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50%

Advanced Energy Design Guide for Large Hospitals

Achieving 50% Energy Savings Toward a Net Zero Energy Building



Developed by:
ASHRAE
The American Institute of Architects
Illuminating Engineering Society of North America
U.S. Green Building Council
U.S. Department of Energy

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Advanced Energy Design Guide for Large Hospitals

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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Acknowledgments

The *Advanced Energy Design Guide for Large Hospitals* is the fourth in a series of publications designed to provide strategies and recommendations for achieving 50% energy savings over the minimum code requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004, *Energy Standard for Buildings Except Low-Rise Residential Buildings*. The 50% AEDG series addresses building types that represent major energy users in the commercial building stock. This Guide is the result of the dedicated, collective efforts of many professionals who devoted countless hours to help hospitals use less energy.

The primary authors were the 12 members of the ASHRAE Special Project 136 Committee (SP-136) who represented the participating organizations—primarily ASHRAE, the American Institute of Architects (AIA), the U.S. Green Building Council (USGBC), the Illuminating Engineering Society of North America (IES), and the U.S. Department of Energy (DOE). The American Society for Healthcare Engineering (ASHE) was also represented. Thanks also to members of the ASHRAE Standing Standards Project Committee (SSPC) 90.1 and ASHRAE Technical Committee (TC) 9.6, Healthcare Facilities.

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The project committee's efforts were guided by the AEDG Steering Committee, composed of members from the partner organizations—ASHRAE, AIA, USGBC, IES—with the additional support and participation of DOE. Its members provided direction and guidance to complete the Guide within 12 months. The Steering Committee assembled an expert team of authors and defined a scope that kept the project committee's task manageable and focused. The representatives from these organizations brought a collegial and constructive spirit to the task of setting policy.

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Shanti Pless
Chair, Special Project 136

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Abbreviations and Acronyms

ach	air changes per hour
AHJ	authority having jurisdiction
AIA	American Institute of Architects
ASC	ambulatory surgery center
ASTM	ASTM International
ANSI	American National Standards Institute
BIAF	backward inclined airfoil
BAS	building automation system
BIM	building information modeling
BF	ballast factor
BoD	Basis of Design
Btu	British thermal unit
C	thermal conductance, Btu/h·ft^2·°F
c.i.	continuous insulation
Cx	commissioning
CxA	commissioning authority
CAV	constant air volume
CBECS	Commercial Buildings Energy Consumption Survey
CCT	corrected color temperature
CDD	cooling degree day
CFL	compact fluorescent lights
cfm	cubic feet per minute
CKI	Commercial Kitchens Initiative
CMH	ceramic metal halide
CMMS	computer maintenance management system
CMS	Centers for Medicare and Medicaid Service
COP	coefficient of performance, dimensionless
CRI	color rendering index
CRRC	Cool Roof Rating Council
CT	computed tomography
CUP	central utility plant
DCV	demand-controlled ventilation
DL	Advanced Energy Design Guide code for *daylighting*

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DOAS	dedicated outdoor air system
DOE	Department of Energy
DX	direct expansion
E_c	efficiency, combustion, dimensionless
ECM	energy conservation measure *or* electronically commutated motors
E_t	efficiency, thermal, dimensionless
EER	energy efficiency ratio, Btu/W·h
EF	energy factor
EL	Advanced Energy Design Guide Code for *electric lighting*
EN	Advanced Energy Design Guide Code for *envelope*
ESCO	energy service company
EUI	energy use intensity
F	slab edge heat loss coefficient per foot of perimeter, Btu/h·ft·°F
FC	filled cavity
fc	foot candles
FGI	Facility Guidelines Institute
FGI Guidelines	*Guidelines for the Design and Construction of Healthcare Facilities*
FHC	family health center
GSHP	ground-source heat pump
Guide	*Advanced Energy Design Guide for Large Hospitals*
HC	heat capacity, Btu/(ft^2·°F)
HDD	heating degree day
HEPA	high-efficiency particulate air
HID	high-intensity discharge
HRC	heat recovery chiller
HSPF	heating seasonal performance factor
HV	Advanced Energy Design Guide code for *HVAC systems and equipment*
HVAC	heating, ventilating, and air conditioning
IAQ	indoor air quality
IDF	intermediate distribution frame
IES	Illuminating Engineering Society of North America
IESNA	Illuminating Engineer12-026ing Society of North America (no longer used)
IGU	insulated glazing unit
in.	inch
IPLV	integrated part load value, dimensionless
kBtu	thousands of British thermal units
kW	kilowatt
LBNL	Lawrence Berkeley National Laboratory
LCCA	life-cycle cost analysis
LDR	labor, delivery, and recovery
LEC	light-emitting capacitor
LED	light-emitting diode
LEED®	Leadership in Energy and Environmental Design
LINAC	linear particle accelerator
LPD	lighting power density, W/ft^2
LPW	lumens per watt
Ls	liner systems
LSG	light-to-solar gain
LWBT	leaving wet-bulb temperature
N/A	not applicable
M&V	measurement and verification
MDF	main distribution frame
MLPW	mean lumens per watt
MOB	medical office building

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MRI	magnetic resonance imaging
NEMA	National Electrical Manufacturers Association
NICU	neonatal intensive care unit
NFRC	National Fenestration Rating Council
NREL	National Energy Renewable Laboratory
O&M	operation and maintenance
OA	outdoor air
OPR	Owner's Project Requirements
PACU	postanesthetic care unit
PET	positron emission tomography
PF	projection factor, dimensionless
PIR	passive infrared
PL	Advanced Energy Design Guide code for *plug loads*
PPL	plug and process loads
PNNL	Pacific Northwest National Laboratory
POE	postoccupancy evaluation
ppm	parts per million
PSC	permanent-split capacitor
PV	photovoltaic
QA	quality assurance
R	thermal resistance, $h \cdot ft^2 \cdot °F/Btu$
R - in.	R-value followed by the depth of insulation in inches
RFID	radio-frequency identification
RFP	request for proposal
rh	relative humidity
ROI	return on investment
SAT	supply air temperature
SCN	special care nurseries
SDU	split dehumidification unit
SEMP	strategic energy management planning
SFU	supply fixture unit
SHGC	solar heat gain coefficient, dimensionless
SHR	sensible heat ratio
SP	special project
SRI	Solar Reflectance Index, dimensionless
SSPC	standing standards project committee
SWH	service water heating
TAB	test, adjust, and balance
TC	technical committee
U	thermal transmittance, $Btu/h \cdot ft^2 \cdot °F$
USGBC	U.S. Green Building Council
UV	ultraviolet
UVGI	ultraviolet germicidal irradiation
VAV	variable air volume
VFD	variable-frequency drive
VT	visible transmittance
W	watts
WH	Advanced Energy Design Guide code for *service water heating*
WSHP	water-source heat pump
WWR	window-to-wall ratio

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Foreword: A Message to Healthcare Leaders

The purpose of healthcare organizations is to improve the life quality of its patients and the health of the communities they serve. As healthcare services and specialized knowledge have dramatically improved, diagnostic and treatment equipment and techniques have evolved to support them. The pace of this change can only increase in the face of the demographic, technological, and regulatory/reimbursement transformations necessary to ensure the financial sustainability of the healthcare delivery process.

In many cases, modern healthcare facilities and their overall environment of care have not contributed to the public health mission and have even been inadvertent contributors to the decline in human health. Understanding the impacts of hospitals on the natural environment and on public health, and connections between the built environment and occupant health, is a relatively recent phenomenon. Although links between these factors and the financial demands on healthcare are increasingly clear, the connections are often indirect, leading some owners to prioritize architecture over operational achievement.

A well designed, constructed, operated, and maintained facility is a major contributor to the environment of care and can improve patient outcomes, safety, and comfort. Quality lighting provides clear and even illumination during diagnosis and intervention, can help prevent medication errors, and help deter criminal activity in parking areas and adjacent grounds. HVAC systems that can deliver clean air quietly and at the correct volume, temperature, humidity, and pressure to support infection control and help keep patients comfortable. Efficient water systems reduce use and maximize reuse where safe, and can help communities by reducing the need for larger, more costly treatment plants that consume more energy. Carefully selected finishes can reduce infections and improve cleanliness.

Because healthcare leadership focuses more on the architectural than operational design of healthcare facilities, many designers substitute quantity for quality, resulting in overlighted spaces or oversized equipment. Reducing lighting power density while increasing lighting quality is not only possible but can accompany a reduction to both first cost and lifecycle cost. Reducing fixture wattage through the use of solid-state lighting allows for fewer circuits to be run and for the purchase of smaller transformers. Longer mean time between failures results in a lower maintenance cost, which can equal or surpass the savings from reduced electricity use. Lower wattage can also mean a lower risk of fire, less lighting waste heat to dissipate, more spare capacity in emergency power systems for egress lighting, and higher circuit reliability. Use of solid-state lighting also allows variable dimming for daylighting and “quiet at night” applications not possible with some sources without expensive modifications.

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Focusing on the fundamental environment of care throughout the lifecycle of a facility provides additional positive effects for the natural environment as well as for the public health. Lower waste heat from lighting can lead to smaller cooling plants, which can lead to lower initial and operating costs. Lower power consumption can lead to a reduction of particulate matter in the air, and of mercury and other waste contamination in groundwater at power stations.

This positive cycle of lower costs; improved patient outcomes, safety, and experience; and better stewardship of community health is not a distant possibility in the far future—it is achievable today, using readily available technology with a history of successful and reliable implementation in facilities around world. Using available technology, designers are capable of delivering quality plans for a large hospital that is up to 50% more energy efficient. Likewise, construction professionals can economically build these low-energy buildings, and hospital facilities' staffs can successfully operate and maintain them.

Healthcare facilities play an influential role in promoting public wellness by educating their staff on the importance and techniques of sustainability, which they take home and spread to their communities at large. Some healthcare institutions have leveraged sustainability efforts to provide even greater value to their communities. At least one large healthcare organization is considering selling the renewable energy credits provided by the large number of solar power panels it has installed and using the proceeds to provide medical care to the uninsured—perhaps the most direct form of community benefit.

The *Advanced Energy Design Guide for Large Hospitals* shows that existing reliable technologies and design philosophies can be used to reduce energy use in large hospitals by up to 50% of ANSI/ASHRAE/IESNA Standard 90.1-2004 recommendations. In addition, the 30% savings guide, *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities*, can be applied to freestanding ambulatory surgery centers and high-acuity medical office buildings, and the 50% savings guide, *Advanced Energy Design Guide for Small to Medium Office Buildings*, can be applied to administrative or low-acuity medical office buildings. Although these guides focus on methods of achieving and documenting up to 30% or 50% energy savings, the approaches used are not intended to limit savings to 50% or to be the only way of achieving savings.

Most important in *Advanced Energy Design Guide for Large Hospitals* is the recognition that patient outcomes, safety, and experience trump all cost- and energy-saving strategies. Regardless of their potential for savings, no strategy is adopted that would cause risk to the direct care of the patients, or to the health of staff and visitors of these facilities. The Guide emphasizes design approaches that reduce risk, and hospitals are encouraged to consider carefully the interrelated factors that contribute to an overall environment of care when making design decisions. As many large hospitals are major employers and community pillars, the need to reduce impact on the natural environmental through energy savings and sustainable operational practices cannot be ignored. Staff and community leaders expect healthcare facilities to be environmentally responsible. These philosophies also make economic sense.

In addition to reducing risk to occupant health and the natural environmental, correctly executed measures to reduce energy consumption can lead to greater staff engagement and attendance, as people like to work in attractive spaces with access to natural light and tend to take fewer sick days. Any improvement to overall environment of care will provide similar improvement to staff work environment. While the greatest measure of a quality medical center is the recommendation of satisfied patients and families, the recommendations of staff to their peers is a close second. Time and again, those healthcare facilities that build green report easier recruiting, and higher retention of staff than competing facilities. In an era of increasingly scarce human assets, this may be the most important additional benefit of a program to conserve energy.

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Introduction

1

The *Advanced Energy Design Guide for Large Hospitals* (the Guide) provides user-friendly, how-to design guidance and efficiency recommendations for large hospitals. Applying the Guide's recommendations should result in facilities that consume 50% less energy than conventional hospitals (defined by the minimum requirements of ANSI/AHSRAE/IESNA Standard 90.1-2004*, Energy Standard for Buildings Except Low-Rise Residential Buildings* (ASHRAE 2004). This document contains recommendations to design a low-energy-use building. It is *not* a minimum code or standard but is rather a voluntary guidance document designed to supplement existing codes and standards. It is not intended to replace, supersede, or circumvent them. Although several design packages are provided in the document, this Guide represents *a way*, but not the *only way*, to build energy-efficient hospitals that use significantly less energy than those built to minimum code requirements.

The intended audience of this Guide includes, but is not limited to, building owners, architects, design engineers, energy modelers, general contractors, facility managers, and building operations staff. Specifically, Chapter 2 is written for a target audience of all design team members, including design professionals, construction experts, owner representatives, and other stakeholders. Chapters 3 through 5 are oriented more toward design professionals. These chapters include sound design advice and identify interdisciplinary opportunities for significant energy reduction. The focus of this Guide is to identify proven concepts that are feasible to implement, and to benchmark necessary energy performance criteria for 50% energy savings. The Guide will require healthcare leaders and design professionals to be intentional about the goals of their projects and to think differently about their processes and operations.

The energy savings projections of this Guide are based on site energy consumption rather than source energy. *Site energy* refers to the amount 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 source energy to produce and deliver 1 kWh to the customer because the production and distribution of electrical energy is roughly 33% efficient.

The Guide was developed by a project committee representing a diverse group of professionals and practitioners. Guidance and support was provided through a collaboration of ASHRAE, the American Institute of Architects (AIA), the Illuminating Engineering Society (IES), the U.S. Green Building Council (USGBC), and the U.S. Department of Energy (DOE).

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Advanced Energy Design Guide for Large Hospitals
Executive Summary

Advanced Energy Design Guide for Large Hospitals is fourth in a series of guides designed to achieve 50% energy savings over the minimum code requirements of ASHRAE/IESNA Standard 90.1-2004. The Guide provides user-friendly assistance and energy savings recommendations to the building community and building owners. Included are prescriptive recommendations for the envelope; fenestration; lighting systems (including electric interior and exterior lights and daylighting); heating, ventilation, and air-conditioning (HVAC) systems; building automation and controls; outdoor air (OA) requirements; service water heating (SWH); and plug and process loads (PPL). The guide provides practical recommendations for exceeding code minimums and helping design teams and owners produce high-efficiency hospitals. In general, the guide contains recommendations for the following:

- A building envelope approximately 45% better on average than Standard 90.1-2004.
- Interior lighting power densities that result in a 25% better whole-building lighting power density than Standard 90.1-2004, along with LED surgery light recommendations that save 60% of the energy used for lighting, while significantly reducing the energy demands for cooling surgeons and warming patients.
- Exterior lighting recommendations that include a 33% reduction over Standard 90.1-2004 for parking lots and drives.
- ENERGY STAR® exclusive plug-in equipment, best-in-class plug in equipment where ENERGY STAR does not apply, best in class commercial kitchen equipment, traction elevators exclusively, and regenerative traction elevators for high use.
- Service water heating that is 13% more efficient than Standard 90.1-2004 on average.
- Aggressive reduction in reheat resulting from decoupling space conditioning loads and ventilation loads, either with a dedicated OA system and zone-level conditioning equipment or advanced variable-air-volume (VAV) with separate OA treatment, heat recovery chiller, aggressive supply air temperature reset, and zone airflow setback.
- Additional HVAC recommendations that include airflow setback in surgery suites, best-in-class equipment efficiencies, demand controlled ventilation, air-side energy recovery, air side pressure drop and coil face velocity reductions, elimination of steam boilers, and high-delta-T chilled-water loops.

As with previous Guides in the series, *Advanced Energy Design Guide for Large Hospitals* provides a simple, easy-to-use reference to help building professionals and owners identify a clear prescriptive path to 50% energy savings over Standard 90.1-2004. The combination of a set of recommendations contained on a single page, along with numerous how-to tips to help the construction team complete the project successfully, should result in increased energy efficiency in new buildings. Case studies of actual applications add to the comprehension of energy-efficiency opportunities. The ultimate goal of the Advanced Energy Design Guide partner organizations is to achieve net zero energy buildings, and the 50% savings guides represent a step in reaching this goal.

Members of the project committee are also affiliated with ASHRAE Standing Standards Project Committee 90.1 (SSPC 90.1), the ASHRAE Technical Committee on Healthcare Facilities (TC 9.6), and the American Society of Healthcare Engineers (ASHE).

In essence, this Guide provides design teams a methodology for achieving energy savings goals that are financially feasible, operationally workable, and otherwise readily achievable. Because technology to conserve and generate energy is growing rapidly, it is clear that innovation is an important ingredient to the success of reducing energy consumption in healthcare facilities. It is the hope of the authors that this publication will expose other existing best practices and lead to new concepts.

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GOAL OF THIS GUIDE

The Guide strives to provide guidance and recommendations to reduce the total energy use in large hospitals by at least 50%, on a site energy basis, using ASHRAE/IESNA Standard 90.1-2004 as the basis for a minimum code-compliant building. The energy savings goal is to be achieved in each climate location rather than an aggregated national average. The 50% savings is determined based on whole-building site energy savings, which includes process and plug loads.

SCOPE

This Guide has been created for a "standard" mid-to-large-size hospital, but the approaches and strategies suggested can be applied to all sizes and classifications of large hospitals. In general, most large hospitals are at least 100,000 ft^2. Space types covered by the Guide include cafeterias, kitchens, and dining facilities; conference, lobby, lounge, and office areas; reception/waiting areas and examination and treatment rooms; clean and soiled workrooms and holding areas; nurse stations, nurseries, patient rooms, corridors and transition spaces, lockers, and restrooms; operating rooms, procedure rooms, recovery rooms, and sterilizer equipment areas; pharmacies, medication rooms, and laboratories; triage, trauma, and emergency rooms; physical therapy and radiology/imaging rooms; and storage, receiving, and mechanical/electrical/telecom rooms. This Guide will not directly address other atypical or special-use spaces.

The primary focus of this Guide is new construction, but recommendations may be equally applicable to hospitals undergoing complete renovation and, in part, to many other hospital renovation, addition, remodeling, and modernization projects (including changes to one or more systems in existing buildings).

Included in the Guide are recommendations for the design of the building opaque envelope; fenestration; lighting systems (including electrical interior and exterior lights and daylighting); heating, ventilation, and air-conditioning (HVAC) systems; building automation and controls; outdoor air (OA) requirements; service water heating (SWH); and plug and process loads (PPL), including kitchen equipment. Additional savings recommendations that are not necessary for 50% savings are discussed in the "Additional Bonus Savings" section of Chapter 5.

The recommendation tables do not include all of the components listed in ASHRAE/IES Standard 90.1. Though this Guide focuses only on the primary energy systems within a building, the underlying energy analysis assumes that all of the other components and systems comply with the minimum design criteria in ASHRAE/IES Standard 90.1, ASHRAE Standard 62.1, and ASHRAE/ASHE Standard 170.

In addition, the Guide is not intended to be a substitute for rating systems or references that address the full range of sustainability issues in hospital 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 comprehensive design text. The Guide assumes good design skills and expertise in hospital design.

PROJECT PROCESS FOR ACHIEVING 50% ENERGY SAVINGS

Meeting the 50% energy savings goal is challenging and requires more than doing business as usual. Below are the essentials. The sidebar "Steps for the Building Owner to Follow when Using the Advanced Energy Design Guide" shows additional steps from an owner's perspective. Many of these issues are addressed in greater detail in Chapter 2.

1. *Obtain building owner buy-in*. There must be strong buy-in from the owner/operator and leadership and staff. The more they know about and participate in the planning and design process, the better they will be able to help achieve the 50% energy savings goal after the

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hospital 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 buildings, innovative thinking, and the ability to work together as a team are all critical to meeting the 50% energy savings goal. Communicate energy savings goals in the request for proposal (RFP) and give significant weight when selecting a design team to the team's ability to meet the goals. The design team implements the goals for the owner.

3. *Adopt an integrated design process*. Cost-effective, energy-efficient design requires trade-offs among potential energy-saving features. This requires an integrated approach to hospital design. The greater the energy savings are, 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.

4. *Consider a daylighting consultant*. Daylighting is an important energy saving strategy to achieve the 50% energy savings goal; however, successful implementation of a daylighting strategy requires sound technical design. If the design team does not have experience with a well-balanced daylighting design, it may need to add a daylighting consultant.

5. *Consider energy modeling*. This Guide provides a few design packages to help achieve energy savings of up to 50% without energy modeling, but whole-building energy modeling programs can provide more flexibility to evaluate the energy efficiency measures on an individual project. These simulation programs have learning curves of varying difficulty, but energy modeling for hospital design is highly encouraged and is considered necessary for achieving energy savings of up to 50%. See the Building Energy Software Tools Directory (DOE 2012) at the Department of Energy, Energy Efficiency and Renewable Energy Web site for links to energy modeling programs. Part of the key to energy savings is first identifying and evaluating major loads, including those imposed by the envelope, and then reducing them. The interactions between climate, hospital buildings, and HVAC systems are complex. Energy modeling helps determine the nonintuitive trade-offs that lead to deep savings that are too complex to evaluate otherwise. Developing HVAC load calculations is neither energy modeling nor a substitute for energy modeling.

6. *Use building commissioning*. Studies verify that building systems frequently do not operate as efficiently as expected, whether due to design, installation, and/or operational factors. The 50% energy savings can be elusive to achieve in practice without thorough building commissioning to ensure that all systems—including envelope, lighting, and HVAC—perform as intended. Comprehensive commissioning increases the likelihood of achieving expected energy savings. See the section "Project Details by Phase" in Chapter 2 and the "Quality Assurance" sections of Chapter 5 of this Guide for more information.

7. *Train building users and operations staff.* The long-term operational efficiency of a building is the result of thousands of individual choices that users and operations staff make every day. Training involves both instructing operations staff in what adjustments are necessary to achieve optimum performance and informing building occupants of the consequences of their choices to use water and energy. Often, the building system users receive training from the operations staff on an exception basis after there is a system failure. Systems that put real-time information about the impact of plug loads and energy-efficient appliances on the user's desktop may be effective in modifying behavior to conserve energy use.

8. *Monitor the building*. Buildings that do not meet energy goals may have operational deficiencies that can be corrected with dramatic effect. An energy monitoring plan is useful in discovering what components of the building load are contributing to high energy use. Even simple plans that record and plot monthly utility bills may offer clues leading to operational changes and performance improvements.

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Steps for the Building Owner to Follow when Using the Advanced Energy Design Guide

Project Phase	Actions	Outcomes
Project Conception	☐ Select the AEDG(s) for your building type from *www.ashrae.org/aedg.* ☐ Learn about the business case for advanced energy design in the Foreword. ☐ Review similar projects in the case studies.	➢ Appropriate AEDG ➢ Project specific energy performance goals
Team Selection	☐ Incorporate AEDG recommendations into RFPs. ☐ Ask proposers how they used AEDG recommendations and made the business case for energy savings in past projects.	➢ Team with AEDG experience ➢ Team committed to using AEDG
Conceptual Design	☐ Require design teams to implement AEDG recommendations. ☐ Learn about integrated design in Chapter 2. ☐ Review site specific cost and benefit of the AEDG recommendations.	➢ Understanding and application of the AEDG recommendations ➢ Awareness of cost impacts of the AEDG recommendations
Design Development	☐ Include AEDG recommendations in the Owner's Project Requirements (OPR). ☐ Integrate AEDG recommendations into project tracking and status meetings.	➢ Design that incorporates AEDG recommendations
Construction	☐ Request regular updates on progress towards AEDG goals. ☐ Ensure that late project modifications to not compromise AEDG goals.	➢ Verification that AEDG recommendations are installed as designed (through commissioning process)
Operation	☐ Verify that AEDG recommended systems function as intended (through commissioning). ☐ Leverage the one-year warranty period to address outstanding issues.	➢ High-performance building incorporating AEDG recommendations ➢ Achievement of design energy goals

CONDITIONS TO PROMOTE HEALTH AND COMFORT

Throughout the project, the design team should continuously determine how energy-saving measures will impact comfort, IAQ, and acoustics. The design and construction of a high-performance hospital requires an integrated approach where these factors remain a priority and are not adversely affected when striving for energy reduction.

The ways in which indoor environmental factors, such as thermal conditions, IAQ, acoustics, and illumination, interact can be either beneficial or detrimental to both sustainability efforts and occupant health. For specific guidance regarding the interaction of indoor

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air quality, thermal comfort, sound and vibration, and other factors, refer to ASHRAE Guideline 10, *Interactions Affecting the Achievement of Acceptable Indoor Environments* (ASHRAE 2011).

VENTILATION AND INDOOR AIR QUALITY (IAQ) IN HOSPITALS

ASHRAE Standard 62.1 and ASHRAE/ASHE Standard 170 define minimum requirements for the design, installation, operation, and maintenance of ventilation systems. Standard 170 also provides minimum requirements for filter specifications, pressure relationships where required, and temperature ranges. It is the standard recognized by Centers for Medicare and Medicaid Services (CMS) for meeting conditions of participation. For more information, refer to *Indoor Air Quality Guide: Best Practices for Design, Construction, and Commissioning* (ASHRAE 2009b), which provides specific guidance for achieving the following key objectives:

- Manage the design and construction process to achieve good IAQ.
- Control moisture in building assemblies.
- Limit entry of outdoor contaminants.
- Control moisture and contaminants related to mechanical systems.
- Limit contaminants from indoor sources.
- Capture and exhaust contaminants from building equipment and activities.
- Reduce contaminant concentrations through ventilation, filtration, and air cleaning.
- Apply more advanced ventilation approaches.

THERMAL COMFORT

AHSRAE/ASHE Standard 170 defines required temperature standards in clinical settings. ASHRAE Standard 55 defines the combinations of indoor thermal environmental factors and personal factors that will produce conditions acceptable to a majority of the occupants in nonclinical environments.

According to ASHRAE Standard 55, six primary factors must be addressed when defining conditions for thermal comfort: metabolic rate, clothing insulation, air temperature, radiant temperature, air speed, and humidity. For example, appropriate levels of clothing, the cooling effect of air motion, and radiant cooling or heating systems can increase occupant comfort efficiently.

Also, all parties should consider allowing a wide deadband for occupied mode setpoints as a measure to reduce energy use (as compared to the minimum deadband range stated in energy codes). However, these expanded temperature ranges should not be so extreme as to compromise productivity in the workspace.

VISUAL COMFORT

To minimize visual comfort issues, integrate daylight and electric light into the design, making sure to meet Illuminating Engineering Society (IES) recommended light levels (IES 2012). Light levels that are too high or too low cause eye strain and result in lost productivity.

Control glare from direct and reflected sunlight to avoid the discomfort caused by high contrast ratio. Orient workstation terminals and audio-visual displays perpendicular to the window line to reduce discomfort from reflections.

Further recommendations on lighting visual comfort can be found in IES's *The Lighting Handbook: Reference and Application*, specifically in Chapter 2 "Vision: Eye and Brain" and Chapter 4 "Perception and Performance" (IES 2012).

ACOUSTIC COMFORT

Proper acoustic design must be a priority when considering all design decisions and must not be sacrificed in striving for energy reduction. Addressing proper acoustics during the design phase of a project, rather than attempting to fix problems after construction, will likely mini-

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mize costs. *Guidelines for the Design and Construction of Healthcare Facilities* (AIA Guidelines) (AIA 2010) defines acoustic performance in the clinical environment.

Additional recommendations on acoustic comfort can be found in the 2009 *ASHRAE Handbook—Fundamentals*, Chapter 8, "Sound and Vibration" (ASHRAE 2009a).

ENERGY MODELING ANALYSIS

A hospital prototype energy model was developed and analyzed using hourly building simulations to provide a baseline to quantify the energy savings for this Guide. The building energy model has an area of 427,000 ft^2, which was carefully assembled to represent typical construction for healthcare facilities of that size and class. Information was drawn from a number of sources, including the Commercial Buildings Energy Consumption Survey (CBECS), Dodge Construction Data, and various hospital templates from around the country. Space types included in each prototype design are shown in Table 1-1. The Guide covers additional spaces in the recommendations beyond those included in the prototype modeling.

Two sets of hour-by-hour simulations were run for each prototype using EnergyPlus Energy Simulation Software (DOE 2011). The first set meets the minimum requirements of ASHRAE/IESNA Standard 90.1-2004, and the second uses the recommendations in this Guide. Each prototype was simulated in eight climate zones adopted by the International Energy Code Council (IECC) and ASHRAE in development of the prevailing energy codes and standards. The climate zones were further divided into moist and dry regions, represented by 16 climate locations. All materials and equipment used in the simulations are commercially available from two or more manufacturers.

Table 1-1 Prototype Design Modeled Space Types

Space Types	
Anesthesia gas storage	Office
Cafeteria	Operating room
Clean workroom/holding	Patient room
Conference room	Pharmacy
Corridor/transition	Physical therapy
Dining facilities	Procedure room
Examination/treatment room	Radiology/imaging
Food preparation center (kitchens)	Reception/waiting
Laboratory	Recovery room
Lobby area	Restroom
Locker	Soiled workroom/holding
Lounge	Sterilizer equipment room
Mechanical/electrical/telecom room	Storage/receiving
Medical supply/medication room	Trauma/emergency room
Nurse station	Triage
Nursery	

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Energy savings for the recommendations vary depending on climate zone and HVAC system type but are at least 50% in all cases when compared to ASHRAE 90.1-2004, ranging from 50% to 59% savings. Analysis also determined energy savings ranging from approximately 49% to 58% when compared to ASHRAE Standard 90.1-2007 (ASHRAE 2007) and from approximately 34% to 45% when compared to Standard 90.1-2010 (ASHRAE 2010c). A savings range of approximately 56% to 64% is estimated when compared to Standard 90.1-1999 (ASHRAE 1999), the baseline standard of the 30% AEDG series. Energy saving analysis approach, methodologies, and complete results of the prototype building simulations are documented in a Bonnema et al. (2010).

HOW TO USE THIS GUIDE

- Review Chapter 2 to understand how integrated design is used to maximize energy efficiency.
- Review Chapter 3 to understand the integrated design strategies, including architectural design features and energy conservation measures by climate zone. This chapter provides integrated design strategies to help design professionals make good decisions in the early stages of project design. This is especially important when the project has building or site characteristics that do not match the baseline building in shape, orientation, and glazing.
- Review Chapter 4 for climate-specific design strategies and select specific energy saving measures by climate zone. This chapter provides prescriptive packages that do not require modeling for energy savings. These measures also may be used to earn credits for LEED® and other building rating systems, pending formal adoption.
- Use Chapter 5 to apply the energy saving measures in Chapter 4. This chapter includes suggestions for 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.
- Refer to the Appendices for additional information:
  - Appendix A—Envelope Thermal Performance Factors
  - Appendix B—International Climatic Zone Definitions
- Note that this Guide is presented in inch-pound (I-P) units only; it is up to the individual user to convert values to the International System (SI) as required. The Guide is also oriented toward projects in the northern hemisphere. Projects located in the southern hemisphere should reverse north/south orientations accordingly.

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Integrated Design

2

INTRODUCTION

Buildings consume approximately 40% of all of the energy used in the United States (USGBC 2012). Healthcare buildings are the second largest consumer of energy per unit of floor area of all building types (EIA 2008). For too many years, the architecture and engineering community has designed buildings to meet minimal energy performance goals. In order to change this practice, energy performance must be considered in the earliest stages of the design process.

Early prioritization of energy performance leads to strategies with the lowest cost to the project overall. Since energy performance questions span all aspects of building planning, design, construction, and project operations, early engagement enables early integrated team building, problem definition, and goal setting. This is true for most types of construction, but particularly true for highly complex, expensive, and lengthy projects, such as large hospitals.

Large hospitals are complicated to design, construct and operate. Integrated design has provided significant advancements in energy and operational efficiency at minimal to no additional capital cost. Since 80% of the building's lifecyle costs occur during the operational phase, these opportunities offer tremendous payback. The prioritization of energy efficiency starts with the earliest business and operations planning phases in the context of strategic energy management planning (SEMP), often several years before the traditional design process starts, and continues through construction to long-term building operations. In order to manage a process designed around long-term operations goals for energy efficiency, the integration of planning, design, construction, and operations team members is absolutely critical. Managing long-term goals requires new lanes of responsibility and new ways of reconciling building performance decisions outside of commonly exclusive, discipline-specific, independent budget categories.

Integrated design is inclusive of construction and operations. It is a framework for incorporating the early and continuous input of engineers, building contractors, and operators into the working process of a collaborative group of key design decision makers. This chapter summarizes the overarching principles of integrated design for energy efficiency. The two following guidance documents for structuring integrated project teams offer more in-depth treatment of the topic.

- *Integrated Project Delivery: A Guide* (AIA 2007)
- *ANSI/MTS 1.0 Whole Systems Integrated Process Guide (WSIP)-2007 for Sustainable Buildings & Communities* (MTS 2007)