air handler and either a hot water coil or electric resistance in the VAV terminals.
- **HV2:** Water-source heat pumps (WSHPs) with either a water boiler or electric resistance heat and a dedicated outdoor air system (DOAS) (see HV4) for ventilation.
- **HV3:** Fan-coils with a water chiller and either a water boiler or electric resistance heat and a DOAS (see HV4) for ventilation.

Unique recommendations are included for each HVAC system type in the recommendation tables in Chapter 3. A few individual zones within small healthcare facilities may be served by single-zone equipment (such as packaged or split DX units). In this case, this equipment must meet the more stringent of the requirements of either the most current version of ASHRAE/IESNA Standard 90.1 or the local code requirements.

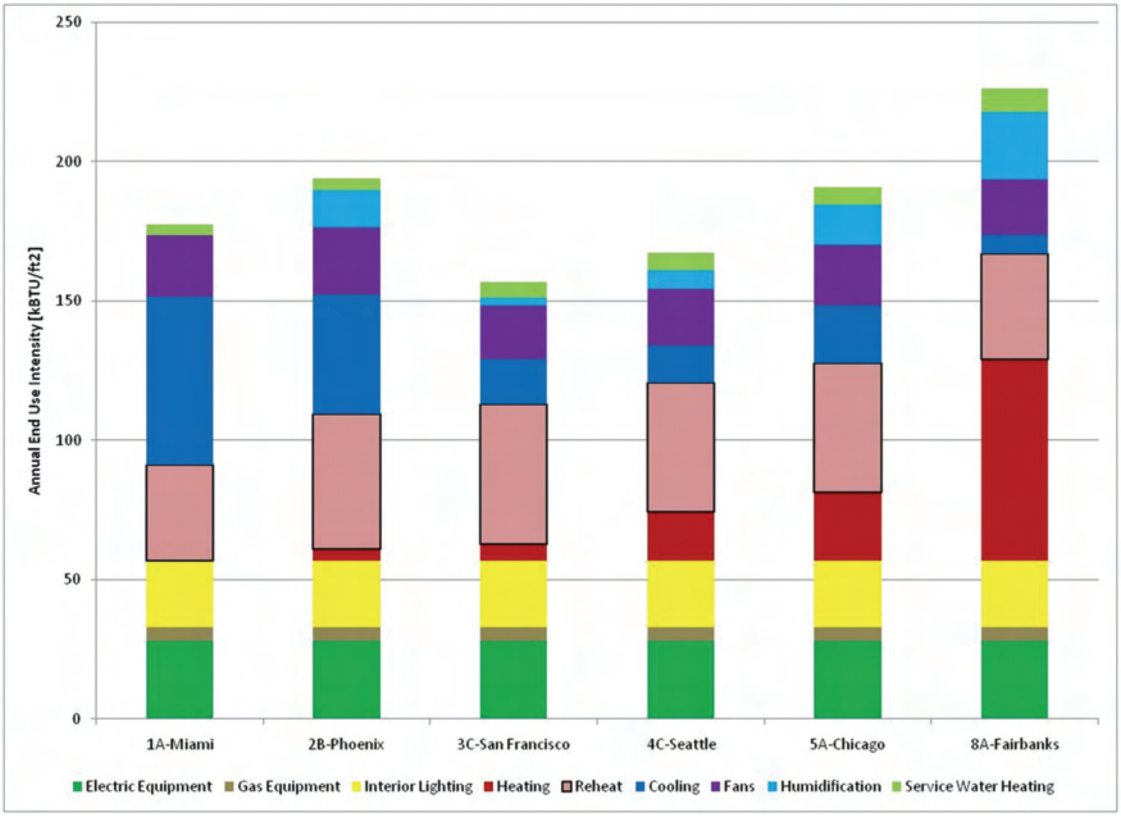


Figure 5-29. Reheat energy as compared to other energy uses in healthcare facilities.

WSHPs and fan-coils are not recommended for critical care areas of the facility (see a partial list below). This is due to the limited filtration capability of this type of equipment as well as concerns related to noise, the difficulty of ensuring cleanliness (including local drain pans), and the need for maintenance access within the critical care areas.

Critical Care Areas (served by system HV1):

- Surgery rooms (and other rooms where invasive procedures are performed)
- Recovery rooms
- Delivery rooms
- Intensive care
- Substerile service areas
- Triage

Non-Critical Care Areas (served by system HV1, HV2, or HV3)

- Patient rooms
- Examination rooms
- Treatment rooms
- Offices

This Guide does not cover purchased chilled water (CHW) for cooling, or solar energy, steam, or purchased steam for heating. These and other systems are alternative means that may be used to help achieve the energy savings target of this Guide.

Good Design Practice

HV1 *Multiple-Zone VAV Air-Handling System* (Climate Zones: all)

In a multiple-zone VAV air-handling system, a central air-handling unit (AHU) (located indoors or outdoors) serves several individually controlled zones. The components of the VAV AHU include outdoor air and return-air dampers, filters, fans, a cooling coil, a heating source, and controls.

Each thermal zone has a VAV terminal unit that is controlled to maintain temperature in that zone and/or to maintain the minimum air change rate required. The components of the VAV terminal units are factory designed and assembled and include an airflow modulation device, controls, and possibly a heating coil, fan, and/or filter. VAV terminal units are typically installed in the ceiling plenum above the occupied space or above an adjacent corridor. However, the equipment should be located to meet the acoustical goals of the space, permit access for maintenance, and minimize fan power, ducting, and wiring. All the VAV terminal units served by each air handler are connected to a common air distribution system (see HV11).

For each healthcare space in which the *Guidelines* or ASHRAE/ASHE Standard 170 require a minimum air change rate, the VAV terminal unit in the supply duct modulates supply airflow to maintain space temperature, but not below the minimum air change rate required. This minimum air change rate is reduced during unoccupied periods, but any required space-to-space pressure relationships must still be maintained (see HV23). Note that if the minimum air change rate required for a zone is higher than the design airflow needed for cooling or heating, the supply airflow to that zone will be constant during occupied periods.

For each healthcare space in which the *Guidelines* or ASHRAE/ASHE Standard 170 require either positive or negative pressure with respect to adjacent spaces, a motorized damper or VAV terminal unit is also included in the return duct from that space. The VAV terminal unit in the supply duct modulates supply airflow to maintain space temperature and/or maintain the minimum air change rate required, and the VAV terminal unit in the return duct modulates to maintain either a positive or negative pressure in the space (through direct pressure measurement or by controlling to an offset from supply airflow rate, see Figure 5-33). Use caution when selecting return-air VAV terminals to minimize air-side pressure loss.

Cooling is provided by either DX refrigeration or a centralized water chiller. For DX cooling, the refrigeration components can either be packaged inside each air handler casing or included in a separate piece of equipment that is connected to a single air handler by refrigerant piping. For chilled-water cooling, the refrigeration components are packaged as either an air-cooled or a water-cooled chiller. All the air handlers, along with the water chiller(s), are connected to a common water distribution system (see HV19).

Heating is typically provided by an indirect-fired gas burner, a hot water coil, or an electric resistance heater located inside the VAV air handler, individual heating coils (hot water or electric resistance) located inside the VAV terminal units, or perimeter radiant heat located in the occupied space. When hot water is used for heating, all the heating coils, along with the water boiler(s), are connected to a common water distribution system (see HV20).

Dehumidification for Systems Serving Areas that Must Only Comply with ASHRAE Standard 62.1. In a typical chilled-water system, a modulating valve reduces cooling capacity by throttling the water flow through the cooling coil. In VAV systems, with a controlled cooling coil discharge temperature that is maintained low enough to satisfy the zone requiring the most cooling or a maximum dew-point temperature, the dehumidification requirement will be satisfied. Resetting coil discharge temperature to minimize reheat will save energy but may fail to comply with the dehumidification limits of the *Guidelines* or ASHRAE/ASHE Standard 170 in humid outdoor conditions.

VAV systems typically dehumidify effectively over a wide range of indoor loads because they generally limit the maximum discharge air temperature at part-load conditions. One caveat: use caution when resetting the supply air temperature (SAT) or chilled water (CHW) supply temperature during the cooling season. Warmer supply air (or water) means less dehumidification at the coil and higher humidity in the space. If SAT reset is used in a non-arid climate, either include one or more zone humidity sensors to limit the reset if the relative humidity within the space exceeds 65% or limit the reset based on outdoor temperature or dew point.

Dehumidification for Systems Serving Areas with Mandatory 60% Maximum Relative Humidity. Many areas of healthcare facilities are required to maintain humidity levels below 60% RH, either by the *Guidelines* or by ASHRAE/ASHE Standard170. This is difficult for DX systems with cycling compressors, especially if they have only a few stages of capacity control. Most HVAC systems dehumidify by cooling. The 60% RH limit equates to a 54°F dew point if the space is maintained at 70°F and has a typical space sensible heat ratio of 90%. For the baseline system serving noncritical care areas, this means a SAT of no more than 56°F after supply fan heat is included. The dew point required may be as low as 45°F when serving surgery rooms that are intended to operate at 60°F dry bulb. Because many spaces in healthcare facilities require high ventilation rates, substantial reheat energy use is forced in many spaces. For this reason, grouping spaces on a centralized AHU requires careful attention (see HV16).

VAV systems typically dehumidify effectively over a wide range of indoor loads, as long as the VAV system continues to provide cool, dry air at part-load conditions (discharge air temperature control). Resetting SAT can provide large savings in reheat energy, but must be done carefully. If SAT reset is used in a non-arid climate, either include one or more zone humidity sensors to limit the reset if the relative humidity within the space exceeds 60% or limit the reset based on outdoor temperature or dew point.

HV2 *Water-Source (including Ground-Source) Heat Pumps* (Climate Zones: all)

In WSHP systems, a separate WSHP is used for each thermal zone. The components are factory designed and assembled and include a filter, fan, refrigerant-to-air heat exchanger, compressor, refrigerant-to-water heat exchanger, and controls. The refrigeration cycle is reversible, allowing the same components to provide cooling or heating.

Individual WSHPs are typically mounted in the ceiling plenum over the corridor (or some other noncritical space) or in a closet next to the occupied space. The equipment should be located to meet the acoustical goals of the space, permit access for maintenance, and minimize fan power, ducting, and wiring. This may require that the WSHPs be located outside of the space.

WSHP systems are applied in four common configurations:

- Fluid-cooler and boiler systems
- Ground-loop systems with tubing located in vertical wells
- Pond systems with tubing at the bottom of a pond
- Hybrid systems that use a fluid cooler to minimize the cost of the well field

In traditional WSHP systems, all the heat pumps are connected to a common water loop. A cooling tower (or fluid cooler) and a water boiler are also installed in this loop to maintain the temperature of the water within a desired range, typically between 60°F and 90°F.

A variation of this system takes advantage of the earth's relatively constant temperature and high heat capacity and uses the ground instead of the cooling tower and boiler. Ground-source heat pump (GSHP) systems (see HV29 in the "Bonus Savings" section of this chapter) primarily do not reject heat; they store it in the ground for use at a different time. During the summer, the heat pumps extract heat from the building and transfer it to the ground. When the building requires heating, this stored heat is transferred from the ground to the building. In a perfectly balanced system, the amount of heat stored over a given period of time equals the amount of heat retrieved. This offers the potential to reduce (or often eliminate) the energy used by a cooling tower and/or boiler, but installation costs will be higher because of the geothermal heat exchanger and the pumping energy may be higher because of the pressure loss of the heat exchanger. Larger hospitals that require cooling during most hours of the year may be better served by pond systems that reject heat very well and absorb heat less well. Well systems have limitations if the net heat gain or loss is too far from equal because all of the net energy transfer must be done through the perimeter of the well field, which is limited by the relatively low conductivity of the ground.

Outdoor air is conditioned and delivered by a separate, dedicated ventilation system (see HV4). This may involve ducting the outdoor air directly to the inlet or outlet duct for each heat pump, delivering it in close proximity to the heat pump intakes, or ducting it directly to the occupied spaces. Depending on the climate, the DOAS may include components to filter, cool, heat, dehumidify, and/or humidify the outdoor air. In many applications, some form of heat recovery is used to reduce the energy associated with tempering (or reheating) the dehumidified outdoor air.

Dehumidification for Systems Serving Areas that Must Only Comply with ASHRAE Standard 62.1. Basic constant-volume systems (such as most heat pumps) match sensible capacity to the sensible load and dehumidification is coincidental. As the load diminishes, the compressor runs for shorter periods and is off for longer periods. The compressors may not run long enough for the majority of the accumulated condensate to fall into the drain pan, and the compressor stays off for longer periods of time, which may allow the remaining moisture on the coil surface to re-evaporate while the fan continues to run. Some dehumidification may occur, but only if the sensible load is high enough. Space relative humidity will tend to increase under part-load conditions, unless the DOAS provides sufficiently dehumidified air to satisfy the latent loads.

For WSHPs, the DOAS should be designed to dehumidify the outdoor air so that it is dry enough (has a low enough dew point) to offset the latent loads in the spaces to maintain indoor humidity levels to comply with the 65% maximum relative humidity recommended by ASHRAE Standard 62.1 (see HV4). This helps avoid high indoor humidity levels without additional dehumidification enhancements in the WSHP units.

Alternatively, some WSHP units could be equipped with hot gas reheat for direct control of space humidity.

Dehumidification for Systems Serving Areas with Mandatory 60% Maximum Relative Humidity. Many areas of healthcare facilities are required to maintain humidity levels below 60% RH, either by the *Guidelines* or by ASHRAE/ASHE Standards 170. This is difficult for systems with cycling compressors, including WSHPs. Most HVAC systems dehumidify by cooling. The 60% RH limit equates to a 54°F dew point if the space has a 90% sensible heat ratio and is maintained at 70°F, which is typical for healthcare facilities where clothing levels are relatively high (refer to *ANSI/ASHRAE Standard 55-2004*, *Thermal Environmental Conditions for Human Occupancy* for detailed information about thermal comfort). For WSHP systems, this means a SAT of no more than 55°F (after supply fan heat is included) or that air with a lower humidity ratio must be supplied from the DOAS (see HV4). Since the heat pump compressors normally run only in response to space temperature, they normally will not dehumidify adequately in cool, humid weather and the DOAS should be the primary dehumidification system. If the outdoor air requirement is low and/or the space latent loads are high, the DOAS may be required to supply air at a lower dew point than traditional systems, either by overcooling and using recovered energy for reheat (if needed) or by employing desiccant technology (see HV33 in the “Bonus Savings” section of this chapter). The largest energy savings from WSHP systems is the elimination of the need for reheat, so reheat should not be used to control humidity.

Alternatively, some WSHP units could be equipped with hot gas reheat for direct control of space humidity.

HV3 *Fan-Coils* (Climate Zones: all)

In fan-coil systems, a separate fan-coil unit is used for each thermal zone. The components are factory designed and assembled and include filters, a fan, heating and cooling coils, and controls.

Fan-coils are typically installed in each conditioned space (often under the window), in the ceiling plenum above the corridor (or some other noncritical space), or in a closet adjacent to the space. However, the equipment should be located to meet the acoustical goals of the space, permit access for maintenance, and minimize fan power, ducting, and wiring. This may require that the fan-coils be located outside of the space.

All the fan-coils are connected to a common water distribution system (see HV19 and HV20). Cooling is provided by a centralized water chiller. Heating is provided by either a centralized boiler or by electric resistance heat located inside each fan-coil.

Outdoor air is conditioned and delivered by a separate dedicated ventilation system (see HV4). This may involve ducting the outdoor air directly to each fan-coil or ducting it directly to the occupied spaces. Depending on the climate, the DOAS may include components to filter, cool, heat, dehumidify, and/or humidify the outdoor air. In many applications, some form of heat recovery is used to reduce the energy associated with tempering (or reheating) the dehumidified outdoor air.

Dehumidification for Systems Serving Areas that Must Only Comply with ASHRAE Standard 62.1. In a typical chilled-water fan-coil system, a modulating valve reduces system capacity by throttling the water flow through the cooling coil. The warmer coil surface that results provides less sensible cooling (raising the supply air dry-bulb temperature from the fan-coil), but it also removes less moisture from the passing airstream (raising the supply air dew point). This type of control may fail to comply with the 65% RH limits from ASHRAE Standard 62.1 during humid weather, unless the DOAS provides sufficiently dehumidified air to satisfy the latent loads.

Another option is to maintain the discharge air temperature low enough to satisfy the dehumidification requirement, but this may overcool the space and require reheat.

For fan-coil units, the DOAS should be designed to dehumidify the outdoor air so that it is dry enough (has a low enough dew point) to offset the latent loads in the spaces (see HV4). This helps avoid high indoor humidity levels without additional dehumidification enhancements in the fan-coil units. Alternatively, fan-coils could be equipped with multiple-speed or variable-speed fans for improved part-load dehumidification (this is only possible in spaces where there is no minimum air change rate requirement) or reheat coils (much less energy efficient) could be added for direct control of space humidity. Consider using recovered heat, such as condenser or solar heat, when using reheat.

Dehumidification for Systems Serving Areas with Mandatory 60% Maximum Relative Humidity. Many areas of healthcare facilities are required to maintain humidity levels below 60% RH, either by the *Guidelines* or by ASHRAE/ASHE Standard 170. The 60% RH limit equates to a 54°F dewpoint if the space is maintained at 70°F and has a 90% space sensible heat ratio. For the baseline system serving noncritical care areas, this means a SAT of no more than 55°F for draw-through fan-coils (after supply fan heat is included).

For fan-coil units, the DOAS should be designed to dehumidify the outdoor air enough to offset the latent loads (see HV4). This helps avoid high indoor humidity levels without additional dehumidification enhancements in the fan-coil units. If the outdoor air requirement is low and/or the space latent loads are high, the DOAS may be required to supply air at a lower dew point than traditional systems, either by overcooling and using recovered energy for reheat (if needed) or by employing desiccant technology (see HV33 in the "Bonus Savings" section of this chapter).

HV4 *Dedicated Outdoor Air Systems* (Climate Zones: all)

Dedicated outdoor air systems (DOASs) can reduce energy use by decoupling the dehumidification of outdoor air for ventilation from sensible cooling and heating in the zone. The outdoor air is conditioned by a separate DOAS that is designed to dehumidify the outdoor air and to deliver it dry enough (with a low enough dew point) to offset space latent loads (Mumma 2001; Morris 2003). Terminal HVAC equipment heats or cools recirculated air to maintain space temperature. Terminal equipment may include fan-coil units, WSHPs, zone-level air handlers, or radiant heating and/or cooling panels. DOASs can also be used in conjunction with multiple-zone recirculating systems, such as centralized VAV air handlers.

DOASs can reduce energy use in primarily two ways: 1) they often avoid the high outdoor air intake airflows at central air handlers needed to satisfy the multiple spaces equation of ASHRAE Standard 62.1, and 2) they eliminate (or nearly eliminate) simultaneous cooling and reheat that would otherwise be needed to provide adequate dehumidification in humid climates. A drawback of many DOASs is that they cannot provide air-side economizing. This is more significant in drier climates where 100% outdoor air can be used for economizing without the concern of raising indoor humidity levels.

Consider delivering the conditioned outdoor air cold (not reheated to neutral) whenever possible, and reheat only when needed. Providing cold (rather than neutral) air from the DOAS offsets a portion of the space sensible cooling loads, allowing the terminal HVAC equipment to be downsized and use less energy (Mumma and Shank 2001; Murphy 2006b). Reheating the dehumidified air (to a temperature above the required dew-point) may be warranted

- if the reheat consumes very little energy (using energy recovery, solar thermal, etc.) and none of the zones are in the cooling mode, or
- if all of the zones are in the heating mode, or
- if, for those zones in the cooling mode, the extra cooling energy needed (to offset the loss of cooling due to delivering neutral-temperature ventilation air) is offset by higher-efficiency cooling equipment and the reduction in heating energy needed for those zones in the heating mode. (This is more likely to be true on an annual basis if the reheat in the DOAS is accomplished via air-to-air or condenser heat recovery.)

In addition, implementing reset control strategies and exhaust air energy recovery (see HV10) can help minimize energy use.

While there are many possible DOAS configurations, Figures 5-30a and 5-30b include a few of the typical system and equipment configurations used with WSHPs and fan-coils.

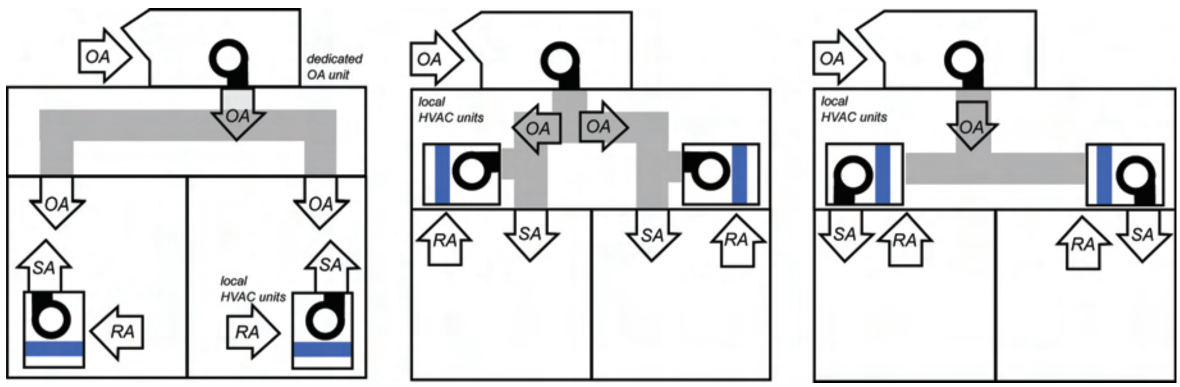
HV5 ***Load Calculations*** **(Climate Zones: all)**

Accurate equipment sizing reduces first costs. For some types of equipment, accurate sizing also lowers utility costs and improves dehumidification performance.

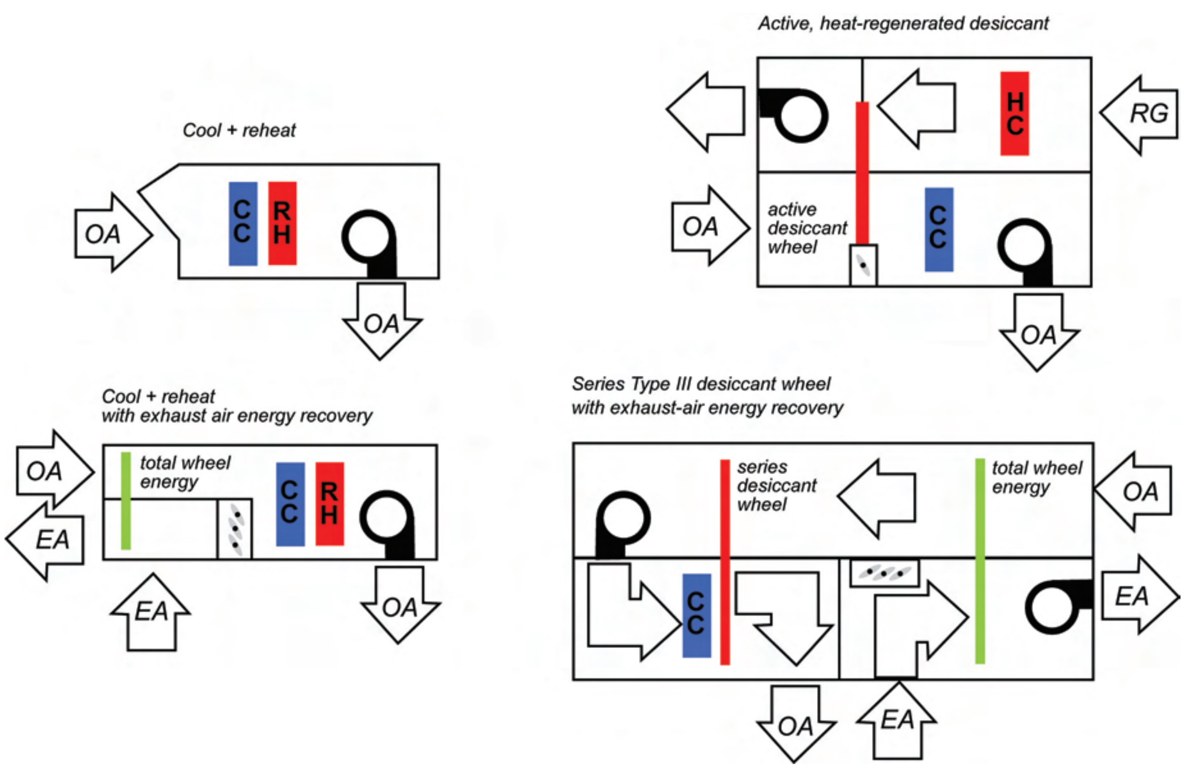
Design cooling and heating loads must be calculated in accordance with generally accepted engineering standards and handbooks, such as the methods described in the *ASHRAE Handbook—Fundamentals* and *ANSI/ASHRAE/ACCA Standard 183-2007, Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings*. Safety factors should be applied cautiously to prevent oversizing of compressors and other types of equipment that are inefficient when oversized. Oversized compressors have limited ability to reduce capacity at part-load conditions, which can cause short cycling. This in turn limits the system's ability to dehumidify and causes large changes in SAT, which may affect occupant comfort.

Cooling and heating load calculations must include the conditioning of outdoor air as well as lighting and plug loads. Separate load calculations should be performed for each thermal zone.

Humidification loads must consider the lowest dew-point condition that is likely to occur at each economizer temperature in the project location. Typically this is not at the coldest outdoor air temperature but at a temperature where the outdoor air percentage is relatively high and dew point is low (Harriman et al. 2001).



(a)



(b)

Figure 5-30. (HV4) Examples of (a) DOAS configurations and (b) DOAS equipment configurations.

HV6 *Cooling and Heating Equipment Efficiencies* (Climate Zones: all)

The cooling and heating equipment should meet or exceed the efficiency levels (both full load and part load) listed in the recommendation tables in Chapter 3. In some cases, recommended equipment efficiencies are based on system size (capacity).

A few individual zones in a small healthcare facility may be served by single-zone equipment (such as packaged or split DX units). In this case, this equipment must meet the more stringent of either the requirements of local code or the current version of ASHRAE/IESNA Standard 90.1.

If DX cooling is used in a VAV system with discharge temperature control, it is important to include enough stages of refrigeration to provide reasonably consistent control of discharge air temperature without the added energy use of hot-gas bypass. Typically, at least four stages are recommended to reasonably control discharge air temperature.

DELIVERING CONDITIONED OA IN SERIES OR IN PARALLEL WITH LOCAL HVAC UNITS

While no one configuration is best for all situations, every effort should be made to deliver the conditioned outdoor air in parallel with the local units (as depicted in the first two configurations in Figure 5-30a) rather than in series (as depicted in the far right configuration in Figure 5-30a). The parallel configuration typically results in smaller local HVAC units and less overall energy use (Mumma 2008).

There are many factors in making a decision whether to use gas or electricity, such as availability of service, utility costs, operator familiarity, and impact on source energy use. Efficiency recommendations for both types of equipment are listed in the recommendation tables in Chapter 3 to allow the user to choose.

HV7 *Fan Power and Motor Efficiencies* (Climate Zones: all)

Fan systems should meet the maximum brake horsepower (bhp) limit listed in the recommendation tables in Chapter 3. In addition, motors for fans 1 hp or greater should meet National Electrical Manufacturers Association (NEMA) premium efficiency motor guidelines where applicable.

For multiple-zone VAV air-handling systems (HV1), the fan power limitation is expressed in terms of a maximum brake horsepower (bhp), as a function of supply airflow (cfm), per the equation below.

For WSHP (HV2) and fan-coil (HV3) systems, the fan power limitation for the fans inside the terminal units is expressed in terms of a maximum input power (W) per unit of supply airflow (cfm). The fan power limitation for the remaining fans in the system (dedicated outdoor-air unit, exhaust fans, etc.) is expressed in terms of a maximum brake horsepower (bhp), as a function of supply airflow (cfm), per the following equation:

$$\text{bhp} < \text{supply airflow} \times 0.0012 + A$$

where

supply airflow	=	design supply airflow to conditioned spaces served by the system, cfm
bhp	=	maximum combined fan brake horsepower for all fans in the system
A	=	sum of (PD × CFMD/4131)

where

PD	=	pressure loss adjustment for each applicable device from Table 5-11, in. w.c.
CFMD	=	design airflow through each applicable device from Table 5-11, cfm

As an example, consider a central VAV air-handling system that serves critical care areas. If the system includes a fully ducted return path, return airflow control devices (for

Table 5-11. Fan Power Limitation Pressure Loss Adjustment

Device	Adjustment
Fully ducted return and/or exhaust air systems	0.5 in w.c.
Return and/or exhaust airflow control devices	0.5 in w.c.
Exhaust filters, scrubbers, or other exhaust treatment	The pressure loss of the device calculated at fan system design condition
Particulate filtration: MERV 9 thru 12	0.5 in w.c.
Particulate filtration: MERV 13 thru 15	0.9 in w.c.
Particulate filtration: MERV 16 and greater and electronically enhanced filters	Pressure loss calculated at 2× clean filter pressure loss at fan system design condition
Carbon and other gas-phase air cleaners	Clean filter pressure loss at fan system design condition
Heat recovery device	0.75 in w.c.
Evaporative humidifier/cooler in series with another cooling coil	Pressure loss of device at fan system design condition
Sound attenuation section	0.15 in w.c.
Fully ducted return and/or exhaust air systems	0.5 in w.c.

Source: Adapted from Table 6.5.3.2.2B, ASHRAE/IESNA Standard 90.1-2007

space pressure control), high-efficiency particulate filtration (MERV 13 to 15), and a sound attenuator, the total pressure loss adjustment is 2.05 in. w.c. (0.5 + 0.5 + 0.9 + 0.15).

Typically, AHUs that are used in healthcare facilities are available with several choices of fan types and sizes. This affords the opportunity to select a fan to optimize the balance of energy efficiency, acoustics, and cost.

Backward-inclined airfoil centrifugal fans with outlets arranged to recover the velocity pressure usually provide high efficiency and low sound levels, but usually at increased cost and with limited outlet arrangements when compared to plenum fans. Plenum fans are very popular because they are compact and their outlets can be located in many positions, but they may be less efficient. Forward-curved fans are an efficient option only in low-static-pressure applications and are often used in small equipment such as fan-coil units, heat pumps, and small air handlers.

HV8 ***Ventilation Air*** **(Climate Zones: all)**

Ventilation air assists in maintaining acceptable indoor air quality and offsets the amount of exhausted air to maintain building pressure. It is air induced into the building either naturally (via open windows) or by mechanical means. Ventilation improves indoor air quality by diluting the concentration of contaminants. In general, the more outside air ventilation used, the higher the energy use, especially in the extreme climate zones. Project teams and healthcare organizations need to select an appropriate balance between ventilation and energy that best aligns with the goals of the project.

A first step is determining the ventilation code or set of criteria that will be used for the design. Outpatient diagnostic and treatment facilities have different ventilation criteria and standards than surgical suites and hospitals. In general, outpatient facilities (excluding surgery) follow the building code requirements that typically reference a version of ASHRAE/ASHE Standard 62.1.

Surgery facilities and hospitals will most often reference federal and state health regulations. In most states, the health departments reference the *Guidelines*. The remaining states have developed their own ventilation requirements. In addition, there is the new ASHRAE Standard 170. The 2010 *Guidelines* are expected to incorporate this standard in its entirety. The code ventilation rates are the minimum requirements.

Some healthcare organizations may require higher-than-code minimum ventilation rates. The U.S. Green Building Council, through the LEED rating system, is promoting higher ventilation rates than required by ASHRAE Standard 62.1.

Implement strategies that minimize the energy needed to condition the ventilation air. Following are some ideas.

General Strategies for Reducing Energy Associated with Conditioning Ventilation Air:

- Be sure to test unoccupied sequences to prevent unnecessary ventilation during off hours.
- Carefully combine rooms to minimize overventilation.
- Do not base the occupant density on that used for egress design.
- Typically, ventilation can be reduced if based on designed occupant densities.
- Refer to HV4 for DOAS.
- Refer to HV9 for economizer strategies.

ASHRAE STANDARD 62.1 AND THE IMC

Many states reference ASHRAE Standard 62-2001. In May 2007, the International Code Council (ICC) approved an ASHRAE proposal to incorporate the prescriptive Ventilation Rate Procedure from ASHRAE Standard 62.1-2004 into the *International Mechanical Code* (*IMC*). The new requirements were first included in the 2007 *IMC* Supplement. Understand that this method will generally reduce the amount of ventilation and associated energy. It may prove beneficial to check with local code officials and suggest a variance requesting to use this method since the ICC has approved it.

Strategies to Avoid Overventilation when Using ASHRAE Standard 62-2001 (or Earlier Versions): The ASHRAE Standard 62-2001 multiple spaces equation should be used to help reduce ventilation at the system level. Waiting or conference rooms are typically the “critical zones,” so consider oversupplying those rooms to limit the percentage of outdoor air to no more than 50%. In order to do so, the system must comply with the section in ASHRAE/IESNA Standard 90.1 that demonstrates that this approach uses less energy.

Strategies to Avoid Overventilation when using ASHRAE Standard 62.1-2004 or 62.1-2007: One approach to optimizing ventilation in a multiple-zone VAV system is to combine the various demand-controlled ventilation (DCV) strategies (see HV31 in the “Bonus Savings” section of this chapter) at the zone level (using each where it best fits) with ventilation reset at the system level.

Install carbon dioxide (CO_2) sensors only in densely occupied zones and those experiencing widely varying patterns of occupancy. These sensors reset the ventilation requirement for their respective zones based on measured CO_2. Zones that are less densely occupied or have a population that varies only a little (such as private offices, open-plan office spaces, or many classrooms) are probably better suited for occupancy sensors. When unoccupied, the controller lowers the ventilation requirement for the zone. Finally, zones that are sparsely occupied or have predictable occupancy patterns may be best controlled using a time-of-day schedule. This schedule can either indicate when the zone will normally be occupied/unoccupied or can be used to vary the zone ventilation requirement based on anticipated population.

These various zone-level DCV strategies can be used to reset the ventilation requirement for their respective zones for any given hour. This zone-level control is then tied together using ventilation reset at the system level, which resets intake airflow based on variations in system ventilation efficiency.

In addition to resetting the zone ventilation requirement, the controller on each VAV terminal continuously monitors primary airflow being delivered to the zone. The building automation system (BAS) periodically gathers this data from all VAV terminals and solves the equations prescribed by ASHRAE Standard 62.1 to determine how much outdoor air must be brought in at the AHU to satisfy all zones served. Finally, the BAS sends this outdoor airflow setpoint to the AHU that modulates a flow-measuring outdoor air damper to maintain this new setpoint.

Strategies to Avoid Overventilation when using the AIA Guidelines: Reduce airflow rates during unoccupied periods in surgery rooms and other spaces with minimum air change rate requirements. Systems must maintain pressure relationships at all times, even during unoccupied periods. This will require being able to control the supply and return air from these zones.

HV9 ***Economizer*** **(Climate Zones: ❸ ❹ ❺ ❻ ❼ ❽)**

Economizers save energy by providing free cooling when ambient conditions are suitable to meet all or part of the cooling load. Theoretically, enthalpy controls are superior to dry-bulb (sensible) controls in many situations, but practically they are less reliable. The designer of each project should consider the relative merits of fixed dry-bulb, differential dry-bulb, fixed enthalpy, differential enthalpy, and dew-point controls. A detailed comparison of these options is included in the 90.1 User's Manual (ASHRAE 2007e).

The *Guidelines* and ASHRAE/ASHE Standard 170 require 30% minimum relative humidity for many healthcare occupancies. Especially in cold and in cool-dry weather, this results in the use of energy to humidify outside air that is being used to conserve cooling energy by the economizer controls. ASHRAE/IESNA Standard 90.1 does not require economizers for systems "[w]here more than 25% of the air designed to be supplied by the system is to spaces that are designed to be humidified above 35°F dew-point temperature to satisfy process needs" (ASHRAE 2007b, p. 36). This exempts healthcare spaces that are required to maintain 30% RH (unless they are always maintained below 66°F).

One way to provide the free cooling of an economizer cycle without the excessive humidification caused by the introduction of more dry outdoor air is to use a water economizer. This involves providing CHW or a water/glycol mixture to a cooling coil using cooling towers coupled with heat exchangers, fluid coolers, or dry coolers. One method is to use cold tower water to cause refrigerant migration in a water chiller to produce CHW without operating the compressor. Water economizers conserve energy by minimizing humidification requirements because excessively dry outside air is introduced only at the minimum required outdoor air flow rate. In cold climates, this savings greatly exceeds the added energy use for additional pumps and heat rejection fans. The main disadvantage is that because of the low (approximately 54°F) indoor dew points needed to satisfy the requirements of the *Guidelines* and ASHRAE/ASHE Standard 170, it is difficult to provide 100% economizer cooling unless the outdoor temperature is below 45°F and/or the wet-bulb temperature is below 40°F.

Example of Energy Use with no Economizer, Air Economizer, or Water Economizer:

- An air-handling system is humidifying 72°F zones to 30% RH. This is 32 grains (0.0046 lb) of water per pound of dry air. Outdoor air is 30°F and 60% RH, which is 14.4 grains (0.0021 lb).
- The air-handling system discharge air setpoint is 54°F, with 2°F of added fan heat, so that the economizer will be operating to provide 52°F mixed air (assuming there is no heat gain from other components in the unit).
- Supply airflow rate is 10,000 cfm.
- The minimum outdoor air requirement is 2000 cfm.
- The mixed air consists of 48% outdoor air and 52% return air. Mixed-air temperatures are 64°F with no economizer and 52°F with either economizer type.
- Cooling energy savings are 10,000 × (64–52) × 1.09 = 126,440 Btu/h
- Humidification energy costs for the air economizer system are:
  10,000 × (0.0046–0.0021) × 1000 × 60/13.5 = 112,000 Btu/h
- Pump energy for the water economizer will be approximately 1 hp (2545 Btu/h)

- Cooling tower fan energy for the water economizer will probably be zero at this outdoor air temperature but will not exceed 1 hp (2545 Btu/h) if the tower complies with ASHRAE/IESNA Standard 90.1-2007 and has variable-frequency drive (VFD) control.
- Totals
  - No Economizer = 148,828 Btu/h
  - Air Economizer = 53,305 Btu/h
  - Water Economizer = 27,478 Btu/h
  - Condenser Reheat = –104,052 Btu/h
    (heating is reduced more than the compressor input energy)

Another method to minimize the impact of economizers on humidification energy in cold climates is to eliminate the economizer and use condenser reheat. In the example above, this option has energy consumption of –104,052 Btu/h. The total is negative because heating energy is reduced more than the compressor input energy. A higher percentage of the energy is electric, however, so the economics depend on local energy costs. The economics also depend greatly on the hours of operation and percentage of zones served that have high minimum ventilation requirements (see HV28 in the “Bonus Savings” section of this chapter).

Traditional (non-dedicated outdoor air) systems must be able to modulate the outdoor air, return air, and relief air dampers to provide up to 100% outdoor air for cooling. (See HV4 for a discussion of DOAS.) The motorized outdoor air damper for all climate zones should be closed during the entire unoccupied period, except when it opens in conjunction with an unoccupied economizer or pre-occupancy purge cycle.

Periodic maintenance is important with economizers, as dysfunctional economizers can cause substantial excess energy use (see HV27).

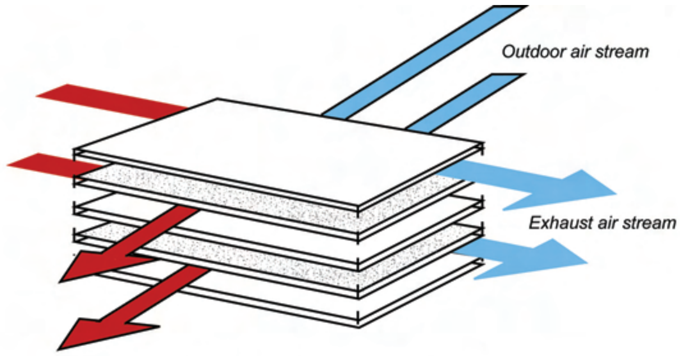
HV10 *Exhaust Air Energy Recovery* (Climate Zones: all)

Exhaust air energy recovery can reduce the sensible outdoor air cooling load during summer conditions. It can also reduce the outdoor air heating load in mixed and cold climates. And, with the use of an enthalpy wheel, it can reduce the humidification and dehumidification load by transferring moisture from exhaust air to dry outdoor air or by transferring moisture from humid outdoor air to exhaust air. It is recommended that HVAC systems that use exhaust air energy recovery be selected to account for only a partial reduction in the outdoor air heating and cooling loads caused by the energy recovery equipment (see *ASHRAE Handbook—HVAC Systems and Equipment*). Upon the failure of an energy recovery device, it may not be feasible to either restrict operation or shut down a healthcare facility because of the inability of the heating and cooling systems to make up for loss of the energy recovery capacity.

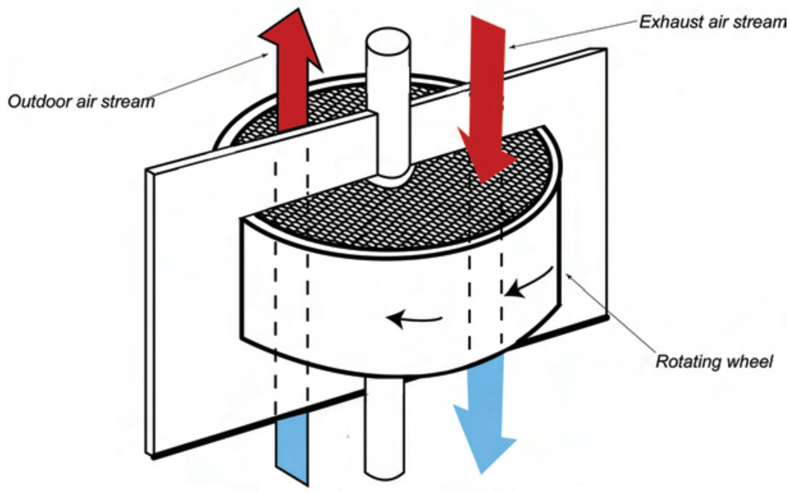
For some HVAC system types, the recommendation tables in Chapter 3 recommend exhaust air energy recovery. If energy recovery is recommended, this device should have a minimum total effectiveness of 50% for all A climate sub-zones (humid) and for sub-zones 3C, 4C, and 5C, or a minimum sensible effectiveness of 50% for all B climate sub-zones (dry).

Sensible energy recovery devices transfer only sensible heat. Common examples include coil loops (runaround loops), fixed-plate heat exchangers, heat pipes, and sensible energy rotary heat exchangers or sensible energy wheels. Total energy recovery devices not only transfer sensible heat but also moisture (or latent heat)—that is, energy stored in water vapor in the airstream. Common examples include total energy rotary heat exchangers (also known as total energy wheels or enthalpy wheels) and total energy fixed-plate heat exchangers (Figure 5-31). As an example, a cross-flow fixed-plate heat exchanger can have a sensible effectiveness of 50% to 70%. If the exhaust air is 70°F and the outdoor air is 0°F, this device can reduce the required energy to heat the entering outdoor airstream by 37 to 52 Btu/h per cfm of outdoor air.

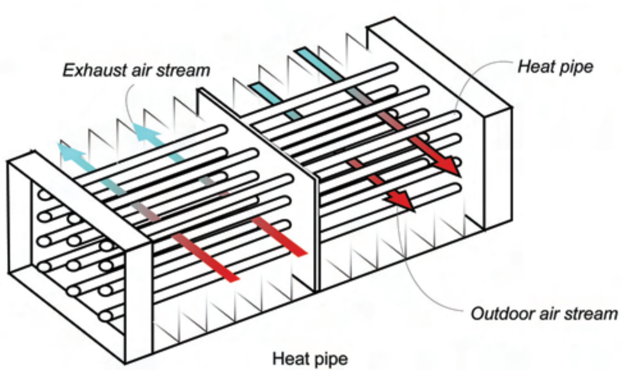
An exhaust-air energy recovery device can be packaged in a separate energy recovery ventilator (ERV) or a dedicated outdoor air unit that conditions the outdoor air



Fixed-plate heat exchanger (crossflow)



Rotary Heat Exchanger (wheel)



Heat pipe

Figure 5-31. (HV10) Examples of exhaust air energy recovery devices.

before it enters the air-conditioning unit, or the device can be integral to the air-conditioning unit.

For maximum benefit, the system should be provided with as close to balanced outdoor and exhaust airflows as is practical, taking into account the need for building pressurization and any exhaust that cannot be ducted back to the energy recovery device.

Exhaust for energy recovery may be taken from spaces requiring exhaust (using a central ducted exhaust system for each unit) or directly from the return airstream (as with a unitary accessory or integrated unit). Ducting all exhaust airflows to a single energy recovery device can be difficult and costly in a healthcare facility because locations of the rooms requiring exhaust are typically remote from each other. This first-cost impact of ducting these remotely located rooms to a central location should be investigated. (See also HV14 and HV4.)

Where an air-side economizer is used along with an ERV, add bypass dampers (or a separate outdoor air path) to prevent airflow through the recovery device, thereby reducing the air-side pressure loss during economizer mode. Furthermore, the ERV should be turned off during economizer mode to avoid adding heat to the outdoor airstream. Where energy recovery is used without an air-side economizer, the ERV should be controlled to prevent the transfer of unwanted heat to the outdoor airstream during mild outdoor conditions.

In cold climates, follow the manufacturer’s recommendations for frost prevention, and design AHUs with adequate air mixing and/or coil circulating pumps to avoid freezing coils due to stratification. Coil runaround loops will also require the circulation of a water/glycol mixture to avoid freezing.

Caution should be exercised when applying rotating wheel type recovery devices to critical care spaces because of the controversial concern about the possibility of cross-contamination of dirty exhaust air to the clean air side of the device. This type of device is not recommended for exhaust from isolation rooms or other locations where infectious patients may be housed, because of the potential for cross-contamination of exhaust air into the outdoor airstream.

HV11 ***Ductwork Design and Construction*** **(Climate Zones: all)**

Good duct design practices result in lower energy use. Low pressure loss and low air leakage in duct systems are critical to lowering the overall fan energy. Lowering the pressure needed to overcome dynamic pressure and friction losses will decrease the fan motor size and the needed fan energy. Refer to the current *ASHRAE Handbook—Fundamentals* (“Duct Design” chapter) for detailed data and practices.

Dynamic losses result from flow disturbances, including changes in direction, duct-mounted equipment, and duct fittings or transitions. Designers should reevaluate fitting selection practices using *ASHRAE Duct Fitting Database* (ASHRAE 2008c), a program that contains more than 220 fittings. For example, using a round, smooth radius elbow instead of a mitered elbow with turning vanes can often significantly lower the pressure loss. Elbows should not be placed directly at the outlet of the fan. To achieve low loss coefficients from fittings, the flow needs to be fully developed, which is not the case at the outlet of a fan. To minimize the system effect, straight duct should be placed between the fan outlet and the elbow. To determine that length, or the loss coefficient for a shorter length, refer to *ASHRAE Duct Fitting Database* (Fitting Series SD7 and ED7). Figure 5-32 illustrates the differences in the local loss coefficient (C) for a few types of round and rectangular supply duct fittings.

Be sure to specify 45° entry branch tees for both supply and return/exhaust junctions. The total angle of a reduction transition is recommended to be no more 45°. The total angle of an expansion transition is recommended to be 20° or less.

Poor fan performance is most commonly caused by improper outlet connections, non-uniform inlet flow, and/or swirl at the fan inlet. Look for ways to minimize the fan/duct system interface losses, referred to as the *system effect losses*. System effect factors, converted to local loss coefficients, are also in *ASHRAE Duct Fitting Database*. Take care in selecting the most efficient fan for the application and orient it to take

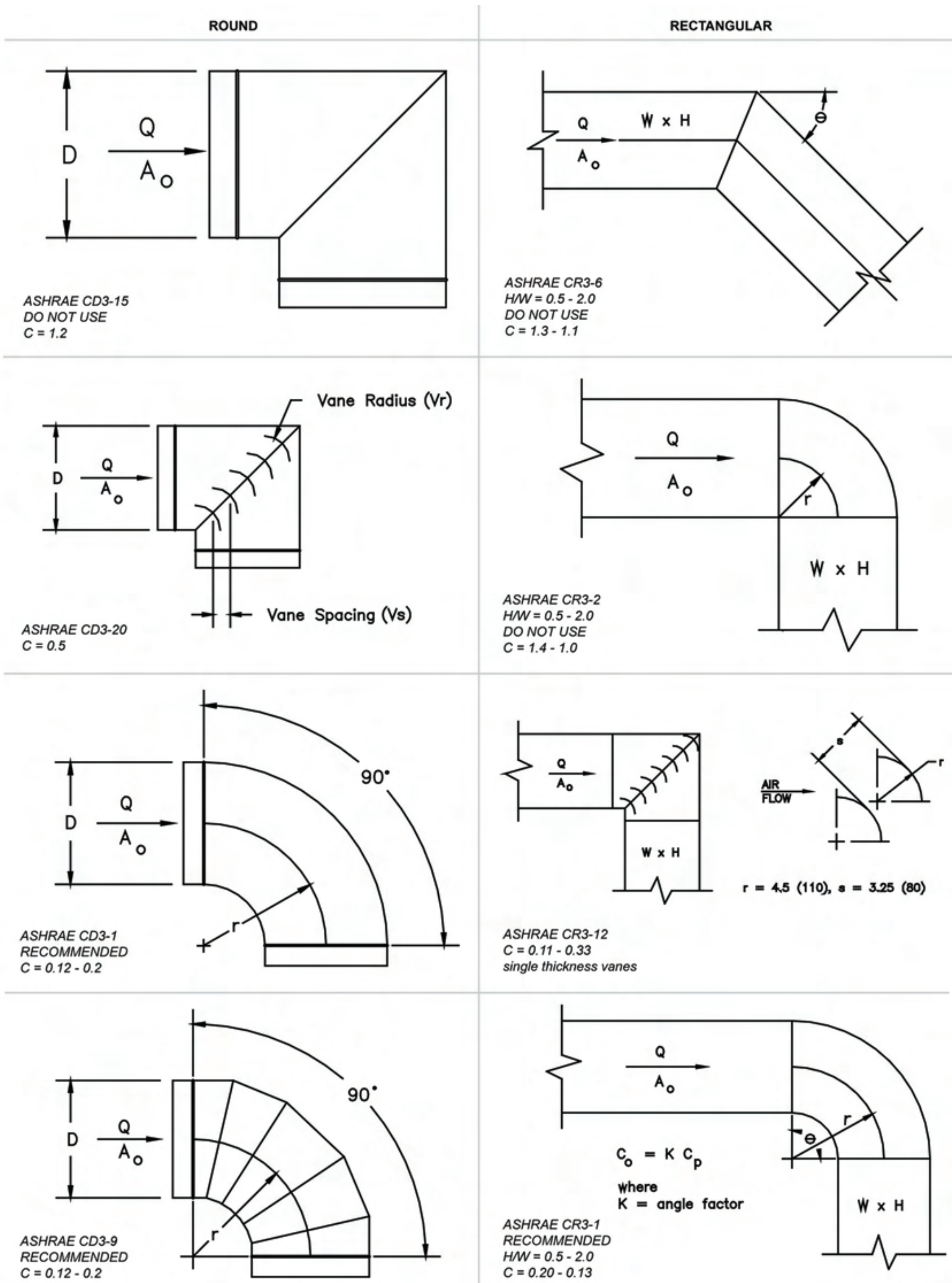


Figure 5-32. (HV11) Examples of supply duct elbows, adapted from *ASHRAE Duct Fitting Database*, Ver. 5.00.00 (ASHRAE 2008c).

advantage of the velocity pressure whenever possible. Be sure the fan outlet fittings and transitions follow good duct design and low pressure loss practices. Project teams must address space requirements for good, low pressure duct design in the early programming and schematic design phases. Allow enough space for low-pressure drop fittings and locate AHUs that result in short, straight duct layouts. Avoid the use of close-coupled fittings.

The use of flexible duct should be limited because these ducts will use more fan energy than a metal duct system. Recent research has shown that flexible duct must be installed with less than 4% compression to achieve less than two times the pressure loss of equivalent-sized metal ductwork (Abushakra et al. 2004; Culp and Cantrill 2009). If the compression is more than 30%, the pressure loss can exceed nine times the pressure loss of metal ductwork. In addition, Lawrence Berkeley National Laboratory (LBNL) has shown that the loss coefficients for bends in flexible ductwork have a high variability from condition to condition, with no uniform trends (Abushakra et al. 2002). Loss coefficients ranged from a low of 0.87 to a high of 3.3 (for comparison purposes, a die-stamped elbow has a loss coefficient of 0.11). If a project team decides to use flexible duct, the following is advised:

- Limit the use of flexible duct to connections between duct branches and diffusers or VAV terminal units.
- Flexible sections should not exceed 5 ft in length (fully stretched).
- Install the flexible duct without any radial compression (kinks).
- Do not use flexible duct in lieu of fittings.

Where permissible, consider using plenum return systems with lower pressure loss. Whenever using a plenum return system, design and construct the exterior walls to prevent uncontrolled infiltration of humid air from outdoors (Harriman et al. 2001).

HV12 ***Duct Insulation*** **(Climate Zones: all)**

The following ductwork should be insulated (as defined by ASHRAE/IESNA Standard 90.1):

- All supply air ductwork
- All outdoor air ductwork
- All exhaust and relief air ductwork between the motor-operated damper and penetration of the building exterior
- All ductwork located in unconditioned spaces or outside the building envelope
- All ductwork located in attics, whether ventilated or unventilated
- All ductwork buried either outside the building or below floors

In addition, all airstream surfaces should be resistant to mold growth and resist erosion, according to the requirements of ASHRAE Standard 62.1. Refer to ASHRAE/IESNA Standard 90.1 for minimum insulation thermal resistance requirements.

While return and exhaust ductwork above a top floor ceiling (with a roof above) or in an unventilated attic may seem like it doesn't need insulation, there is a real possibility that air removed from the space can have moisture condensation if the duct is located in a cold space. This condensation could cause physical damage and be a source of mold growth.

HV13 ***Duct Sealing and Leakage Testing*** **(Climate Zones: all)**

The sealing of supply ductwork in accordance with ASHRAE/IESNA Standard 90.1 requirements can substantially reduce airflow leakage. If 1000 cfm of supply air does not reach the space it is intended to condition, almost 2 tons (22,000 Btu/h) of cooling is wasted. Unsealed rectangular ductwork is considered to be Seal Class 48. Class A sealing of this duct can improve its performance to Seal Class 6, which reduces average leakage from 15% to approximately 2%. Additional information can be obtained in the "Duct Design" chapter of *ASHRAE Handbook—Fundamentals*.

All supply ductwork and all ductwork located outside or run through unconditioned spaces should be Seal Class A as defined in ASHRAE/IESNA Standard 90.1. All return and exhaust ductwork should be sealed for Seal Class B. All duct joints should be inspected to ensure they are properly sealed and insulated. All ductwork located outdoors and 25% of the total installed area of indoor Seal Class A ductwork should be leak-tested as described in ASHRAE/IESNA Standard 90.1-2007, Section 6.4.4.2.2. See HV15 for guidance on ensuring the air system performance.

HV14 ***Exhaust Air Systems*** **(Climate Zones: all)**

Exhaust air systems in healthcare facilities are typically more extensive than those in many other types of facilities. They not only provide odor control but also play an important role in infection control. In many cases, the amount of air exhausted from a room is chosen to create negative air pressure relative to the adjacent rooms, lowering the potential for airborne transmission of odor and contaminants. In some cases, the potential contaminants are dangerous enough that fume hoods are required or other capture scenarios are applied. The mechanical system designer should be experienced and collaborate with the healthcare organization's Infection Control Officer and Industrial Hygienist.

Exhaust airflow rates and relative air pressure criteria will be listed in the ventilation standard being used. As for ventilation requirements (see HV8), outpatient treatment and diagnostic clinics or medical office buildings are likely to use a different standard for exhaust airflow rates and air pressure differences than surgical or hospitals facilities use. Clinics will often reference local building code requirements, while surgery facilities and hospitals will often reference local or state health department regulations. In many states, health departments reference the *Guidelines* for ventilation, exhaust, and pressure requirements. In addition, ASHRAE/ASHE Standard 170 has recently been published. Once the applicable standard is determined, apply it to determine the exhaust flow rates and whether the exhaust systems can be cycled based on occupancy or must operate continuously.

Central exhaust systems do not typically exist in healthcare facilities, or at least are only a portion of the total exhaust. The rooms requiring exhaust tend to be numerous and spread throughout the floor plans, making it difficult to centralize exhaust air from them. They typically are combined based on location and whether they are cycled based on occupancy or must operate continuously. Medical terminology (such as that used for room names) varies from organization to organization, and some terms differ from one geographic region to another. It is important that the mechanical designer understand what the room name actually implies for each specific project. That will allow the designer to apply the most appropriate room type listed in the reference regardless of the room name used. For example, one of the most comprehensive lists of room types can be found in ASHRAE/ASHE Standard 170. The following from ASHRAE/ASHE Standard 170 lists rooms that require exhaust:

- ER waiting
- Triage
- ER decontamination
- Radiology waiting
- Toilet room
- Airborne infection isolation (AII) room
- Physical therapy
- Bathing room
- Locker room
- Darkroom
- Bronchoscopy
- Sputum collection

- Medical gas storage
- Pentamidine administration
- Laboratory
- Endoscope cleaning
- Hydrotherapy
- Sterilizer equipment room
- Soiled or decontamination areas
- Ware washing
- Laundry
- Soiled linen sorting storage
- Linen and trash chute room
- Janitor closet or room
- Hazardous material storage

Following are some tips on how to save energy in exhaust systems. Provide motorized dampers that open and close with the operation of the fan. Locate the damper as close as possible to the duct penetration of the building envelope to minimize conductive heat transfer through the duct wall and avoid having to insulate the entire duct. In colder climates, consider insulating 10–20 ft of duct that is connected to the exterior exhaust fan to avoid condensation. For fans that are interlocked with AHUs, be sure to keep the exhaust fans off and dampers closed during unoccupied periods, even if the HVAC system is operating to maintain setback or setup temperatures. Consider designing exhaust ductwork to facilitate recovery of energy (see HV10) from Class 1 and Class 2 (e.g., restroom) exhaust air (ASHRAE Standard 62.1-2007).

Food service kitchens and laundry functions may exist in small healthcare facilities. However, the trend for many organizations is to outsource these services when possible. If the facility does have food service, the kitchen will generally have separate exhaust and makeup air systems (see PL3 and PL4).

Exhaust system design must ensure that there is enough makeup air to avoid placing the facility under a negative pressure. Existing hospitals are notorious for operating under a negative pressure. This results in infiltration and can lead to moisture control problems. Designers of hospital additions or connections to new facilities should be aware that new facilities often become the sources of makeup air for the original facilities. This can create problems for the new HVAC systems and cause excessive infiltration at new entries.

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

After the equipment has been installed, cleaned, and placed in operation, the system should be tested, adjusted, and balanced in accordance with *ASHRAE Standard 111, Measurement, Testing, Adjusting, and Balancing of Building HVAC Systems* or the TAB manuals published by the Associated Air Balance Council (AABC), the National Environmental Balancing Bureau (NEBB), or the Sheet Metal and Air Conditioning Contractors National Association (SMACNA). This will help to ensure that the sizes of diffusers, registers, and grilles match the design, that each space receives the required airflow, that the fans meet the intended performance, and that heating, cooling and ventilating equipment is performing as intended (see the “Quality Assurance and Commissioning” section). An unbalanced or improperly balanced system can contribute to discomfort and increased energy consumption by the HVAC systems and may permit flow of contaminated air into areas where a sterile environment is mandatory.

The TAB subcontractor should certify that the instruments used in the measurement have been calibrated within 12 months of use. A written report should be certified as accurate by the TAB contractor and submitted for inclusion in the O&M manuals.

HV16 *Thermal Zoning* (Climate Zones: all)

Thermal zoning should consider outdoor exposure, minimum airflow requirements, pressure relationship requirements, space layout and function, and occupancy scheduling. Areas that have required air exchange rates add complexity to thermal zoning. Combining dissimilar rooms can cause excessive supply air and ventilation air, both resulting in the use of unnecessary energy.

Some data/information technology rooms and equipment and control rooms for diagnostic systems (such as MRI, CT, and linear accelerators) may need 24/7 cooling. In outpatient facilities, this usually results in the use of dedicated HVAC systems. In surgery and in-patient facilities, central systems are operating 24/7 and can potentially serve these spaces as well. Redundancy is sometimes a consideration for these applications. Consider serving these spaces with a combination of both a dedicated system and connection to the central system. Operate the most efficient system as the primary and the other as the redundant (backup) system. Typically, energy efficiency is a second-level priority on these systems. This means that the designer should determine how to deliver the highest efficiency without compromising reliability.

HV17 *System-Level Control Strategies* (Climate Zones: all)

Control strategies can be designed to help reduce energy. In addition, properly applied BAS can help minimize maintenance labor and improve response time to occupant complaints. Having a setback temperature, or air change rate reduction (i.e., airflow reduction, see HV23), for unoccupied periods during the heating season or a setup temperature during the cooling season can help save energy by reducing or avoiding altogether the need to operate heating, cooling, and ventilation equipment. Programmable thermostats are typically separate devices that are connected to single-zone HVAC equipment, and have only daily and weekly scheduling capabilities. The use of a BAS adds the capability of annual scheduling, including holidays, allowing each zone to vary the temperature setpoint based on time of day, day of the week, and day of the year. The use of local, programmable thermostats or occupant override switches, however, thwarts any potential for energy savings as they allow occupants to override these setpoints or ignore the schedule altogether (by using the “hold” feature on the thermostat).

A more appropriate approach is to equip each zone with a zone temperature sensor and then use a BAS that coordinates the operation of all components of the system. This BAS contains time-of-day schedules that define when different areas of the building are expected to be unoccupied. During these times, if the *Guidelines* do not require a continuous air change rate, the system may be shut off and the temperature allowed to drift away from the occupied setpoint. If there is, however, even the remotest possibility that the space may be occupied after hours or during these “unoccupied” periods, a system override should be provided to permit occupants to obtain an occupied condition. The requirements of the *Guidelines* and other codes or standards must be observed for the maintenance of the required minimum pressure relationships and air change rates during the unoccupied periods (see HV23).

If the *Guidelines* require a constant air change rate (as in critical care areas), the system must be maintained in operation and temperature setback may save little to no energy. In a constant-volume or VAV reheat system, temperature setback can actually increase energy consumption because the system often uses more energy to reheat the mechanically cooled air to attain that setpoint. However, reducing the airflow delivered to these types of spaces is permissible and can save a significant amount of fan, cooling, and heating energy.

A pre-occupancy ventilation period can help purge the building of contaminants from the off-gassing of products and packaging materials that build up overnight. When it is cool at night, this can also help pre-cool the building. In humid climates, however, extreme care should be taken to avoid bringing in humid outdoor air during unoccupied periods.

Optimal start uses a system-level controller to determine the length of time required to bring each zone to the occupied setpoint temperature. Then, the controller waits as long as possible before starting the system so the temperature in each zone reaches the occupied setpoint just in time for occupancy. This strategy reduces the number of hours that the system needs to operate and saves energy by avoiding the need to maintain the indoor temperature at the occupied setpoint when the building is unoccupied.

Chilled-water reset can reduce chiller energy use at part-load conditions. Its use with variable-flow pumping systems must be done with caution, and space humidity levels must be observed closely to ensure than an elevated chilled-water temperature does not permit any space to rise above 60% RH. The use of direct digital control (DDC) can permit variable flow and chilled-water reset controls to function in a coordinated fashion so that all zones are satisfied.

In a constant-volume or VAV system, SAT reset should be implemented to minimize overall system energy use. This requires considering the trade-off between compressor, reheat, and fan energy as well as the impact on space humidity levels. If SAT reset is used in a humid climate, include one or more zone humidity sensors to relax reset requirements if the relative humidity in the space exceeds 60%. Each zone should have the SAT monitored to verify that each is delivering the correct temperature.

HV18 ***Filters*** **(Climate Zones: all)**

Particulate air filters are typically included as part of the factory-assembled HVAC equipment and should be at least MERV 8 for areas covered by the *Guidelines* and MERV 7 for other areas, both based on *ASHRAE Standard 52.2, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*. Use a filter differential pressure gauge to monitor the pressure loss across the filters and send an alarm if the predetermined pressure loss is exceeded. The differential pressure at which filters are to be replaced should not always be the maximum rated pressure loss of the filter. In many, if not most, cases economics favor lower pressure loss filter change-out pressures based on weighing fan power against filter replacement cost. Designers should consider labeling a differential pressure setpoint that is lower than the maximum for the specified filter based on calculations of when the combination of fan energy cost and filter replacement cost provide the lowest life-cycle cost. Regardless of the pressure reading, the gauge should be checked and the filter should be visually inspected at least once each year.

ASHRAE/ASHE Standard 170 and the *Guidelines* require many healthcare occupancies to employ at least two filter banks in series. In those occupancies, ASHRAE/ASHE Standard 170 and the *Guidelines* require MERV 14 or 17 (HEPA) filters for the downstream bank. It is common to use three filter banks in series with high efficiency particulate air (HEPA) filters serving a portion of the flow from an AHU. This practice wastes of energy because the supply fan must supply enough pressure to satisfy the zones that are served by three filter layers and because the fan must overcome pressure loss for three sets of dirty filters. If HEPA filters are required for some areas served by an AHU, a booster fan should be provided for that branch of the duct system. If high-efficiency (MERV 14 or HEPA) filters are to be used, consider using lower-efficiency (MERV 8 to 13) filters during the construction period. When construction is complete, all filters should be replaced before the building is occupied. Systems designed with particle filters should not be operated without the filters in place.

Fan energy accounts for approximately 16% of the total energy use in conventional VAV reheat hospitals. Any filtration system that reduces pressure loss while complying with the applicable ASHRAE Standard 52.2 MERV rating will reduce building energy use substantially. Designers should consider the average pressure loss of each filter system, including the clean pressure loss, final pressure loss, and dirt holding capacity. For example, it is often economically justified to use 4 in. pleated MERV 8 prefilters in lieu of 2 in. filters because the average pressure loss over the life of the filters and the labor cost of replacements is lower.

Compliance with the fan power limitations of some versions of ASHRAE/IESNA Standard 90.1 can be very difficult for healthcare facilities with multiple filters in series and/or with HEPA filters. ASHRAE/IESNA Standard 90.1-2007 includes adjustment to the allowable fan power based on the efficiency of each filter bank (see HV7). Multiple adjustments can be made for multiple filter banks in series.

HV19 *Chilled-Water System* (Climate Zones: all)

The use of chilled-water systems is an efficient way to move energy around the building, and with the load profile of many healthcare facilities, they can be a great way to combine a thermal storage system (see HV32 in the "Bonus Savings" section of this chapter) with the building HVAC systems. Furthermore, with the significant requirement for reheating in healthcare facilities, the use of condenser heat recovery is another method of reducing the use of purchased energy (see HV28, in the "Bonus Savings" section of this chapter). Chilled water systems with modulating valves should be designed for variable flow and be capable of reducing pump flow rates to 50% or less of the design flow rate. Care should be taken to maintain the minimum flow through each chiller, as defined by the chiller manufacturer.

Very small systems with total system pumping power of 10 hp or less may be designed for constant flow and still comply with ASHRAE/IESNA Standard 90.1, but the use of modulating control valves and VFDs should be considered for both energy reduction and controllability reasons.

Piping should generally be sized for a pressure loss of no more than 3 ft of water per 100 ft of pipe, or less. Large pipes, however, may be sized at much higher pressure loss, based on velocity limitations. (Refer to Table 5-12 for pipe sizing recommendations. ASHRAE/IESNA Standard 90.1 should be consulted for more complete pipe sizing limitations.) The use of smaller pipe sizes increases the pressure loss and velocity through the pipe and may cause internal pipe erosion if velocity is too high. Larger pipe sizes result in additional pump energy savings but increase the installed cost of the pipe system. In systems that operate for longer hours, larger pipe sizes are often very economical.

The use of VFDs on chillers can be beneficial in applications where condenser relief occurs for a significant number of hours. Air-cooled condensers are typically designed for ambient temperatures of 95°F or higher, and water-cooled condensers are typically designed for entering water temperatures of approximately 85°F. If a chiller will operate for a significant number of hours at temperatures at least 10°F below these

Table 5-12. Maximum Flow Rate (gpm) for Piping System Design

Operating Hours/Year	≤ 2000		> 2000 and ≤ 4400		> 4400 and ≤ 8760	
Nominal Pipe Size, in.	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed
2 1/2	120	180	85	130	68	110
3	180	270	140	210	110	170
4	350	530	260	400	210	320
5	410	620	310	470	250	370
6	740	1100	570	860	440	680
8	1200	1800	900	1400	700	1100
10	1800	2700	1300	2000	1000	1600
12	2500	3800	1900	2900	1500	2300
Maximum Velocity for Pipes Over 12 in. Size	8.5 fps	13.0 fps	6.5 fps	9.5 fps	5.0 fps	7.5 fps

Source: Table 6.5.4.5, ASHRAE/IESNA Standard 90.1-2007 conditions, a VFD should be considered to reduce the compressor lift in response to the reduced condensing temperature. Not all chillers need to be equipped with a VFD; typically a VFD on the chiller that operates with the most amount of condenser relief (the lead chiller) will provide the most energy savings and, therefore, the shortest payback. Generally, climates that are hot and humid are not good candidates for VFDs on chillers. In addition, some compressor technologies will permit the use of colder condenser water with an accompanying improvement in operational efficiency. The manufacturer of the chiller should be consulted on this possibility before making a commitment to the control scheme.

Energy use and installed costs are typically both reduced by selecting CHW ΔT of 12°F to 20°F rather than the traditional 10°F (ASHRAE 2006). This will save pump energy, permit the reduction of pipe sizes (reducing installation cost), and minimize pump heat added to the water because of the use of reduced pump horsepower, but it will also affect cooling coil performance. This can be overcome by lowering the chilled-water temperature to deliver the same air conditions leaving the coil. Chilled-water temperature setpoints should be selected based on a life-cycle analysis of pump energy, fan energy, and desired air conditions leaving the coil.

The use of a water-side economizer (see HV9) can be a viable efficiency improvement option over an air-side economizer in certain climate zones. (Perform an energy analysis as defined in HV9 for justification.) Where low-temperature discharge air is required of an air handler, the use of the cooling tower in arid climate zones takes advantage of evaporative cooling to produce CHW during periods when the dry-bulb air-side economizer may not be available. The use of this option in hot and humid climates may have little or no applicability.

HV20 ***Heating-Water System*** **(Climate Zones: all)**

Condensing boilers can operate at above 90% efficiency (based on the lower heating value of petroleum fuels) and most models operate at higher efficiency at part load. Any reduction in heating-water return temperature increases boiler efficiency. To achieve 91% to 97% efficiency, condensing boilers typically require return water temperatures below 120°F. Designers should compare boiler efficiency curves, as some condensing boilers do not have high efficiencies until the return water temperatures are very low while others can be above 90% efficient at low fire with 150°F return water. High-efficiency boilers fit well with hydronic systems that are designed with ΔTs greater than 20°F (many designers believe that the optimal ΔT is 30°F to 40°F). Higher ΔTs also allow smaller piping and less pumping energy, which reduce first costs. Another option is to use low temperature heating water systems (e.g., 140°F supply with 120°F return) to help increase boiler efficiency.

Systems that comply with ASHRAE/IESNA Standard 90.1 often have very low summer reheat loads. To prevent rapid boiler cycling, designers should weigh the options of high-turndown boilers, multiple low-turndown boilers, and/or storage tanks. Because most condensing boilers work most efficiently at part load, it is desirable to select boilers with high turndown ratios.

Many condensing boilers have very low minimum return water temperatures, which minimizes the possibility of damage due to low return water temperature.

Condenser-water heat recovery (see HV28 in the “Bonus Savings” section of this chapter) is also an option to reduce heating system energy use. One very efficient method is to use condenser reheat (140°F supply with 120°F return) and condensing boilers as the secondary heat source.

HV21 ***Relief or Return Fans*** **(Climate Zones: all)**

Relief or return fans should be used when necessary to maintain building pressurization. If return duct static pressure loss exceeds 1 in. H_2O, return fans are typically used. For this reason, systems with a fully-ducted return path (which is common in many types of healthcare facilities) often use return fans.

HV22 ***Zone Temperature Control*** **(Climate Zones: all)**

The number of spaces in a zone and the location of the temperature sensor (thermostat) will affect the control of temperature in the various spaces of that zone. Providing a temperature sensor in every space will provide the best possible control of each space but will significantly increase the installed cost. Locating the thermostat in one room of a zone with multiple spaces provides feedback based only on the conditions in that room. Locating a single thermostat in a large open area of a zone that includes additional spaces may provide a better response to the conditions of that multiple-space zone. Selecting the room or space that will best represent the thermal characteristics of the zone due to both external and internal loads will provide the greatest comfort level.

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

In spaces with high ceilings (such as lobbies and atriums), consider using ceiling fans or high/low air distribution to reduce temperature stratification during the heating season.

In addition, the required space pressure relationships must be considered when using VAV. It is strongly recommended that independent control of spaces requiring pressure control be considered (see HV23). Combined control of these spaces can cause the pressure relationships to vary out of the required conditions.

Six primary factors must be addressed when defining conditions for thermal comfort:

- Metabolic rate
- Clothing insulation
- Air temperature
- Mean radiant temperature
- Air speed
- Humidity

Appropriate levels of clothing, the cooling effect of air motion, and radiant cooling or heating systems, for example, can reduce the energy required to provide occupant comfort. Refer to ASHRAE Standard 55 for more information.

HV23 ***Zone Airflow Control and Setback*** **(Climate Zones: all)**

For each healthcare space in which the *Guidelines* or ASHRAE/ASHE Standard 170 require a minimum air change rate, the VAV terminal unit in the supply duct modulates supply airflow to maintain space temperature, but not below the minimum air change rate required. This minimum air change rate can be reduced during unoccupied periods, but required space-to-space pressure relationships must still be maintained. Note that if the minimum air change rate required for a zone is higher than the design airflow needed for cooling or heating, the supply airflow to that zone will be constant during occupied periods.

For each healthcare space in which the *Guidelines* or ASHRAE/ASHE Standard 170 require either positive or negative pressure with respect to adjacent spaces, a motorized damper or VAV terminal unit is also included in the return duct from that space (Figure 5-33). As the VAV terminal unit in the supply duct modulates supply airflow, the VAV terminal unit in the return duct modulates to maintain either a positive or negative pressure in the space (through direct pressure measurement or by controlling to an airflow offset from supply airflow rate). Use caution when selecting return air VAV terminals to minimize air-side pressure drop.

Cautions

HV24 ***Heating Sources*** **(Climate Zones: all)**

Many factors come into play in making a decision whether to use gas or electricity for heating, including installation cost, availability of service, utility costs, operator familiarity, and the impact on source energy use. Efficiency recommendations for both types of heating equipment are listed in the recommendation tables in Chapter 3 to allow the user to choose. Many healthcare facilities use steam for central process uses and humidification. The use of high-efficiency boilers to supply this steam also provides a source for space heating and service water heating.

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

HV25 ***Humidification System*** **(Climate Zones: all)**

ASHRAE/ASHE Standard 170 and the *Guidelines* require humidification to 30% RH in many healthcare spaces. Some states have higher minimum requirements for some spaces (e.g., Illinois requires 40% minimum relative humidity for operating rooms). The traditional method of humidifying in healthcare systems is to provide either a direct steam injection humidifier (which may not comply with ASHRAE Standard 62.1) or a clean steam system using domestic water and powered by steam, fossil fuel, or electricity.

Humidification energy can be reduced by several methods:

- Systems can incorporate enthalpy recovery (see HV10).
- Systems can incorporate water economizers instead of air economizers (see HV9).
- Systems can employ a DOAS, which normally includes enthalpy recovery.
- Spray-type humidifiers might be considered in warm, dry climates. However, infection control staff and accreditation authorities should be consulted. These units should not be reservoir type or evaporative pan type, neither of which is permitted by ASHRAE/ASHE Standard 170.

HV26 ***Noise Control*** **(Climate Zones: all)**

Oral communication, especially speech intelligibility, is critical in healthcare occupancies. Poor acoustical conditions affect the performance of all staff members. *ASHRAE Handbook—HVAC Applications* is a source for recommended background sound levels in healthcare spaces. Another excellent reference is the AIA/AHA *Interim Sound and Vibration Design Guidelines for Hospital and Healthcare Facilities*.

Avoid installation of noisy HVAC equipment directly above occupied spaces. Consider locations above less critical spaces such as storage areas, restrooms, and corridors or in acoustically treated closets adjacent to critical spaces. Acoustical requirements may necessitate attenuation of the noise associated with the supply and return air or of the noise radiated from the HVAC equipment. Acoustical concerns may be particularly critical in short, direct runs of ductwork between fans and air inlets or outlets.

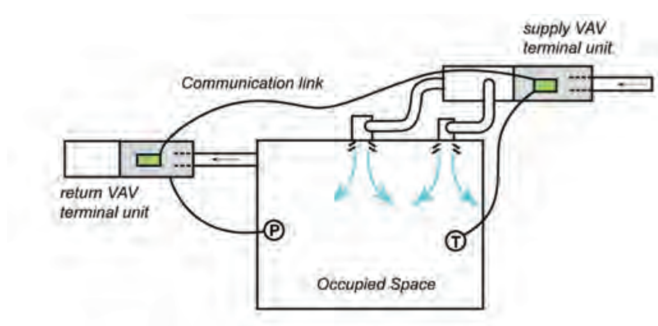


Figure 5-33. (HV23) Supply and return VAV terminals for space pressure control.

VAV noise can be especially problematic in healthcare facilities because the rating system for VAV boxes (AHRI Standard 885-2008, Appendix E) assumes that the ducts downstream of VAV boxes are lined. This is seldom true in healthcare facilities, and this can cause the ratings to underestimate room noise levels by 10 to 20 dB. Another concern related to VAV boxes is that the pressure loss across VAV box dampers near the AHU may be very high in duct systems with high pressure loss. The noise ratings for VAV boxes depend strongly on the pressure loss across them. Minimizing the pressure loss between the first and last VAV box in the duct systems is the best method of combating this problem, and it simultaneously helps reduce fan energy consumption.

Refer to *A Practical Guide to Noise and Vibration Control for HVAC Systems* for specific guidance by system type and to *ASHRAE Handbook—HVAC Applications*.

HV27 *Operation and Maintenance* (Climate Zones: all)

Operation and maintenance (O&M) is a critical consideration and will likely have a large impact on a facilities' energy use over its life. Designers should consider O&M from the onset of any building project to help ensure that energy savings is realized year after year. Designers need to take some responsibility for making the building owner aware of:

- proper means of operation of mechanical systems,
- describing the scope of an appropriate maintenance program, and
- estimating the annual operating and maintenance budget.

In too many circumstances, owners are sold on investing in new, high-tech systems with promises of energy savings and quick paybacks. Too often, the savings is never realized because of improper installation, operation, or maintenance. In a recent study, with 85 existing facilities reporting over 3500 deficiencies, approximately 80% of the recommended retro-commissioning measures were O&M issues, while only 20% were design, installation, or replacement issues (Mills et al. 2004). In many of these cases, owners have no way of knowing that their energy systems are underperforming. Avoid this pitfall by commissioning the systems and by planning and implementing appropriate (simple) verification and maintenance programs.

System selection evaluations must include O&M. Providing only the energy savings of an alternate system is incomplete and misleading. O&M items to consider include the following:

- Evaluate existing maintenance staff capacity and skill level
- Include staff additions and/or training
- Maintenance self performed or by a service contractor
- Estimate preventative and unexpected failure maintenance
- Consider O&M in economic evaluations

Some facilities have no maintenance staff and rely completely on service contractors. Some facility owners should consider negotiating premiums for service contractor "quick response," such as in the case of a hospital or outpatient surgery or imaging facility. Facility owners may want to have some spare parts on site or at the service contractor's storage facility to minimize downtime. The facility's O&M staff capacity and capability need to align with the level of complexity of the mechanical and electrical systems. This evaluation should take place during the programming phase.

Consider assisting the building owner in developing an energy verification program. It should include data collection, analysis, and recommendations. After time, the data becomes a benchmark that is useful for identifying changes and potential problems. Verification programs can utilize some of the procedures from the Cx functional or performance testing (see QA10).

Make use of the BAS. Take advantage of the data trending, alarm, and preventative maintenance features. Consider installing electrical sub-meters at key circuits. Be sure that this is a coordinated effort with the electrical designer and the proposed circuiting design. Just like the maintenance programs, the verification program needs to align with the complexity of the systems. It can be as simple as a monthly examination of the utility bills and ensuring the systems are operating on the right schedule. The person in charge of reviewing the data needs to be familiar with the systems and data to recognize deficiencies and unacceptable levels.

Designers need to understand that healthcare facility owners provide their services to their clients in these facilities. Designers also need to consider that healthcare staff recruitment and retention is a top priority throughout the industry. If systems fail, or merely underperform, the results will likely include lost revenue and lower patient and staff satisfaction levels. Designers need to provide reliable systems that an owner is capable of operating properly and maintaining year after year.

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SERVICE WATER HEATING

Good Design Practice

WH1 *Service Water Heating Types* (Climate Zones: all)

This Guide assumes that the service water heating (SWH) equipment uses the same type of fuel source as is used for the HVAC system. This Guide does not cover systems that use oil, hot water, steam, or purchased steam for generating SWH, nor does it address the use of solar or site-recovered energy (including heat pump water heaters). These systems are alternative means that may be used to achieve 30% (or greater) energy savings over ASHRAE/IESNA Standard 90.1-1999 and, where used, the basic principles of this Guide would apply.

The SWH equipment included in this Guide are the gas-fired water heater (both standard and high efficiency) and the electric water heater. Natural gas and propane fuel sources are available options for gas-fired units.

Many factors come into play in making a decision whether to use gas or electricity, including availability of service, installation cost, utility costs, operator familiarity, and the impact of source energy use. Efficiency recommendations for both types of equipment are provided to allow for choice.

WH2 *System Descriptions* (Climate Zones: all)

Gas-Fired Storage Water Heater. A water heater with a vertical or horizontal water storage tank. A thermostat controls the delivery of gas to the heater's burner. The heater requires a vent to exhaust the combustion products. An electronic ignition is recommended to avoid the energy losses from a standing pilot. Standard heater efficiency is typically 80%, but heaters of the condensing type have efficiencies as high as 95%.

Gas-Fired Instantaneous Water Heater. A water heater with minimal water storage capacity. The heater requires a vent to exhaust the combustion products. An electronic ignition and flue gas damper are recommended to avoid the energy losses from a standing pilot and exfiltration due to stack effect. Using an instantaneous water heater requires increased peak input but eliminates the typical storage tank jacket heat losses for a net increase in water heating efficiency.

Electric Resistance Storage Water Heater. A water heater consisting of a vertical or horizontal storage tank with one or more immersion heating elements. Thermostats controlling heating elements may be of the immersion or surface-mounted type. The efficiency is inherently higher than for gas heaters because there is no pilot and no flue loss.

Electric Resistance Instantaneous Water Heater. A compact under-cabinet or wall-mounted type water heater with insulated enclosure and minimal water storage capacity. A thermostat controls the heating element, which may be of the immersion or surface-mounted type. Instantaneous, point-of-use water heaters should provide water at a constant temperature regardless of input water temperature. The use of this type of water heater may not be advisable for patient rooms because of the considerable increase in cost of the large electrical feeders that may be required based on the large number of heaters required. They may, however, be advantageous for public restrooms and other small, remote toilet rooms.

WH3 *Sizing* (Climate Zones: all)

The water heating system should be sized to meet the anticipated peak hot water load, stated both in gallons per minute (gpm) and gallons per hour (gph). Plumbing codes include a supply fixture unit (SFU) sizing method that yields peak building gpm. In the SFU method, each hot-water-using fixture or appliance is assigned an SFU value.

The SFU values are totaled for the entire building, and then a diversity factor is applied to arrive at expected peak gpm.

Where instantaneous water heaters are used, sizing is based on peak gpm. If peak gpm can be met, instantaneous water heaters will have excess capacity at all other lower demand periods.

Storage type water heaters are sized using manufacturer-published first-hour delivery capacity, which is a combination of storage capacity and recovery capacity. If a storage water heater system can meet the largest hourly demand, the storage water heaters will have excess capacity at all other lower demand periods.

Hourly hot water demand is calculated by assigning each hot-water-using fixture an expected hourly usage then applying a diversity factor. For both instantaneous and storage type systems, timing of peak functional area usage should be analyzed. For example, peak kitchen or laundry hot water use may not coincide with peak shower demand. Water heater capacity may be reduced based on this analysis.

Healthcare facilities cannot operate without hot water. Should a healthcare facility be forced to close because of a lack of hot water, unacceptably high losses, both revenue and reputation, would be incurred. Because of this, diversity must be evaluated and included in the design. At least two water heaters should be in the base design. Common diversity factors would be 50%, 100%, or N+1.

WH4 ***Equipment Efficiency*** **(Climate Zones: all)**

Efficiency levels are provided in the climate-specific tables in Chapter 3 for the four types of water heaters listed in WH2.

The gas-fired storage water heater efficiency levels correspond to condensing storage water heaters. High-efficiency condensing gas storage water heaters (energy factor [EF] higher than 0.90 or thermal efficiency (E_t) higher than 0.90) are alternatives to the use of gas-fired instantaneous water heaters.

For gas-fired instantaneous water heaters, the EF and E_t levels correspond to commonly available instantaneous water heaters. Gas-fired instantaneous water heaters have historically proved difficult to incorporate into a recirculating service hot water system at periods of low or no system demand. Also, in a recirculating system, the benefit of lower standby losses with an instantaneous water heater are easily overwhelmed by the recirculating hot water piping losses, further reducing the appeal of an instantaneous unit.

Electric water heater efficiency should be calculated as

$$0.99 - 0.0012 \times \text{Water Heater Volume}\ ,$$

where volume equals zero for instantaneous water heaters.

Electric instantaneous water heaters may be an acceptable alternative to high-efficiency storage water heaters. Electric instantaneous water heaters are more efficient than electric storage water heaters because of the reduced standby losses. However, their peak electric demand is significant and should be taken into account during design. Where high peak hot water loads (e.g., showers or laundry facilities) are present, the high kilowatt demand of electric instantaneous water heaters are the limiting factor.

A point-of-use version of the electric instantaneous water heater is a good solution for smaller demands at remote locations. In healthcare facilities, this might occur at imaging equipment such as a linear particle accelerator (LINAC), where a single cold water line can be routed to the remote sink.

WH5 ***Location*** **(Climate Zones: all)**

Plumbing codes require that the maximum noncirculated distance from water heater to point-of-use must not exceed 100 ft. Good design limits the noncirculated distance to approximately 25 ft or less, minimizing unacceptable delays for users to receive hot water.

Healthcare facilities have a relatively high density of hot-water-using plumbing fixtures, located throughout the building, so it is usually not possible to locate the water heater satisfactorily close to all hot water demand points. Because of high service hot water usage and many demand points, healthcare facilities typically use a recirculating service hot water system. One notable exception is a multi-suite medical office building where, to simplify the lease, each tenant is held responsible for his or her own service hot water needs.

If a recirculating service hot water system is used, the optimum water heater location is at the building water service entrance, near the water softeners (if required), minimizing overall piping costs. Due to the premium cost for space at a water entrance room, another common location is in a remote mechanical room (a penthouse for example). Combustion air and flue gas exhaust venting requirements for gas water heaters need to be reviewed and for aesthetic reasons may dictate the location.

Heat tracing on hot water supply piping may be used to satisfy code or user requirements, and advantages are noted for future remodeling projects. Disadvantages of heat tracing include maintenance and limited product lifetime. Heat tracing lends itself to longer "dead-legs" and, where waterborne bacterial control is an issue, heat tracing applications should be carefully reviewed.

WH6 *Pipe Insulation* (Climate Zones: all)

All SWH piping should be installed in accordance with accepted industry standards. Insulation levels should be in accordance with the recommendation levels in the recommendation tables in Chapter 3, and the insulation should be protected from damage.

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BONUS SAVINGS

EXTERIOR LIGHTING

The following recommendations are provided for design for parking lots, building exteriors, and grounds.

EX1 *Exterior Lighting Power* (Climate Zones: all)

Limit exterior lighting power to 0.10 W/ft^2 for parking lot and grounds lighting. Calculate only for paved areas, excluding grounds that do not require lighting. Design walkways and hardscape plazas not to exceed 0.2 W/ft^2, and areas under drop-off canopies should use less than 1.0 W/ft^2.

Facade lighting can improve safety and security. Limit exterior decorative facade lighting to 0.15 W/ft^2 or 3 W per lineal foot of illuminated surface. This does not include lighting of walkways or entry areas of the building that may also light the building. Limit the lighting equipment mounting locations to the building and do not install floodlights onto nearby parking lot lighting standards. Use downward-facing lighting to comply with light trespass and light pollution concerns.

EX2 *Sources* (Climate Zones: all)

All general lighting luminaires should use pulse start metal halide, fluorescent, induction, or compact fluorescent amalgam lamps with electronic ballasts. These sources should have initial efficacy of at least 60 lumens/W.

Standard high-pressure sodium lamps are not recommended because of their reduced visibility and poor color-rendering characteristics. Incandescent lamps are also not recommended.

For colder climates in climate zones 6, 7, and 8, fluorescent lamps and CFLs must be specified with cold-temperature ballasts. Use CFL lamps with amalgam.

EX3 *Parking Lighting* (Climate Zones: all)

Parking lot lighting locations should be coordinated with landscape plantings so that tree growth does not block effective lighting from pole-mounted luminaires. Use luminaires with cutoff to minimize light pollution and wasteful distribution of lighting energy into the sky.

Parking lot lighting should not be significantly brighter than lighting of the adjacent street. Follow *IESNA RP-33-1999, Recommended Practice on Lighting for Exterior Environments* recommendations for uniformity and illuminance recommendations.

Caution: For parking lot and grounds lighting, carefully design so that luminaire wattage is not increased in an attempt to use fewer lights and poles. Increased contrast reduces visibility at night beyond the immediate fixture location. Do not use floodlights and non-cutoff wall-packs, as they can cause glare and light trespass onto neighboring properties. Limit lamp selection for lighting in parking and drive areas to not more than 350 W pulse-start metal halide.

References

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PLUG, PHANTOM, AND PROCESS LOADS

PL1 *Plug and Phantom Loads* (Climate Zones: all)

Plug loads are devices or appliances that plug into a 120/208 volt receptacle. Some plug loads in a medical facility may include computers, DVD players, VCRs, printers, scanners, copiers, fax machines, radios, microwaves, coffee pots, desktop lights, stoves, refrigerators, vending machines, smart boards, vocational equipment and tools, soda machines, drinking fountains, and many other devices.

Phantom loads, also known as *standby power* or *leaking electricity*, are when a device consumes energy even when the switch indicates the device is off. Equipment with electronic clocks or timers or remote controls, portable equipment, and office equipment with wall cubes (small boxes that plug into an AC outlet to charge cell phones or provide power to computers) all have phantom loads. Phantom loads can consume up to 5% of an electrical plug load.

To reduce plug and phantom loads, consider controlling the top outlet of each duplex outlet in selected locations with the occupancy sensor used to control the lighting in the room. The best direct way to control these loads is to unplug them when not in use. In lieu of directly unplugging the item, all these items can be plugged into a power strip that is switched off at the end of each day, over the weekend, and during holidays and vacations. Create a personal appliance policy and conduct constant energy awareness training on equipment and appliance use.

PL2 *Process Loads—Medical Equipment* (Climate Zones: all)

Healthcare facilities can include various kinds of equipment contributing to different processes within the building. Some of this equipment may be for dietary purposes, office use, data centers. Other equipment performs medical functions, either directly (as in an imaging machine) or indirectly (as in a sterilizer). In healthcare facilities, there is an overlap between process loads and plug loads (infusion pumps, otoscopes, blood pressure cuffs, monitoring equipment, computers used for electronic health records that also plug into 120 V receptacles). Where appropriate, use energy control methods described in PL1 for these loads. In addition, consider the following measures:

- Do not use once-through water cooling for equipment; a large percentage of overall energy use goes toward processes related to potable water.
- Do not use film systems for imaging equipment.
- For all medical and other kinds of equipment that are not associated with HVAC systems, and for which no ENERGY STAR label is available, use only equipment that is among the 25th percentile of lowest energy consumers for that class of equipment. Compare equipment performance using continuous (or standby) mode electrical energy consumption and heat rejection.

PL3 *High-Performance Kitchen Equipment* (Climate Zones: all)

While most outpatient healthcare facilities do not have a full-service commercial kitchen, the small hospitals included in the scope of this Guide will have various components of a full commercial kitchen. The general strategy for minimizing energy use in commercial kitchens includes the following steps.

Minimize Exhaust and Ventilation Energy Use. Design exhaust ventilation system with proper layout of cooking equipment and the proper hood design to minimize total airflow while still providing sufficient exhaust flow. After minimizing ventilation needs, consider variable-speed exhaust hood flow systems. The specification of the exhaust hood within the design of a commercial kitchen typically falls under the scope of the food service consultant whereas the design and specification of the ductwork, exhaust fan, and makeup air side of the system falls under the mandate of the mechanical engineer. This requires sufficient collaboration and communication between the food service consultant and mechanical engineer. Additional opportunities can include makeup air energy recovery.

A number of resources are available from the Food Service Technology Center (FSTC) with links and guidance on efficient design for commercial kitchens. The FSTC is the industry leader in commercial kitchen energy efficiency and appliance performance testing. Operated by Fisher-Nickel, Inc., the FSTC has developed over 30 standard test methods for evaluating commercial kitchen appliance performance. The following design guides provide additional guidance for energy efficiency, specifically for the kitchen ventilation system.

- *Design Guide 1: Improving Commercial Kitchen Ventilation System Performance—Selecting and Sizing Exhaust Hoods. Design Guide 1* covers the fundamentals of kitchen exhaust and provides design guidance and examples. This guide was made possible by the efforts and support of Southern California Edison. www.fishnick.com/equipment/ckv/designguides/
- *Design Guide 2: Improving Commercial Kitchen Ventilation System Performance - Optimizing Makeup Air. Design Guide 2* augments *Design Guide 1*, with an emphasis on the makeup air side of the equation. This guide was previously published by the California Energy Commission under the title *Improving Commercial Kitchen Ventilation Performance.* The guide is based on a PIER research project conducted by the CKV Lab in Chicago. www.fishnick.com/equipment/ckv/designguides/

Select Energy-Efficient Kitchen Equipment: Select energy-efficient equipment, including dishwashers, freezers (solid door), fryers, hot food holding cabinets, ice machines, refrigerators (solid and glass door), and steamers. In addition, select low-flow hot water fixtures to minimize both water use and hot water energy use. The Commercial Kitchens Initiative (CKI) provides a good list of efficiency strategies and ENERGY STAR-rated commercial kitchen equipment. These documents are available on the CKI Web site www.cee1.org/com/com-kit/com-kit-equip.php3 and on the ENERGY STAR

Web site http://www.energystar.gov/index.cfm?c=commercial_food_service.commercial_food_service). The goal of the CKI is to provide clear and credible definitions in the marketplace as to what constitutes highly efficient energy and water performance in cooking, refrigeration, and sanitation equipment and then to help streamline the selection of products through a targeted market strategy.

PL4 *High-Performance Laundry Equipment* (Climate Zones: all)

The size of textile care operations can vary greatly between the types and sizes of healthcare facilities they are designed to support. Typically, outpatient facilities do not have an on-premise laundry with the exception of some physical therapy centers. Hospitals have significant laundering needs that usually run about 2% of their total operating budget. In some cases they have an on-premise laundry, but otherwise they contract with outside or off-site resources for their textile care needs. There are examples where competitive hospital organizations have come together to help fund a centralized laundry facility because it was the most economical solution for all of them. Large laundries can take advantage of economies of scale and realize greater efficiencies throughout their operations. Tunnel washers, ironers with feeders and folders, washers with high-speed extract, ozone laundry systems, water reuse systems, and improved linen management systems can all significantly lower water, energy, labor, and linen replacement costs. New technology, better management, and larger state-of-the-art equipment can use far less water and energy to clean linen, as compared to older, traditional laundering methods. Conventional commercial washers consume approximately 1.2 gal of hot water per pound of laundry processed. New water-conserving commercial washers consume approximately 0.9 gal of hot water per pound of laundry. These improvements in washer efficiency will add up to sizable water and energy savings over time.

Ozone laundry washing systems can dramatically reduce the amount of water and energy used for textile care each day. Ozone and its derivatives are powerful oxidizers that replace many of the chemicals normally used in traditional laundering methods. Water must be cold for ozone to dissolve into it, and the colder the water is, the more efficiently it works. Ozone will absolutely not dissolve into water that is above 95°F. These rules are what provide the exceptional energy savings that can be delivered by an effective ozone laundry system. All light- to medium-soiled linen and most medium- to heavily-soiled linen can be very effectively cleaned and sanitized with cold water and a proper, uniform dose of dissolved ozone. In a traditional laundry, 70% of the water used is heated by as much as 100° or more. This can be reduced to 10% or less with a good ozone laundry system.

Another important characteristic of commercial washers is the amount of water removed or extracted during the spin cycle. Extraction efficiency is a function of the gravitational force (g-force) generated in the washer drum. Standard washers generate a g-force of only about 85 g. High-performance washers generate g-forces over 350 g. Water retained after extraction in a traditional slow-speed (85 g) machine is roughly 87.5% of the dry weight of the laundry. Washers with high-speed extract can reduce water remaining in the linen to around 50% of the dry weight of the linen. The use of ozone and the elimination of many of the traditional chemicals in the wash can enhance extraction efficiency and reduce water weight retention even further. All linen must be dry when it leaves the laundry. Therefore, all of the water remaining in the linen after extraction must be evaporated using heat in the dryers or ironers. It takes approximately 2000 Btu to evaporate one pound of water. Therefore, the more water removed from the linen before it goes into the ironer or dryer, the more energy saved drying the linen. Shorter dryer cycles equate to substantial energy savings. On average, high-performance washers use about 25% more electricity than standard slow-speed extract washers but more than make up for this increased electricity use by offsetting hot water and drying energy use.

In general, because dryers are direct-fired appliances, sending both heated air and products of combustion through the bin containing the clothes to be dried, there are very few efficiency differences among them. Adding insulation to a dryer will help retain heat and lower energy consumption, and microprocessor-controlled timers and moisture

Table 5-13. Recommendations for Efficient Plug Load Equipment

Equipment/Appliance Type	Purchase Recommendation	Operating Recommendation
Desktop computer	ENERGY STAR only	Implement sleep mode software
TV/VCR	LCD (not plasma); ENERGY STAR only; purchase with flat screens and sleep modes	
Laptop computer—use where practical instead of desktops to minimize energy use	ENERGY STAR only	Implement sleep mode software
Computer monitors	LCD (not plasma); ENERGY STAR only; purchase with flatscreen monitors only	
Printer	ENERGY STAR only	Implement sleep mode software
Copy machine	ENERGY STAR only	Implement sleep mode software
Fax machine	ENERGY STAR only	Implement sleep mode software
Vending machines	ENERGY STAR only	De-lamp display lighting

Free sleep mode software is available on the ENERGY STAR Web site www.energystar.gov/index.cfm?c=power_mgt.pr_power_mgt_ez_wiz

sensors can prevent overdrying and save a substantial amount of energy over time. The key to reducing dryer energy consumption the most is to reduce the retained moisture content of the linen before it is put through the dryer cycle.

PL5 *ENERGY STAR Equipment* (Climate Zones: all)

For all equipment being purchased for the building for which ENERGY STAR-qualified equipment is available, the project should include only ENERGY STAR qualified equipment. See Appendix D for a list of items with ENERGY STAR ratings.

The recommendations presented in Table 5-13 for the purchase and operation of plug load equipment are an integral part of this Guide, but the energy savings from these recommendations will be in addition to the targeted 30% savings.

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RENEWABLE ENERGY

RE1 *Photovoltaic (PV) Systems* (Climate Zones: all)

Photovoltaic (PV) systems have become an increasingly popular option for on-site electric energy production. Most PV systems are relatively small compared to the total energy use of the building due to the ratio of roof area to total building area and the high energy consumption of healthcare facilities. These systems require very little maintenance and generally have long lifetimes.

Options for installing PV systems include rooftop (including collectors integrated with the roofing membrane), ground-mounted, or as the top of a covered parking system.

**TECHNOLOGY CASE STUDY
PIONEERS MEMORIAL HOSPITAL
PV SYSTEM**

PV solar power generation technology can be problematic for healthcare institutions due to cost and space considerations as well as the need for a significant amount of sunlight. Seeking help, Pioneers Memorial Hospital, a 107-bed, publicly owned acute care facility in Brawley, CA, submitted a grant proposal to the local utility to help fund some of the cost of the PV project at their facility. In 2007, the proposed installation became a community demonstration project approved by the local utility.

The resulting system went on-line in August 2008 and is able to provide 5% of the facility's energy needs. While the original plan was to install the 630 solar panels on the facility's rooftop, that plan was changed in order for the project to receive federal tax incentives, which required that the solar panels be removable. The panels were ultimately installed on property owned by the hospital immediately behind the facility (see Figure 5-34). The solar power installation will pay for itself in about 10 years at current energy prices.

Photograph copyright Pioneers Memorial Healthcare District.

Figure 5-34. PV solar generation panels.

The systems may be fixed mounted or tracking. Each installation method offers different combinations of advantages and disadvantages.

RE2 *Solar Hot Water Systems* (Climate Zones: all)

Simple solar systems are most efficient when they generate heat at low temperatures. Service water preheating offers an excellent opportunity in healthcare facilities. Because of the relatively high SWH demands in many healthcare facilities, solar hot water systems often provide economically justifiable energy savings.

General suggestions for solar domestic hot water heating systems include the following:

- It is typically not economical to design solar systems to satisfy the full annual service water heating load.
- Systems are typically most economical if they furnish 50–80% of the annual load.
- Properly sized systems will meet the full load on the *best* solar day of the year.
- Approximately 1–2 gal of storage should be provided per square foot of collector.

- 1 ft^2 of collector heats about 1 gal per day of service water at 44° latitude.
- Glazed flat plate systems often cost in the range of $100 to $150 per square foot of collector.
- Collectors do not have to face due south. They receive 94% of the maximum annual solar energy if they are 45° east or west of due south.
- The optimal collector tilt for service water applications is approximately equal to the latitude where the building is located; however, variations of ±20° only reduce the total energy collected about 5%. This is one reason that many collector installations are flat to a pitched roof instead of being supported on stands.
- The optimal collector tilt for building heating (not domestic water heating) systems is approximately the latitude of the building plus 15°.

Collectors can still function on cloudy days to varying degrees depending on the design, but they perform better in direct sunlight; collectors should not be placed in areas that are frequently shaded.

Solar systems in most climates require freeze protection. The two common types of freeze protection are systems that contain antifreeze and drainback systems.

Drainback solar hot water systems are often selected in small applications where the piping can be sloped back toward a collection tank. By draining the collection loop, freeze protection is accomplished when the pump shuts down, either intentionally or unintentionally. This avoids the heat transfer penalties of antifreeze solutions.

Closed-loop, freeze-resistant solar systems should be used when piping layouts make drainback systems impractical.

In both systems, a pump circulates water or antifreeze solution through the collection loop when there is adequate solar radiation and a need for service water heat.

Solar collectors for service water applications are usually flat plate or evacuated tube type. Flat plate units are typically less expensive. Evacuated tube designs can produce higher temperatures because they have less standby loss but also can pack with snow and if fluid flow stops are more likely to reach temperatures that can degrade antifreeze solutions.

Annual savings can be estimated using performance data from the Solar Rating and Certification Corporation Web site (www.solarrating.org/ratings/rating.htm). A free downloadable program called RETScreen from Natural Resources Canada (www.retscreen.net) can assist with economic feasibility analysis, and many utility rebate programs use it in calculating rebates or determining eligibility. The first cost of the system must be estimated.

RE3 *Wind Turbine Power* (Climate Zones: all)

Wind energy is one of the lowest-priced renewable energy technologies available today, costing between 5 to 11 cents per kilowatt-hour, depending upon the wind resource and project financing of the particular project. For small hospital and healthcare applications, small to medium sized wind turbines are typically considered. These turbines range from 4 to 200 kW and are typically mounted on towers from 50 to 100 ft and connected to the utility grid through the building's electrical distribution system.

One of the first steps to developing a wind energy project is to assess the area's wind resources and estimate the available energy. From wind resource maps, you can determine if your area of interest should be further explored. Note that the wind resource at a micro level can vary significantly; therefore, you should get a professional evaluation of your specific area of interest.

The map in Figure 5-35 shows the annual average wind power estimates at 50 m above ground. It combines high- and low-resolution datasets that have been screened to eliminate land-based areas unlikely to be developed due to land use or environmental issues. In many states, the wind resource has been visually enhanced to better show the distribution on ridge crests and other features. Estimates of the wind resource are expressed in wind power classes ranging from Class 1 (lowest) to Class 7 (highest), with each class representing a range of mean wind power density or equivalent mean speed at specified heights above the ground. This map does not show Classes 1 and 2, as Class 2 areas are marginal and Class 1 areas are unsuitable for wind energy development. In general, at 50 m, wind power Class 4 or higher can be useful for generating wind power. More detailed state wind maps are available at www.windpoweringamerica.gov/wind_maps.asp.

Although the wind turbines themselves do not take up a significant amount of space, they need to be installed an adequate distance from the nearest building for several reasons, including turbulence reduction (which affects efficiency), noise control, and safety. It is essential that coordination occurs between the owner, design team, and site planner to establish the optimal wind turbine location relative to the other facilities on the site.

The three largest complaints about wind turbines noise, the killing of birds, and aesthetic appearance. Most of these problems have been resolved or greatly reduced through technological development or by properly siting wind turbines. Most small wind turbines today have an excellent safety record. An important factor is to consider how the wind turbine controls itself and shuts itself down. Can operators shut it off and stop the turbine when they want or need to do so? This is extremely important, and unfortunately there are very few small turbines that have reliable means to stop the rotor on command. The few that do may require you to do so from the base of the tower—not exactly where you want to be if the turbine is out of control in a wind storm. Look for a system that offers one or more means to shut down and preferably stop the rotor remotely.

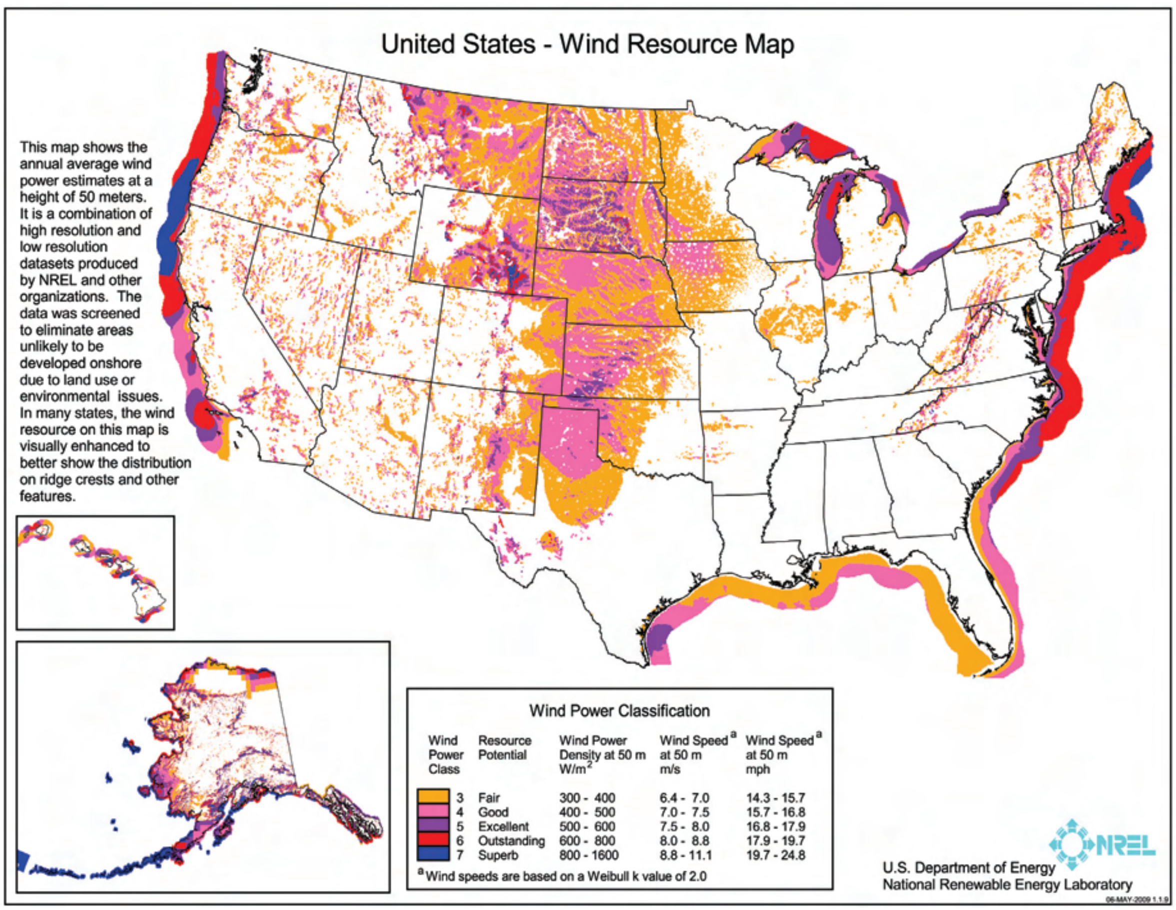

Figure 5-35. (RE3) Average annual wind power estimates.

Using energy modeling, the electric energy consumption of the building can be modeled. Using this data in conjunction with the financial detail of the project including the rebates, the owner and designer must then chose the correct size turbine that meets their needs. Note that the closer the match of the turbine energy output to the demand, the more cost-effective the system will be. Make sure that all costs are listed to give a total cost of ownership for the wind turbine. This includes the wind turbine, tower, electrical interconnection, controls, installation, maintenance, concrete footings, guy wires, and cabling.

In addition to evaluating the initial cost of the turbine, it is extremely important to consider the federal and state policies and incentive programs that are available. The database for state incentives for renewables and efficiency (www.dsireusa.org/) provides a list of available incentives, grants, and rebates. Also critical to the financial success to a wind turbine project is a favorable net metering agreement with the utility.

RE4 ***Power Purchase Agreements*** **(Climate Zones: all)**

A primary barrier to the use of various on-site renewable energy strategies is the high initial capital investment cost. One way to finance and thus implement such a strategy is the power purchase agreement. This kind of arrangement involves a third-party who will design, install, own, operate, and maintain the power generation asset. The healthcare facility then contracts to purchase the energy produced by the generation system, usually for a long period of time. This arrangement not only allows the facility to avoid the high first cost but it also keeps the balance sheet clear of obligation and locks in an energy price, thus hedging the cost of energy over time from fluctuations in the prices of other energy sources. These agreements are especially attractive to non-profit organizations who cannot access tax-based incentives that help to offset the cost of renewable systems. These agreements are complicated, with many considerations, and require negotiation by people familiar with the complexities, both from an engineering perspective as well as from a legal and financial perspective.

TECHNOLOGY CASE STUDY
PIONEERS MEMORIAL HOSPITAL
POWER PURCHASE AGREEMENTS

As part of a solar power generation project undertaken by the facility, Pioneers Memorial Hospital, a 107-bed, publicly owned acute care facility in Brawley, California, set up a power purchase agreement as a way to conserve capital and ensure energy savings. Under the power purchase agreement, a third-party financial institution owns the PV solar power system installed on the hospital's property in 2008 and was able to receive federal tax incentives that Pioneers could not take advantage of since it is a non-profit institution. Under a long-term power purchase agreement, Pioneers will pay a fixed rate to the financial institution for the next 20 years, creating predictable costs for the 100 kW of renewable energy it is purchasing each day (which is about 5% of the hospital's electricity needs).

Johnson Controls, the project manager for the energy efficiency improvements, also identified other money-saving opportunities for the hospital. The projects included lighting upgrades, water-conserving technology, and repairing or replacing outdated air-conditioning equipment. A performance contract allowed the hospital to use the operational and energy savings to offset the cost of the improvements. Expected savings over the performance contract's 10-year term are $238,000 in energy and $174,000 in operational improvements.

Information source: Inside ASHE, November/December 2008, "Solar Energy Powers Positive Environment of Care."

COMBINED HEAT AND POWER

CHP1 *Combined Heat and Power Systems* (Climate Zones: all)

Combined heat and power (CHP) systems essentially operate as some portion of the heat generation system for the facility (taking the place of some boiler capacity) with the side benefit of "free" electricity generation. Because of their high efficiency, these systems provide overall source energy savings, even though they do not reduce facility energy consumption. The heat from these systems can be used to preheat water and offset dedicated boiler capacity for reheat systems, domestic hot water systems, or steam systems, as well as for certain kinds of absorption chillers. These systems require an initial capital investment but may provide significant life-cycle cost advantages, depending upon relative cost differences between available fuel costs and electrical costs.

Several technologies are available for facilities of the size considered by this Guide. Microturbines are available in sizes up to 250 kW. These systems require extensive overhaul annually and major retrofit after about 10 years. Conventional engine-driven units are more familiar to most engineering staff and may be more easy to service. Newer options include fuel cells, which eliminate all emission problems associated with other CHP strategies, thus facilitating compliance with air quality requirements.

ADDITIONAL HVAC SYSTEMS

HV28 *Condenser-Water Heat Recovery* (Climate Zones: all)

The principle behind condenser-water heat recovery is that HVAC systems should use heat rejected from cooling equipment before using new heating energy. Healthcare projects are an excellent application for condenser-water heat recovery. This is because most HVAC systems use cooling to reduce humidity and most healthcare facilities require both large amounts of domestic hot water (service water heating) and high minimum air change rates. This combination requires significant reheat in nearly all conditions. The highest efficiency is realized by preheating domestic water. This is because of the low temperature of the inlet water and resulting low head pressure of the condenser. On the other hand, the annual demand for HVAC reheat is much larger than the domestic water heating needs in most healthcare facilities with conventional reheat systems.

Several issues must be considered when designing condenser heat recovery systems:

- The heating and cooling loads must exist simultaneously and both must be large enough to make the system economical. In cold climates there may be times in winter when there is no need for cooling, although energy recovery systems can overcome this limitation in all but the coldest climates.
- There must be a use for relatively low temperature heat (usually below 150°F, and preferably lower). This requirement is easily met by preheating domestic water. To increase the energy savings greatly, heating coils can be selected to operate with inlet water temperatures of between 100°F and 140°F. At these temperatures, depending on utility rates, chillers may produce heat at lower cost than even condensing boilers, even when the cooling must be rejected outdoors. In these cases, the cooling can be thought of as a "free" by-product. Under different utility rates, these systems are only economical to operate when there is a simultaneous need for cooling.

Despite these limitations, condenser heat recovery systems often have simple payback periods of two to four years, depending on the fuel-to-electric cost ratio. When combined with air-side energy recovery, the payback periods can be immediate (no increase in first cost).

Service water preheating systems are more economical for chillers with low-pressure refrigerants than for chillers with high-pressure refrigerants because they do not require heat exchangers (depending on the applicable plumbing code) to protect the potable water from potential contamination; these systems are common for both high- and low-pressure refrigerant chillers.

If a system is chosen that can produce hotter water for reheat coils, then there is an opportunity to use the same chillers to heat service water to the final distribution temperature instead of only to 85°F or a similar preheat temperature.

One caveat with condenser heat recovery systems is that the designers must make accurate estimates of the *simultaneous* needs for heating and cooling. Otherwise, the owner may not realize the desired return on investment because the heat recovery chillers don't run a sufficient number of hours per year. Often systems will incorporate either solar service water preheat or condenser water heat recovery, although for some applications it may be economical to use solar for service water preheating and condenser heat recovery only for reheat loads.

Figure 5-36 depicts the principle of condenser heat recovery. The left-hand schematic depicts a traditional all-air system with the chiller and cooling tower operating to satisfy the cooling and dehumidification needs and the boiler operating to satisfy the reheat needs. The right-hand schematic depicts the same system with a heat recovery chiller. Under most operating conditions, the heating and cooling loads are not equal, so either the boiler or the cooling tower will run at reduced load to bring the system into heat balance. The main saving is the boiler energy. The same concepts apply to service water heating.

Any process that has trouble complying with the simultaneous heating and cooling limitations of ASHRAE/IESNA Standard 90.1 is a good candidate for condenser heat recovery. The largest waste of energy in healthcare facilities that condenser heat recovery systems can help reduce is operating chillers while also using reheat coils to prevent overcooling. This occurs in virtually all zones that have minimum air change rate requirements. In zones without minimum air change rate requirements, compliance with ASHRAE Standard 62.1 or the applicable ventilation code may also cause this to occur. A typical condenser heat recovery design for chilled-water systems involves a mixture of high-efficiency chillers that operate with cooling towers during periods of peak cooling loads and heat-recovery chillers that are less efficient but can generate hot water at a temperature that is warm enough for the desired use. Usually this is in the range of 100°F to 140°F for reheat systems. Some chillers can produce higher temperatures, but this must be weighed against the decrease in compressor efficiency.

Dedicated outdoor air systems largely avoid this waste of reheat energy (see HV4). However, dedicated outdoor air systems normally do not avoid this entirely at the central dedicated outdoor air unit. Where DOASs are used, and the discharge air must be reheated to prevent overcooling, the use of energy recovery devices or condenser heat recovery is recommended.

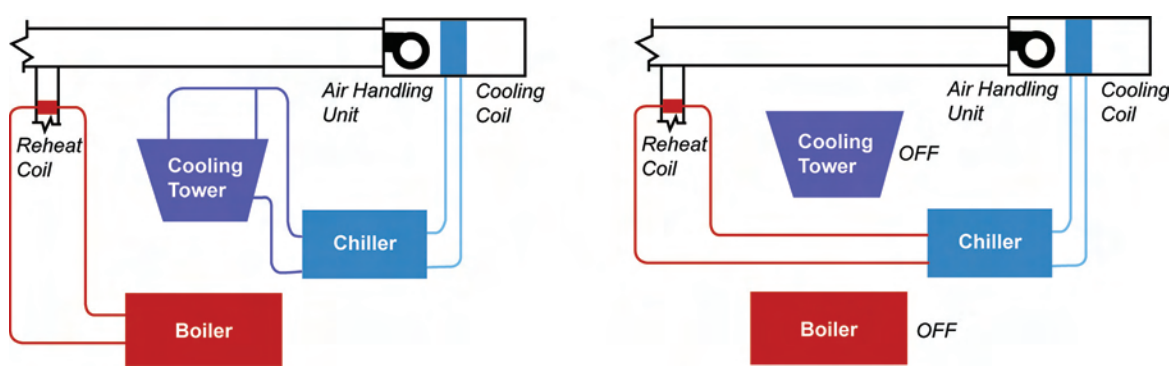

Figure 5-36. (HV28) Principle of condenser heat recovery.

HV29 *Ground-Source Heat Pumps* (Climate Zones: all)

A variation of the WSHP system (see HV2), the ground-source heat pump (GSHP) takes advantage of the earth's relatively constant temperature and uses the ground instead of a cooling tower and boiler. GSHP systems store heat in the ground for use later. During the summer, heat pumps extract heat from the building and transfer it to the ground. When the building requires heating, the heat pumps transfer this stored heat from the ground into the building. In a perfectly balanced system, the amount of heat stored over a given period would equal the amount of heat retrieved.

GSHP systems are one of the most energy-efficient options available, for several reasons:

- They are normally coupled with DOASs that incorporate air-to-air energy recovery.
- Since heating or cooling is applied at each zone instead of centrally, the need for reheat is eliminated. This is the largest factor that improves the efficiency of these systems (see Figure 5-29 for additional information on reheat energy usage).
- In cool climates, the heat pumps are often turned off because the cooling from the ventilation air and building envelope approximately match the internal loads.
- The use of ground-source systems reduces the cooling condenser temperature and increases the heating evaporator temperature. This makes GSHPs more efficient than air-source units, especially during the winter.
- Boiler and cooling tower energy use are eliminated.

Note that fan-coil systems coupled with DOASs also have the first three features listed above but have the disadvantage that unless more expensive four-pipe systems with water economizers are added they can have control problems when cooling is needed in cold weather (for example, a south-facing zone with significant glazing).

Eliminating the cooling tower has architectural, acoustic, and maintenance advantages, and eliminating the boiler and fluid cooler frees up floor space in the building.

Although eliminating both the cooling tower and boiler will likely result in the greatest overall energy savings, for most applications this requires the largest (and most expensive) geothermal heat exchanger to account for the imbalance between heat stored and heat extracted. For example, in a cooling-dominated building, a large amount of heat must be rejected to the ground during the cooling season but a much smaller amount of heat is extracted from the ground during the heating season. This imbalance can cause the temperature of the ground surrounding the geothermal heat exchanger to increase over time.

In many areas of the country, this imbalance requires the geothermal heat exchanger to be larger to minimize the ground temperature changes over time. The first cost to install such a large heat exchanger often dissuades people from considering this approach. Using a hybrid approach, however, can often make GSHP systems more economical, opening up the possibility to reap energy savings.

The hybrid approach involves adding a small cooling tower to the loop for a system that is installed in a cooling-dominated climate or potentially adding a small boiler to a system in a heating-dominated climate. In either case, the geothermal heat exchanger is sized based on the smaller of the two loads: for the total heat absorbed in a cooling-dominated climate or the total heat rejected in a heating-dominated climate. Then, a small cooling tower (or boiler) is added to reject (or add) the remaining heat.

This approach reduces the required size of the geothermal heat exchanger by avoiding the imbalance. The overall energy savings may not be as great as in a system with a larger heat exchanger, but this approach often results in a more acceptable return on investment.

HV30 *Displacement Ventilation* (Climate Zones: all)

Displacement ventilation (DV) systems are different from conventional overhead air delivery systems. DV systems deliver air near the floor, at a low velocity and at a temperature of about 65°F (compared to around 55°F with overhead air delivery). The goal of DV systems is to cool the occupants, not the space. Cool air flows at low velocity (typically < 50 fpm) along the floor until it encounters heat sources, such as equipment and people. As the air is warmed, it rises around occupants, bathing them in cool air.

Air quality improves because contaminants from occupants and other sources tend to rise out of the breathing zone rather than being mixed in the space. Similarly, cooling loads decrease because much of the heat generated by occupants, lights, and computer equipment rises directly out of the occupied zone and is exhausted from the space. (This is especially true in spaces designed for 100% outdoor air.)

DV is most appropriate for spaces with ceilings higher than 10 ft to permit temperature stratification. However, heating performance may be worse than with systems that deliver air at greater velocities, since mixing (not stratification) is desirable for heating. In non-arid climates, the supply air must be sufficiently dehumidified before it is mixed with warm return air to achieve the desired 65°F SAT.

HV31 ***Demand-Controlled Ventilation (DCV)*** **(Climate Zones: all)**

Demand-controlled ventilation (DCV) can reduce the energy required to condition OA for ventilation. To maintain acceptable indoor air quality, the setpoints (limits) and control sequence must comply with ASHRAE Standard 62.1. Refer to the *62.1 User's Manual* for specific guidance.

For some HVAC system types, the recommendation tables in Chapter 3 recommend either exhaust air energy recovery or DCV. If the DCV option is selected, the controls should vary the amount of outdoor air in response to the need in a zone. The amount of outdoor air could be controlled by (1) a time-of-day schedule in the BAS, (2) an occupancy sensor (such as a motion detector) that indicates when a zone is occupied or unoccupied, or (3) a CO_2 sensor, as a proxy for ventilation airflow per person that measures the change in CO_2 level in a zone relative to the CO_2 level in the outdoor air A controller will then operate the outdoor air, return air, and relief air dampers to maintain the ventilation required for the sensed occupancy level.

CO_2 sensors should be used in zones that are densely occupied, with highly variable occupancy patterns, such as lobbies, waiting rooms, and cafeterias, during the occupied period. For the other zones, occupancy sensors should be used to reduce ventilation when a zone is temporarily unoccupied. For all zones, time-of-day schedules in the BAS should be used to introduce ventilation air only when a zone is expected to be occupied.

Multiple-zone, recirculating systems (such as VAV systems) require special attention to ensure adequate outdoor air is supplied to all zones under varying loads. Employing DCV in a DOAS requires an automatic damper and sensor for each DCV zone.

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

Finally, when DCV is used, the system controls should prevent building or space pressures that are in contradiction to the *Guidelines*. If the amount of air exhausted remains constant while the intake airflow decreases, the building or space may change from positive to negative pressure relative to outdoors or to adjacent spaces. When air is exhausted directly from the zone (kitchens, locker rooms, isolation rooms, or even a space with a restroom connected to it), the DCV control strategy must avoid reducing intake airflow below the amount required to replace the air being exhausted. The pressure relationship requirements defined in the *Guidelines* should also be consulted since the outdoor air adjustment caused by the DCV can impact this relationship.

When considering the use of DCV, the pressurization and pressure relationship requirements of the *Guidelines* must be considered. The automatic adjustment of ventilation air can cause significant disruption to these pressure requirements. In addition, the minimum required ventilation air rates must be observed.

HV32 *Thermal Storage* (Climate Zones: all)

Adding thermal storage to an HVAC system can reduce the utility costs associated with cooling by shifting operation of the chiller from times of high-cost electricity (daytime) to times of low-cost electricity (nighttime). This avoids, or reduces, the electricity required to operate the chiller during the daytime hours. Operation of the chiller is shifted to the off-peak period, during which the cost of electricity and the demand charge are lower. The chiller is used during that period to cool or freeze water inside storage tanks, storing the thermal energy until the on-peak period.

During the nighttime hours, the outdoor dry-bulb and wet-bulb temperatures are typically several degrees lower than during the day. This lowers the condensing pressure, allowing the chiller to regain some of the capacity and efficiency it lost by producing colder fluid temperatures to recharge the storage tanks.

Another potential benefit of thermal storage is a reduction in the size and capacity of the chiller. When thermal storage is used to satisfy all or part of the design cooling load, the chiller may be able to be downsized as long as it has enough time to recharge the storage tanks. This is more likely in an outpatient clinic or medical office building, which is unoccupied at night, than in a hospital that operates 24/7.

HV33 *Desiccant-Based Dehumidification* (Climate Zones: all)

Indoor temperature and humidity ranges for healthcare facilities are usually prescribed by local codes or by industry-accepted guidelines. But, particularly in surgery rooms, surgeons often demand lower temperatures than are stated in the guidelines. The need to control humidity at lower room temperatures can challenge conventional dehumidification approaches.

Desiccant-based dehumidification relies on adsorption (or absorption) to remove water vapor from an airstream. These systems can deliver air at very low dew points without needing to overcool the air. In some applications, desiccant-based dehumidification systems (Figure 5-37) can save energy compared to the conventional cool + reheat dehumidification approach (Murphy 2006a).

HV34 *Evaporative Condensing* (Climate Zones: all)

Some air-conditioning equipment (most commonly packaged DX equipment) can be equipped with evaporative condensers. Hot refrigerant vapor flows through tubes and outdoor air is drawn or blown over the tubes by a fan. Water is sprayed on the outer surfaces of the tubes and, as air passes over the tubes, a small portion of the

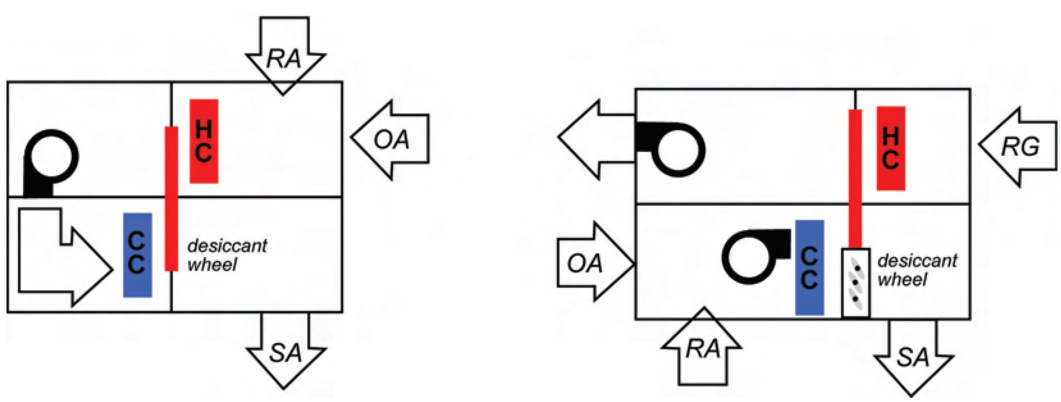

Figure 5-37. (HV33) Examples of desiccant-based dehumidification systems.

water evaporates. This evaporation process absorbs heat, causing the refrigerant vapor inside the tubes to condense into a liquid. The remaining water then falls into a sump, where a pump recirculates it to be used again. The water that evaporates in this process must continuously be replaced with fresh water.

In a conventional air-cooled condenser, the refrigerant condensing temperature is dependent on the dry-bulb temperature of the ambient air. In an evaporative condenser, the condensing temperature is dependent on the wet-bulb temperature. This lowers the condensing temperature (pressure), which reduces the energy used by the compressor.

Evaporative condensers require more maintenance than air-cooled condensers and are typically more expensive and heavier. In addition, in sub-freezing climates, they require freeze protection.

ELECTRICAL DISTRIBUTION SYSTEMS

ED1 ***Transformer Efficiency*** **(Climate Zones: all)**

The use of energy-efficient transformers can provide additional energy savings. The Energy Policy Act of 2005 (U.S. Congress 2005) established minimum energy efficiency standards for low-voltage, dry-type distribution transformers and specifies that any such transformer manufactured after January 1, 2007, "shall be the Class I Efficiency Levels for distribution transformers specified in Table 4-2 of the 'Guide for Determining Energy Efficiency for Distribution Transformers' published by the National Electrical manufacturers Association (NEMA TP-1-2002). These specifications are referred to by DOE as *TP-1* and are the lowest efficiency available today."

Energy-efficient transformers that are roughly 30% more efficient than the minimum TP-1 were classified by DOE as Candidate Standard Level 3 (CSL-3) in the July 29, *2004 Advanced Notice of Proposed Rulemaking* for energy conservation standards for distribution transformers. It is recommended that all low-voltage, dry-type distribution transformers (single phase or three phase) used in small hospital and healthcare facility construction meet the CSL-3 efficiency specifications.

The use of the CSL-3 efficiency classification will improve the energy efficiency of distribution transformers. This efficiency classification recognizes the low loading and no-load losses with current transformer design. The classification includes specifics on the no-load losses for specific sized transformers and specific percent efficiencies at given loadings. For example, a CSL-3 75 KVA 277/480 to 120/208 volt transformer maximum no load loss is 170 W/h versus the pre-2007 industry average of more than 850 W/h. This same transformer will meet or exceed 98.4% efficiency at one-sixth loading. The efficiency of the pre-2007 standard transformers specified at one-sixth loading is 80% to 85%.

Energy-efficient transformers should be specified using DOE's CSL-3 classification efficiencies as the basis. Specifications must include maximum no-load losses for specified transformer sizes and percent efficiencies at 16.7% loading. A statement should be included in the specifications that requires the bid submission to include test data for the transformers being provided.

ED2 ***System Design*** **(Climate Zones: all)**

Electrical distribution design can affect energy consumption, at least at the margins. Distribution systems can impact voltage drop across both transformers and conductors, all such loss representing needless energy consumption. In general, a system consisting of shorter, larger conductors will result in lower overall energy loss. On the other hand, sizing transformers larger than the load will result in underloading and energy loss. Similarly, higher-voltage systems for a given load will result in lower overall losses. The right balance between higher voltage distribution and transformer location, coupled with larger, shorter feeders and more closely tailored transformer sizing, will minimize useless system energy losses.

ED3 *Metering* (Climate Zones: all)

Distribution systems can also facilitate or complicate the metering and sub-metering of energy within the building, thus making the building easier or more difficult to tune to optimal performance. Experience has shown that simply paying attention to energy consumption can change behaviors and help the building staff to improve and optimize the operation of the building, including achieving lowest energy consumption. And, the cost of metering systems coupled with advances in energy control systems make it easier and less expensive to provide more extensive metering systems. Project teams, using integrated design, should involve the building operating staff to help plan the distribution system so as to allow appropriate metering facilities to allow optimal performance. Design the electrical distribution system to make sub-metering easier, rather than more difficult.

Provide sub-metering for the following electrical and mechanical systems (as applicable to the scope of the project): lighting systems, plant loads, air distribution systems, voice/data systems, emergency power systems, and large process loads (i.e., dietary area, imaging area, etc.).

Reference

U.S. Congress. 2005. *Energy PolicyAct of 2005*, Bill H.R.6, Public Law:109-58.

Appendix A
Envelope Thermal Performance Factors

Each climate zone recommendation table in Chapter 3 presents a prescriptive construction option for each opaque envelope measure. Table A-1 presents U-factors for above-grade components, C-factors for below-grade walls, and F-factors for slab-on-grade floors that correspond to each prescriptive construction option. Alternative constructions would be an equivalent method for meeting the recommendations of this Guide provided they are less than or equal to the thermal performance factors listed in Table A-1.

Table A-1. International Climate Zone Definitions

Opaque Construction Options					
Roof Assemblies		**Walls**		**Floors**	
Insulation Entirely Above deck		**Above Grade Mass Walls**		**Mass**	
R	**U**	**R**	**C**	**R**	**U**
20	0.048	5.7	0.151	4.2 c.i.	0.137
25	0.039	7.6	0.123	10.4 c.i.	0.074
30	0.032	11.4	0.090	12.5 c.i.	0.064
35	0.028	13.3	0.080	14.6 c.i.	0.056
		15.2	0.063	16.7 c.i.	0.050
		25.0	0.049	19.5 c.i.	0.044
		Steel-Framed		20.9 c.i.	0.042
		R	**U**	23.0 c.i.	0.038
		13	0.124	**Steel Joist**	
		13 + 7.5 c.i.	0.064	**R**	**U**
		13 + 15.6 c.i.	0.042	19	0.052
		13 + 18.8 c.i.	0.037	30	0.038
		13 + 21.6 c.i.	0.034	38	0.032
		Below Grade Mass Walls		49	0.027
		R	**C**	60	0.024
		7.5	0.133	**Slabs**	
		12.5	0.080	**Unheated**	
		15.0	0.067	**R-in.**	**R-in.**
		17.0	0.057	10–24	0.54
				15–24	0.52
				20–24	0.51

Appendix B International Climatic Zone Information

The following tables show the climate zone definitions that are applicable to any location and the climate zone numbers for a variety of Canadian and Mexican cities. These tables are based on information in ASHRAE/IESNA Standard 90.1-2007, Normative Appendix B—Building Envelope Climate Criteria, Tables B-2, B-3, and B-4. Weather data is needed in order to use the climate zone definitions for a particular city. Weather data by city is available for a large number of international cities on the *2009 Handbook—Fundamentals* CD.

Table B-1. International Climate Zone Definitions

Climate Zone Number	Name	Thermal Criteria
1A and 1B	Very Hot–Humid (1A) Dry (1B)	9000 < CDD[a]50°F
2A and 2B	Hot–Humid (2A) Dry (2B)	6300 < CDD50°F ≤ 9000
3A and 3B	Warm–Humid (3A) Dry (3B)	4500 < CDD50°F ≤ 6300
3C	Warm–Marine (3C)	CDD50°F ≤ 4500 AND HDD[b]65°F ≤ 3600
4A and 4B	Mixed–Humid (4A) Dry (4B)	CDD50°F ≤ 4500 AND 3600 < HDD65°F ≤ 5400
4C	Mixed–Marine (4C)	3600 < HDD65°F ≤ 5400
5A, 5B, and 5C	Cool–Humid (5A) Dry (5B) Marine (5C)	5400 < HDD65°F ≤ 7200
6A and 6B	Cold–Humid (6A) Dry (6B)	7200 < HDD65°F ≤ 9000
7	Very Cold	9000 < HDD65°F ≤ 12600
8	Subarctic	12600 < HDD65°F

a. CDD = cooling degree-day
b. HDD = heating degree-day

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

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

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

Not marine and

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

where

P = annual precipitation in in. and

T = annual mean temperature in °F.

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

Table B-2. Mexican Climate Zones

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

Table B-3. Canadian Climate Zones

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

Appendix C
Commissioning Information and Examples

Following are examples of what a commissioning scope of services and a responsibility matrix might include (Table C-1). Project teams should adjust it to meet the needs of the owner and project scope, budget, and expectations.

COMMISSIONING SCOPE OF SERVICES

INTRODUCTION

Commissioning (Cx) is a quality assurance (QA) process with four main elements. First, the architectural and engineering (A&E) team must clearly understand the building owner's goals and requirements for the project. Next the A&E team must design systems that support or respond to those requirements. The construction team must understand how the components of the system must come together to ensure that the system is installed correctly and performs as intended. Last, the operators of the system must also understand how it is intended to function and have access to information that allows them to maintain it as such. This process requires more coordination, collaboration, and documentation between project team members than traditionally has been provided.

The intent is to help provide an understanding of the tasks, deliverables, and costs involved. An independent commissioning authority (CxA), one that is contracted directly with the building owner, will be the building owner's representative to facilitate the Cx process and all of its associated tasks. The Cx authority will lead the team to ensure everyone understands the various tasks, the roles they have, and the desired outcome or benefit for following the Cx process. The systems required to be commissioned are those that impact the use of energy. Project team members responsible for the design or installation of those systems will have the majority of the Cx work. The majority of the field work will be the responsibility of the mechanical, electrical, and control contractors.

Cx of a new building will ultimately enhance the operation of the building. Reduced utility bills, lower maintenance costs, and a more comfortable and healthier indoor environment will result. Cx focuses on creating buildings that are as close to the owners' and users' objectives (Owner's Project Requirements) as possible. Early detection and resolution of potential issues are the keys to achieving a high-quality building without increasing the total effort and cost to the team members. Resolving design issues early will significantly reduce the effort during construction. Finding mistakes after installation or during start-up are costly to everyone. Checklists will assist the contractors during installation, and installation issues will be detected early. Early detection will reduce the amount of rework required compared to late detection at final inspection. This will also benefit the owner and occupants since the building will work as intended from day one of operation.

SYSTEMS

The systems under this scope of services:

- The entire HVAC system (boilers, chillers, pumps, piping, and air distribution systems)
- The building automation system (BAS) for the HVAC system
- The domestic hot water system
- The electrical systems (lighting and receptacle systems, electrical panels, transformers, motor control centers, electrical motors, and other electrical items excluding emergency power)
- The building envelope as it relates to energy efficiency (insulation, wall framing—thermal bridging, air leakage, glazing solar and thermal characteristics, fenestration framing—thermal bridging)

These listed systems will be commissioned by the tasks described in the following.

DELIVERABLES

The following deliverables are part of the Cx scope of services:

- Cx plan
- Owner's Project Requirements (OPR)
- CxA's design review
- Construction installation checklists
- CxA's Site Visit Reports
- System functional performance tests
- Systems manual
- Owner training
- Cx report
- Systems warranty review
- Final Cx Report

SCHEDULE

Commissioning (Cx) begins in the early stage of design and continues through building operation. The following details the specific step-by-step activities that owners, designers, and construction team members need to follow in each phase of the project's delivery.

Planning Phase

- Document OPR (project intent)
- Develop commissioning plan
- Specify architect/engineer Cx requirements
- Assist with the architect/engineer selection process

Design Phase

- Verify that the Design meets the Owner's Project Requirement
- Write Commissioning Specifications

Construction Phase

- Verify that the submittals meet OPR
- Verify that the installation meets OPR
- Verify that the components function as required
- Facilitate training of building operators

Acceptance Phase

- Verify that the systems work as required and meet OPR
- Verify that the OPR are met throughout the building
- Review contractors' operation & maintenance (O&M)/systems manuals
- Develop systems manual

Operational Phase

- Warranty review
- Verify that the operation of the building is optimal

COMMISSIONING TASKS

Commissioning Plan

The CxA will write the Cx plan and detail the Cx tasks and schedule for the executing the Cx plan tasks. In addition, the communication channels will be listed and samples of all forms, procedures, and checklists used for the project will be provided. The Cx responsibilities of each of the project team members will be listed. The Cx plan will be updated as the project progresses and as forms, procedures, checklists, schedules, agendas, reports, etc. are finalized or revised. These updates will be distributed at major milestones to all project team members.

Owner's Project Requirements

The OPR describes the main expectations the owner wants this project to meet. As the owner usually wants to meet most of the expectations of all stakeholders, input from a representative of each stakeholder is beneficiary.

For the referenced project the CxA will facilitate and write the OPR with input from the owner.

Commissioning Specifications

The Cx specifications will clearly state what will be expected from the contractors. This will include activities the contractor needs to participate in and documentation procedures required through the construction period. Sample forms and procedures will be provided to show the contractor visuals of what he will need to complete in the construction and acceptance phases. The Cx specifications will also include the training requirements as well as the documentation needed to develop the systems manual.

The CxA will provide the requirements for Cx in the construction phase to be integrated into the specifications.

Basis of Design

The Basis of Design (BoD) includes all engineering and architectural calculations and assumptions on how to design the systems such that the OPR is met. This document will be written by the architect and engineers and will be reviewed by the CxA for completeness and quality. Comments will be provided if any pertinent information is missing or more details are needed. The BoD will need to be updated if any changes occur throughout the project. This is needed to inform all project team members about revised assumptions and new directions the project is heading.

Design Review

During the design review the CxA will focus on verifying that the OPR will be met. In addition, the design documents will be reviewed for constructability, operability, and maintainability. The review will take place at 70% completion and be back-checked for resolution of issues at 95% and design completion. An effort will be made to resolve all design issues through the remaining design and verify that they have been resolved in the later design submittals and the construction documents.

The design review will focus on the selection, evaluation, and choice of the main systems. Review this process against the OPR to verify that the project will meet the intent of the owner. It will also focus on the constructability, operability, and maintainability of the design. Any choices, conclusions, or design details that deviate from the OPR will be brought to the attention of the owner and the general contractor. Additional information will be requested when documentation is insufficient to support the conclusions and choices or when required design assumptions or calculations have not been provided.

Energy efficiency is achieved by verifying the design and operation of the systems and by making the building owner aware of alternative building systems and equipment options.

Examples of building systems that will be evaluated include the following:

- Building envelope
- Building ventilation
- Lighting
- Office equipment
- HVAC equipment
- Control systems and strategies
- HVAC distribution systems
- Domestic hot water systems
- Water use
- Occupancy schedules
- Utility rate structures

Installation Checklist Database

A checklist database will be established for all components included in the commissioned systems. The checklists will focus on providing the contractor guidance about critical requirements during installation to clearly establish the expectations of the installations.

The CxA will design these checklists to minimize the paperwork for the contractors but at the same time to cover the critical installation issues.

Construction Verification

The CxA will facilitate monthly on-site construction meetings to ensure all design, construction, and building owner representatives understand the process, the desired outcomes, and the roles/responsibilities of the various team members. The CxA will focus on training and on the Cx process during construction while at these site visits. During the construction review, the CxA will focus on verifying that the Cx process is being followed by statistical sampling and that the construction checklists are completed and submitted as required. The CxA will also verify that the record drawings are on site and are being updated with any deviations in installations compared to the construction drawings. In addition, the construction progress will be evaluated against the established OPR. The CxA will verify that the Cx process is proceeding as intended during the construction phase and will review the site visit reports and Cx meeting minutes. The CxA will notify the building owner and general contractor if the Cx process is not progressing as intended by identifying and resolving issues. The day-to-day follow up will be the responsibility of the general contractor and the sub contractors.

Review Submittals

The CxA will review the submittals concurrently with the architect and engineers. Any observed deviations from the OPR will be noted and submitted to the architect and engineers to be evaluated and submitted with their comments back to the contractor. The architect and engineers submittal review process will also be evaluated. A selection of the architect and engineers submittals responses will be reviewed to verify that any deviations from the design documents are properly addressed. The CxA must understand the general contractor's project delivery process and its impact on the submittal review step.

Training

The training agenda format will be submitted by the engineers to the general contractor and owner to schedule the required training sessions. The CxA will review this training agenda and attend a key training session. Each training session will be evaluated after the completion of any training. Any deviations from the expected competence level of the O&M staff will be discussed with the owner and contractors, and the remaining training agendas will be revised to accommodate any lacking knowledge.

Systems Performance

The systems performance tests will be completed as soon as all submittals for the systems manual have been received and all installation checklists are completed. These systems performance tests will focus on the installed systems' capabilities to meet the design intent. The CxA will document the procedures required for these tests and submit these test procedures to general contractor for the project team and general contractor's review. The sub-contractors are responsible for ensuring that all systems can meet the specified requirements and for demonstrating that the systems are able to perform all procedures successfully. The CxA will witness a representative number of systems performance tests to verify that all systems work as intended. If any of the systems performance tests are unsatisfactory, these systems and a representative number of other similar systems will be required to be retested at the contractors' expense.

Review Systems Manual

The general contractor will generate the systems manual based on the sub-contractor submittals for the installed equipment and the test and start-up results. The CxA will review this systems manual and provide any comments to general contractor.

Commissioning Report

The Cx report will summarize the results of Cx activities for the project. This Cx report will essentially be the Cx plan with all the results of the Cx activities. The initial Cx report will be submitted two weeks after substantial completion and the final report one year after substantial completion. This is the responsibility of the CxA.

Operation and Warranty Review

The operation and warranty review will be completed at 10 months after completion. The review will focus on the experiences of the O&M staff with the building operation and evaluate the systems performance and operation relative to the OPR. Any deviations from the original operational intent or component failures will be noted and addressed with the owner's representative. A report will be issued to the owner with suggested actions to take.

Table C-1. Sample Commissioning Scope Matrix—Responsibilities and Schedule

Responsibility						Project Phase				Commissioning Tasks
Architect	Engineer	GC / CM	Sub-Contractor	CxA	Client	Pre-Design	Design	Construction	Construction	
										Designate CxA (Qualifications Apply)
										Provide name, firm, and experience information for the CxA.
										Document the Owner's Project Requirements; include:
										Primary purpose, program, and use of proposed project
										Project history
										Program needs, future expansion, flexibility, quality of materials, and construction and operational cost goals
										Environmental and sustainability goals
										Energy efficiency goals
										Indoor environmental quality requirements
										Equipment and system expectations
										Building occupant and O&M personnel requirements
										Develop and Implement a Commissioning Plan
										Commissioning program overview
										Goals and objectives
										General project information
										Systems to be commissioned
										Commissioning team
										Team members, roles, and responsibilities
										Communication protocol, coordination, meetings, and management
										Description of commissioning process
										Documenting the Owner's Project Requirements (OPR)
										Preparing the Basis of Design (BoD)
										Documenting the commissioning review process
										Developing systems functional test procedures
										Reviewing contractor submittals
										Verifying systems performance
										Reporting deficiencies and resolution processes
										Developing the systems manual
										Verifying the training of operations
										Accepting the building systems at substantial completion
										Reviewing building operation after final acceptance
										Basis of Design (BoD)
										Narrative of systems to be commissioned

Table C-1. Sample Commissioning Scope Matrix—Responsibilities and Schedule

Responsibility						Project Phase				Commissioning Tasks
Architect	Engineer	GC / CM	Sub Contractor	CxA	Client	Pre-design	Design	Construction	Construction	
										Design assumptions
										Applicable standards and codes
										Commissioning Requirements in Construction Documents (Include in Specifications)
										Specify commissioning team involvement
										Specify contractors responsibilities
										Specify submittals and submittal review procedures for Cx process/systems
										Specify operation and maintenance (O&M) documentation requirements
										Specify meetings documentation process and responsibilities
										Specify construction verification procedures and responsibilities
										Specify start-up plan development and implementation
										Specify responsibilities and scope for functional performance testing
										Specify criteria for acceptance and closeout
										Specify rigor and requirements for training
										Specify scope for warranty review site visit
										Conduct Commissioning Design Review in Design Phase
										Review and update OPR. Review for clarity, completeness, and adequacy.
										Review BoD for all issues identified in OPR
										Review design documents for coordination.
										Review design documents for compliance to OPR and BoD.
										If multiple reviews are performed, check compliance to previous review comments
										Review of Contractor Submittals
										Review all product submittals to make sure they meet BOD and OPR
										Review all product submittals to make sure they meet OPR and O&M requirements.
										Evaluate submittals for facilitating performance testing.
										Review all contractor submittals for compliance to design intention and construction documents.
										Verity the Installation and Performance of the Systems to be Commissioned
										Installation inspection (pre-functional checklist)
										System performance testing (functional test)
										Evaluation of results compared to OPR and BoD
										Complete a Summary Commissioning Report
										Executive summary

Table C-1. Sample Commissioning Scope Matrix—Responsibilities and Schedule

Responsibility						Project Phase				Commissioning Tasks
Architect	Engineer	GC / CM	Sub Contractor	CxA	Client	Pre-design	Design	Construction	Construction	
										History of system deficiencies/issues
										System performance test results
								■		**Develop Systems Manual.**
										Develop systems manual in addition to O&M manuals submitted by contractor.
										Include in systems manual;
										Final version of BoD
										System single line diagrams
										As-built sequence of operations, control drawings and original set-points.
										Operating instructions for integrated building systems
										Recommended schedule f maintenance requirements and frequency.
										Recommended schedule for retesting of commissioned systems.
										Blank testing forms from original commissioning plan for retesting.
										Recommended schedule for calibrating sensors and actuators.
					■			■	■	**Project Training Requirements**
										Create project training requirements document with owner.
										Participate in project training session.
										Ensure O&M staff and occupants receive required training and orientation.
										Create and document post training survey.
										Verify and document that training requirements are met.
					■				■	**8–10 Month Warranty Walkthrough**
										Perform a warranty system review within 10 months after substantial completion
										Resolve any issues found
										Create a plan for resolution of outstanding commissioning related issues

Appendix D
ENERGY STAR Equipment

PL5 in the Bonus Savings section of Chapter 5 requires that equipment be ENERGY STAR labeled, where such labeling is available. The following equipment and appliances that are commonly found in healthcare facilities have ENERGY STAR labels. Please note that this list is not exhaustive, and the project team should consult the ENERGY STAR Web site (www.energystar.gov) for a complete and current listing.

Appliances

- Battery chargers
- Clothes washers
- Dishwashers
- Refrigerators and freezers
- Water coolers
- Ice makers

Heating and Cooling

- Air-source heat pumps (see also the energy-efficiency requirements in Chapter 3)
- Boilers (see also the energy-efficiency requirements in Chapter 3)
- Central air conditioners (see also the energy-efficiency requirements in Chapter 3)
- Ceiling fans
- Dehumidifiers
- Furnaces (see also the energy-efficiency requirements in Chapter 3)
- Geothermal heat pumps (see also the energy-efficiency requirements in Chapter 3)
- Programmable thermostats
- Fans

Electronics

- Cordless phones
- Combination units (TV/VCR/DVD)
- DVD products
- Audio
- Televisions
- VCRs

Office Equipment

- Computers
- Copiers
- Fax machines
- Laptops
- Mailing machines
- Monitors
- Multifunction devices
- Printers
- Scanners

Lighting

- Compact fluorescent light bulbs
- Ceiling fans

Commercial Food Service

- Commercial fryers
- Commercial hot-food holding cabinets
- Commercial solid-door refrigerators and freezers
- Commercial steam cookers

Other Products

- Transformers
- Vending machines

Appendix E
Additional Resources

BOOKS AND STANDARDS

ASHRAE. 1999. *ANSI/ASHRAE/IESNA Standard 90.1-1999, Energy Standard for Buildings Except Low-Rise Residential Buildings*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ASHRAE. 2001. *ANSI/ASHRAE/IESNA Standard 90.1-2001, Energy Standard for Buildings Except Low-Rise Residential Buildings*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

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

ASHRAE. 2004. *ANSI/ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

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

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

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EPRI. 1997. *EPRI Daylight Design: Smart and Simple*. New York: Electric Power Research Institute. (Available from Illuminating Engineering Society of North America.)

IES. 2006. *ANSI/IES RP-29-2006, Lighting for Hospitals and Health Care Facilities.* New York: Illuminating Engineering Society of North America.

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

IES. 2003. *IES G-1-03, Guideline on Security Lighting for People, Property, and Public Spaces*. New York: Illuminating Engineering Society of North America.

LBNL. 1997. Tips for daylighting with windows. *Windows & Daylighting*. Berkeley, CA: Lawrence Berkeley National Laboratories. http://windows.lbl.gov/daylighting/designguide/designguide.html.

LRC. 1996. *Outdoor Lighting Pattern Book*. Troy, NY: Lighting Research Center. Available for purchase from www.lightingresearch.org.

NBI. 2003. *Advanced Lighting Guidelines*. White Salmon, WA: New Buildings Institute. www.newbuildings.org/lighting.htm.

NEEP. 2003. *Know-How Guide for Retail Lighting*. Lexington, MA: Northeast Energy Efficiency Partnerships. Available as free download from www.designlights.org.

Pradinuk, R. 2008. Doubling daylight. *Sustainable Healthcare Architecture*. R. Guenther and G. Vittori, eds. Hoboken, NJ: John Wiley & Sons. 326–31.

Torcellini, P.A., D.B. Crawley. 2006. Understanding zero-energy buildings. *ASHRAE Journal* 48(9):62–69.

Torcellini, P., S. Pless, M. Deru, B. Griffith, N. Long, and R. Judkoff. 2006. *Lessons Learned from Case Studies of Six High-Performance Buildings*. NREL Report No. TP-550-37542. Golden, CO: National Renewable Energy Laboratory. www.nrel.gov/docs/fy06osti/37542.pdf.

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

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

WEB SITES

3E Plus (Insulation Thickness Computer Program)
www.pipeinsulation.org

Advanced Lighting Guidelines, NBI
www.newbuildings.org/lighting.htm

AIA—American Institute of Architects
www.aia.org

AIA Committee on the Environment Top Ten Awards
www.aiatopten.org

AAMA—American Architectual Manufacturers Association
www.aamanet.org
ANSI—American National Standards Institute
www.ansi.org
API—Alliance for the Polyurethanes Industry
www.polyurethane.org
ASHRAE—American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
www.ashrae.org
ASTM—ASTM International
www.astm.org
Building Energy Codes Program, EERE, DOE
www.energycodes.gov
Building Energy Codes Resources Center, PNNL
http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter
CBECS—Commercial Buildings Energy Consumption Survey, EIA
www.eia.doe.gov/emeu/cbecs/contents.html
CRRC—Cool Roof Rating Council
www.coolroofs.org
DesignLights Consortium
www.designlights.org
DOE—U.S. Department of Energy
www.energy.gov
www.energycodes.gov
EIA—Energy Information Administration
www.eia.doe.gov
EERE—Energy Efficiency and Renewable Energy, DOE
www.eere.energy.gov
ENERGY STAR
www.energystar.gov
EPS Molders Association
www.epsmolders.org
High Performance Buildings Database, EERE Buildings Program, DOE
www.eere.energy.gov/buildings/database/
IES—Illuminating Engineering Society of North America
www.ies.org
LBNL—Lawrence Berkeley National Laboratory
www.lbl.gov
LEED—Leadership in Energy and Environmental Design, USGBC
www.usgbc.org/LEED
Lessons Learned from Case Studies of Six High-Performance Buildings, NREL
www.nrel.gov/docs/fy06osti/37542.pdf.
LRC—Lighting Research Center
www.lightingresearch.org
NAIMA—North American Insulation Manufacturers Association
www.naima.org
NBI—New Buildings Institute
www.newbuildings.org
NEEP—Northeast Energy Efficiency Partnerships
www.neep.org

NEMA—National Electrical Manufacturers Association
www.nema.org
NFRC—National Fenestration Rating Council
www.nfrc.org
NREL—National Renewable Energy Laboratory
www.nrel.gov
ORNL—Oak Ridge National Laboratory
www.ornl.gov/sci/engineering_science_technology/buildings.shtm
PIMA—Polyisocyanurate Insulation Manufacturers Association
www.polyiso.org
RPI—Rensselaer Polytechnic Institute
www.rpi.edu
SRI Calculator, ORNL
www.ornl.gov/sci/roofs+walls/calculators/ssreflect/index.htm
"Tips for Daylighting with Windows," *Daylight and Windows*
http://windows.lbl.gov/daylighting/designguide/designguide.html
USGBC—U.S. Green Building Council
www.usgbc.org
The Whole Building Design Guide
http://wbdg.org/
XPSA—Extruded Polystyrene Foam Association
www.xpsa.com

ORGANIZATIONS

American Institute of Architects (AIA)
1735 New York Ave., NW
Washington, DC 20006-5292
800-AIA-3837 or 1-202-626-7300
www.aia.org
American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
1791 Tullie Circle, N.E.
Atlanta, GA 30329
800-527-4723 or 1-404-636-8400
www.ashrae.org
Illuminating Engineering Society of North America (IES)
120 Wall Street, Floor 17
New York, NY 10005
1-212-248-5000
www.ies.org
U.S. Department of Energy (DOE)
1000 Independence Ave., SW
Washington, DC 20585
800-dial-DOE (1-800-342-5363) or 1-202-586-5000
www.energy.gov
U.S. Green Building Council (USGBC)
1800 Massachusetts Ave., NW, Suite 300
Washington, DC 20036
800-795-1747 or 1-202-742-3792

www.usgbc.org

American Society of Healthcare Engineers (ASHE)
One North Franklin, 28th Floor
Chicago, IL 60606
312-422-3800
www.ashe.org

COMMISSIONING

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

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

NIBS. 2006. *NIBS Guideline 3-2006, Exterior Enclosure Technical Requirements for the Commissioning Process.* Washington, DC: National Institute of Building Sciences.

OPERATIONS AND MAINTENANCE

ASHRAE. 1993. *Preparation of Operational Maintenance documentation for Building Systems.* Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

ASHRAE. 2007. *ASHRAE Handbook—HVAC Applications*, Chapter 38. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ZERO ENERGY

Torcellini, P., D. Crawley. 2006. Understanding zero-energy buildings. *ASHRAE Journal* 48(9):62–69.

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Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities

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

This Guide focuses on small healthcare facilities up to 90,000 ft^2 in size including acute care facilities, outpatient surgery centers, and small critical access and inpatient community hospitals. These buildings have a wide variety of heating and air-conditioning equipment, which is reflected in the recommendations contained in this Guide. There is also extensive information about lighting systems, including daylighting—an important energy-saving measure.

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

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

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

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