NATIONAL RENEWABLE ENERGY LABORATORY

50% Advanced Energy Design Guides

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50% Advanced Energy Design Guides

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ABSTRACT

This paper presents the process, methodology, and assumptions for the development of the 50% Energy Savings Advanced Energy Design Guides (AEDGs), a series of design guidance documents that provide specific recommendations for achieving 50% energy savings above the requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004 in four building types:

- Small to medium office buildings
- K-12 school buildings
- Medium to big box retail buildings
- Large hospital buildings

The AEDGs provide user-friendly recommendations and clear steps for building owners, architects, designers, engineers, and builders to achieve significant energy savings without performing intensive calculations or complex analyses outside the scopes of their normal practices. The guides encourage energy-efficient design by providing prescriptive, climate zone-specific recommendations to achieve 50% energy savings. Energy-saving solutions presented in the guides also represent a further step toward achieving net-zero energy building goals.

This paper describes how to use the AEDGs, the format of the guides, and the strategies to reach the 50% savings goal. Key topics include:

- High-performance building envelope
- Lighting/daylighting
- Plug and process load control
- Service water heating
- Heating, ventilation, and air-conditioning system design
- Commissioning and measurement and verification

Steps that can potentially yield a 50% reduction in whole-building energy use with industry-vetted, economically replicable, and commercially available technologies are described. The energy simulation analysis results are also presented, outlining recommended packages of energy efficiency measures achieving at least 50% energy savings in all 16 U.S. climate zones, relative to Standard 90.1-2004.

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Introduction

The 50% Advanced Energy Design Guides (AEDGs) (ASHRAE et al. 2011a, 2011b, 2011c, 2012) are a series of publications designed to provide recommendations for achieving energy savings over the minimum code requirements of ANSI/ASHRAE/IESNA Standard 90.1 (ASHRAE 2004a). The AEDGs are developed in collaboration with the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the American Institute of Architects, the Illuminating Engineering Society of North America (IES), the U.S. Green Building Council (USGBC), and supported through the U.S. Department of Energy (DOE) via the National Renewable Energy Laboratory and Pacific Northwest National Laboratory. The guides are available as free downloads from http://www.ashrae.org/aedg.

The AEDGs include prescriptive, climate zone-specific recommendations for the design of the building envelope, fenestration, lighting systems (including electrical lights and daylighting); plug loads; heating, ventilation, and air-conditioning (HVAC) systems, building automation and controls; outside air (OA) treatment; and service water heating (SWH). Additional savings recommendations for items such as renewable energy systems are also included, but are not necessary to achieve 50% savings.

Building designers comply with minimum energy code requirements, but often lack the opportunity or have insufficient design fees to pursue innovative, energy-efficient strategies. The AEDGs present user-friendly prescriptive design assistance to owners and designers who want greater energy efficiency than they can achieve through minimum code compliance.

The purpose of the 50% AEDGs is to significantly transform the marketplace with speed and scale by providing user-friendly, "how-to" design guidance and efficiency recommendations to owners, builders, energy modelers, and designers of the applicable building types to achieve energy savings of 50% over ASHRAE Standard 90.1-2004. Designer experience with the AEDGs will increase skill and knowledge related to energy efficiency strategies and technologies that can be applied to a variety of building projects beyond those defined in the guides.

This paper describes the development of energy efficiency recommendations for the 50% AEDG series. Our objectives are to:

- Describe the purpose, intent, and goal of the 50% AEDGs.
- Describe the steps that were taken to demonstrate the achievement of a 50% reduction in whole-building energy use via the implementation of industry-vetted, economically replicable, and commercially available technologies.
- Describe the format of the guides.
- Present the energy simulation analysis results.
- Summarize the recommended packages of energy efficiency measures that achieved at least 50% energy savings in all 16 U.S. climate zones, relative to Standard 90.1-2004.

Overview of the 50% AEDG Series

Each AEDG was developed by a project committee (PC) representing a diverse group of commercial building design professionals. Alongside the PC, an energy modeling team used whole-building energy simulation to analyze packages of potential design strategies. The energy models were formulated via a one-year iterative process, in parallel with the guide development;

discussions about the model inputs and the model results were held with the PC. Results from the modeling, combined with input from the PC, led to the final recommendations. The goal of 50% energy savings over Standard 90.1-2004 was the primary focus of the 50% AEDGs. Recommendations reflect efficiency best practices and the related energy savings, without any particular restrictions related to economic payback.

The recommendations of the 50% AEDGs meet the 50% savings goal for each of the U.S. climate zones covered by the guides. This is a hard goal as opposed to an approximate target, and represents a significant step toward increased energy efficiency beyond the 30% AEDGs. Energy savings are achieved by identifying packages of design measures and state-of-the-art building systems and design concepts that result in energy-efficient spaces.

The intended audiences of the 50% AEDGs are:

- Owners and design teams of the particular building types who are interested in 50% energy savings and supported by energy modeling expertise. This is typically a sophisticated design team that can use modeling to evaluate prospective designs to ensure they meet AEDG recommendations.
- Engineers and designers who are interested in developing the skills needed to achieve 50% energy savings in buildings.

The recommendations in the 50% AEDGs follow two distinct paths: (1) a prescriptive path, for which tables of recommendations are provided for the most common 50% design strategies and alternative design strategy subsystem performance; and (2) a performance-based path based on whole-building energy use. Prescriptive measures are assigned performance-based benchmarks. The performance-based path allows increased design freedom, requiring adherence to a performance-based benchmark only with respect to whole-building energy use intensity. Recommendations are presented in a user-friendly format to ease the burden for designers and give decision makers an easy-to-follow overview of the design process. Recommendations do not specify unique products; all recommended products must be available from at least two manufacturers. We used best practice examples of design and technology and up-to-date performance and cost inputs to develop the recommendations. They illustrate how to apply integrated design concepts, design process, and team working relationships to minimize implementation costs.

Several case studies are included in the guides to provide examples of whole-building integrated design concepts and the implementation of energy-efficient components or techniques. Some case studies are specific to particular geographic regions.

The AEDGs are not intended to substitute for rating systems or references that address the full range of sustainable issues in buildings, such as acoustics, productivity, indoor air quality, water efficiency, landscaping, and transportation, except as they relate to operational energy consumption. Nor are they intended to be design texts; the AEDGs assume that good design skills and expertise in building design will be used to successfully apply the design recommendations.

Development Process

The AEDGs were developed by a PC that represents a diverse group of professionals. ASHRAE, AIA, IES, USGBC, and DOE collaborated to provide guidance and support. Members of the PC came from these partner organizations, the ASHRAE Standing Standards Project

Committee 90.1, and various ASHRAE technical committees. A steering committee (SC) made up of representatives of ASHRAE, AIA, IES, USGBC, ASHE, and DOE oversaw the PC as the guides were developed. The SC assigned a timeline for the task, an energy savings goal, a target audience, space types to include, and possible topics to incorporate.

Following SC guidance, the PC developed a one-year plan for completing each document. The PC used a schedule to plan for two peer review periods that corresponded with a 65% completion draft (technical refinement review) and a 90% completion draft (final review for errors). Many meetings and conference calls were also held with the full PC during the development of each guide.

Evaluation Approach

The guides contain sets of energy efficiency recommendations for each of the U.S. climate zones across the United States. The following steps describe how the energy savings potential of the each guide's recommendations was determined.

Develop "typical" facility models

For building characteristics that are not specified by Standard 90.1 but that are needed to develop code-compliant models, the PC surveyed publication data to determine "typical" facility characteristics (form and floor plate, ventilation rates, operating schedules, etc.). The publications surveyed include the 2003 Commercial Buildings Energy Consumption Survey (EIA 2003); The DOE Buildings Database (http://eere.buildinggreen.com/); McGraw Hill Dodge construction data (http://www.construction.com/dodge/); DOE Commercial Buildings Reference Building Models (Deru et al. 2011); and ASHRAE Standard 62.1-2004 (ASHRAE 2004b).

Create energy models that are minimally code compliant with Standard 90.1-2004

Code-compliant models were developed by applying the applicable criteria in Standard 90.1-2004 to the "typical" facility models. The energy modeling assumptions obtained from Standard 90.1-2004 informed the development of envelope characteristics, building lighting loads, HVAC equipment efficiencies, controls, sizing, fan power assumptions, and SWH efficiencies.

Create energy models based on the recommended energy efficiency technologies

The final recommendations were determined based on an iterative process combining each PC's expertise and modeling results. To quantify the potential energy savings from the final recommended energy efficiency measures, low-energy building models were simulated by implementing the following energy efficiency technologies. The energy efficiency measures that were applied to all climate zones and included in resultant energy savings calculations are:

- Enhanced building opaque envelope insulation
- Enhanced window glazing with overhangs
- Reduced lighting power density (LPD) and occupancy control
- Reduced plug and process loads and improved control of those loads
- Daylighting

- Higher efficiency HVAC equipment and systems
- High-efficiency SWH

Verify 50% energy savings across the various HVAC system types across the U.S. climate zones

EnergyPlus was used to perform building energy simulation analyses to assess and quantify the energy savings potential of the guides' recommendations. Two series of simulations were run for each building type: the first meets the minimum requirements of Standard 90.1-2004; the second incorporates the recommendations in the corresponding guide to achieve 50% energy savings. For each low-energy design, a variety of HVAC equipment types were modeled. The recommendations result in greater than 50% energy savings in all climate zones for each building type for the documented range of HVAC system types.

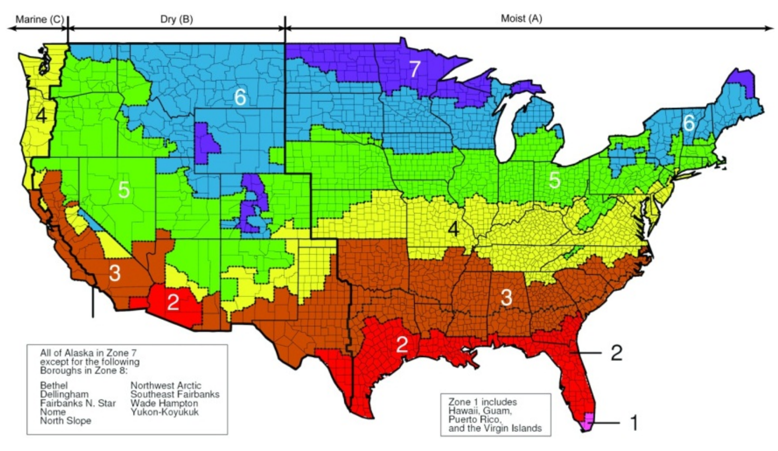
Modeling Methods

Climate Zones

The guide contains a unique set of energy efficiency recommendations for a range of climate zones. DOE has identified eight climate zones for the United States, each defined by county borders, as shown in Figure 1 (DOE 2005). Climate zones are categorized by heating degree days and cooling degree days, and range from the very hot zone 1 to the very cold zone 8. Some climate zones are divided into subzones based on humidity levels. Humid subzones are "A" zones, dry subzones are "B" zones, and marine subzones are "C" zones. The combination of climate zones 1 through 8, along with their respective subzones ("A," "B," and "C") results in 16 unique climate zones.

Figure 1 Climate Zone Map

(Credit: DOE 2005)



16 specific climate locations (cities) were selected as being most representative of the 16 unique climate zones. To determine energy savings, Typical Meteorological Year 2 weather files for each location were used to simulate the energy models:

- Zone 1: Miami, Florida (very hot, humid)
- Zone 2A: Houston, Texas (hot, humid)
- Zone 2B: Phoenix, Arizona (hot, dry)
- Zone 3A: Atlanta, Georgia (warm, humid)
- Zone 3B: Las Vegas, Nevada (warm, dry) and Los Angeles, California (warm, dry)
- Zone 3C: San Francisco, California (warm, marine)
- Zone 4A: Baltimore, Maryland (mixed, humid)
- Zone 4B: Albuquerque, New Mexico (mixed, dry)
- Zone 4C: Seattle, Washington (mixed, marine)
- Zone 5A: Chicago, Illinois (cool, humid)
- Zone 5B: Denver, Colorado (cool, dry)
- Zone 6A: Minneapolis, Minnesota (cold, humid)
- Zone 6B: Helena, Montana (cold, dry)
- Zone 7: Duluth, Minnesota (very cold)
- Zone 8: Fairbanks, Alaska (subarctic)

Analysis Platform and Approach

EnergyPlus (DOE 2010a, 2010b, 2011) was used to perform the energy simulations. EnergyPlus is a building simulation tool that accounts for the complicated interactions between climate, internal gains, building form and fabric, HVAC systems, and renewable energy systems. Alongside EnergyPlus, software research tools that integrate with EnergyPlus were used to create and manage the EnergyPlus input files.

Layout and Content

Goal, Scope, and Usage Recommendations

The 50% AEDGs begin with content that details their overall goals and scopes, and informs readers how to leverage guide content to achieve significant energy savings. Goals are shared between the guides (achieving 50% site energy savings beyond the requirements of Standard 90.1-2004) and are guide-specific (some guides contain building type-specific guidance for setting whole-building absolute energy targets that reflect recommended design, construction, and operation practices). The scope for each guide is clearly defined, including represented building functionality, space types, size, design, and constructions. A how-to section summarizes the content of each chapter and identifies key design opportunities.

Integrated Design Guidance

A key aspect of the approach that the 50% AEDG series recommends for achieving 50% site energy savings beyond Standard 90.1-2004 is integrated design, a holistic approach to design that focuses on optimizing the synergy between building systems, as opposed to independent design at the system level. Each AEDG highlights how the principles of integrated design can be used at each stage of design, construction, and operation (and, more specifically, key stakeholder roles at each stage) to improve energy efficiency cost effectively. This content is valuable for designers and builders who want to augment and improve their practices so energy efficiency is deliberately considered at each stage of the development process, from project conception through building operation. Each guide features specific details about the integrated design process, including step-by-step guidance for the four process phases: predesign, design, construction, and acceptance/occupancy/operation.

Integrated Design Strategies and the Performance-Based Path

The AEDGs employ case studies to demonstrate successful implementation of efficiency and integrated design strategies. Case studies highlight successful, economically replicable strategies, providing users with lessons learned during real-world projects. Each case study reflects and reinforces a subset of recommended strategies. Readers are encouraged to view more case studies at http://www.ashrae.org/aedg, and to submit their own. Case studies provide the motivation and the examples for others to follow.

In a departure from the 30% AEDG series, which focused solely on a prescriptive design approach to improving energy efficiency, the 50% AEDG series also presents a performance-based path to achieving the efficiency goal. As savings targets become more aggressive, it becomes less and less practical to recommend a one-size-fits-all approach to design. Recognizing that a particular prescriptive design approach may not apply to all situations, the 50% AEDGs supplement detailed prescriptive recommendations with a performance-based approach that can be applied to all projects. In particular, many of the 50% AEDGs present whole-building absolute energy targets that reflect recommended strategies and encourage design teams to develop innovative, project-specific solutions that can leverage the principles of integrated design to maximize the cost effectiveness of high-performance design.

Prescriptive Design Recommendations

A primary focus of the 30% and 50% AEDG series is to provide users with detailed, climate-specific, prescriptive design recommendations that align with the efficiency target. Recommendations are tabulated and organized by category: envelope, electric lighting, daylighting, HVAC, and SWH. Where applicable, recommendations are specific to construction and equipment type, such that the applicability of the prescriptive recommendations is as broad as possible for the stated efficiency goal. For each guide, prescriptive tables of recommendations are provided for each U.S. climate zone. As mentioned with regard to the performance-based path, the prescriptive path represents a subset of the approaches, but not the only approaches, to achieve the desired performance goal. Other approaches may also save energy, but identifying all possible solutions is beyond the scope of these guides; the user needs to ensure that other approaches save energy cost effectively.

The AEDGs assumes compliance with the more stringent of either the applicable edition of Standard 90.1 or the local code requirements for all areas not addressed in the climate-specific recommendation tables. Future editions of energy codes may have more stringent requirements. In such cases, the more stringent requirements are recommended.

Recommendation Implementation

The 50% AEDGs explain how to implement the prescriptive design recommendations, and caution users about known problems in energy-efficient design and construction. This guidance is divided into the following categories: quality assurance and commissioning, envelope, lighting, daylighting, HVAC, SWH, and bonus savings. The bonus savings category highlights additional good practices that, if implemented properly and in conjunction with the prescriptive recommendations, should result in energy savings greater than 50%.

The quality assurance and commissioning category contains specific details about commissioning and its importance in every step of the design process. The envelope category contains climate zone-specific guidance related to walls, roofs, floors, doors, insulation, infiltration, and vertical fenestration. The lighting category details best practices for interior finishes, lamp and ballast types, lighting layouts, and control strategies for specific space types. The daylighting category provides tips on general principles, using daylighting analysis tools, daylighting space types and layouts, building shape and orientation with respect to daylighting, window-to-wall or window-to-floor-area ratios, sidelighting, toplighting, skylight construction, shading devices, photosensor specification, and photocell placement.

The HVAC category includes good practices for multiple-zone variable air volume air-handling systems, water source (including ground source) heat pumps, dedicated outdoor air systems (DOASs), HVAC load calculations, equipment efficiencies, economizers, exhaust air energy recovery, ductwork design, duct insulation, duct sealing, exhaust air systems, system-level control strategies, filters, chilled water systems, heating water systems, and zone-level controls.

The bonus savings category includes good practices for renewable energy generation (photovoltaic and solar hot water systems and wind turbines), additional HVAC systems (condenser water heat recovery, ground source heat pumps, displacement ventilation, demand controlled ventilation, thermal storage, desiccant-based dehumidification, and evaporative condensing), and electrical distribution systems (transformer efficiencies and metering).

Energy Savings Results

Hourly building energy simulations were used to quantify the energy savings for the AEDGs. Two series of hour-by-hour simulations were run for each building type. The first series meets the minimum requirements of Standard 90.1 and the second incorporates the recommendations in the AEDG. The AEDG recommendations include multiple HVAC system types, requiring a separate low-energy model to be generated for each HVAC system type in the AEDG.

The energy models demonstrate that the recommendations of the guides meet the 50% savings goal for each U.S. climate zone. The 50% savings goal is a hard goal as opposed to an approximate target. Complete results of the analyses are presented in the Technical Support Documents that accompany each AEDG (Bonnema et al. 2010, 2011, Hale et al. 2009, Thornton et al. 2010, 2011).

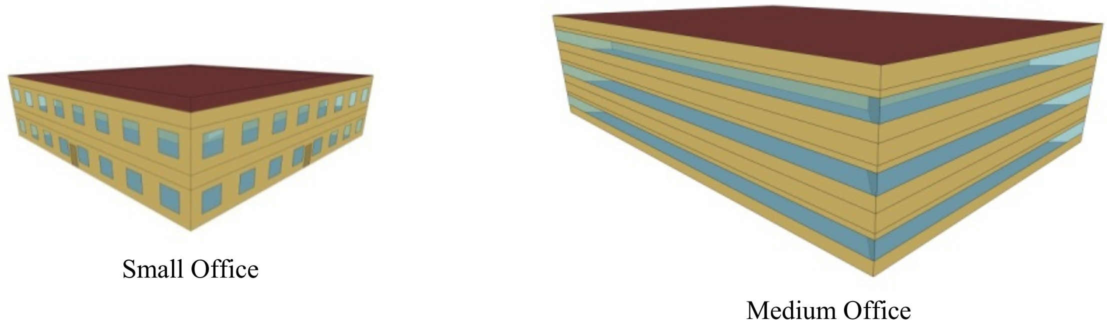
Small to Medium Office Buildings

This AEDG defines a small to medium office building as one that has both open plan and private offices; conference rooms; corridors, stairways, and transition spaces; lobbies and lounges; and storage spaces and mechanical/electrical rooms.

This guide does not consider specialty spaces such as data centers, which are more typical in large office buildings. This AEDG applies to office buildings up to 100,000 ft^2. Recommendations are based on two designs: a 20,000-ft^2 small office and a 53,000-ft^2 medium office. Renderings of the two designs are shown in Figure 2.

Figure 2 Small and Medium Office Energy Model Renderings

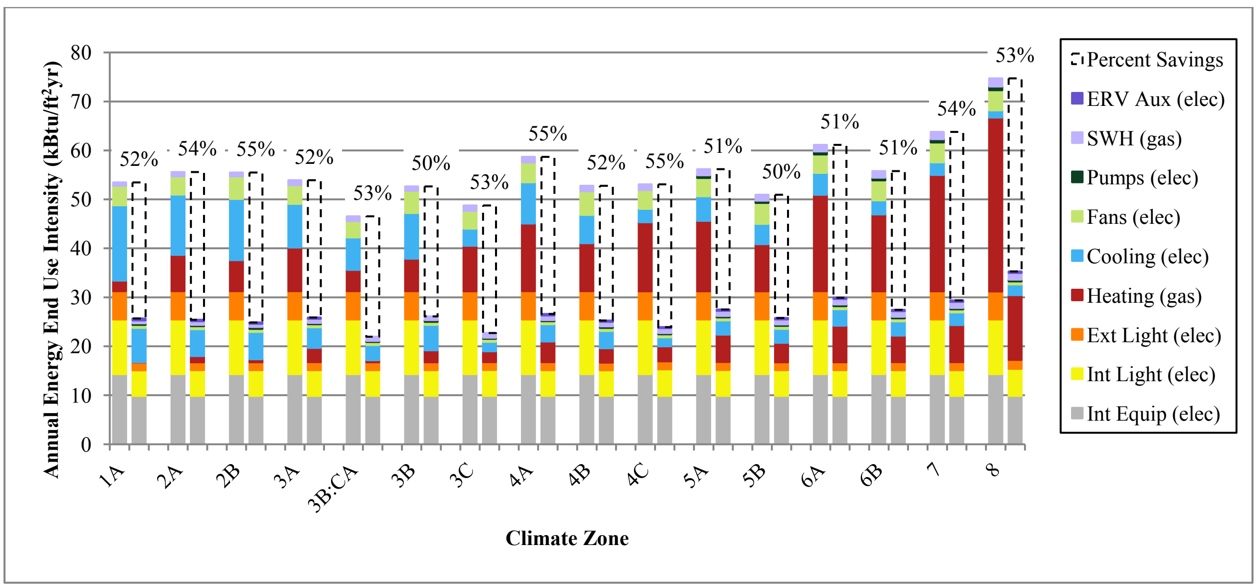
(Credit: Thornton et al. 2009, 2010)



This AEDG includes recommendations for six HVAC system types; Figure 3 demonstrates an example of the energy modeling results for the medium office with radiant heating and cooling.

Figure 3 Medium Office Model with Radiant Heating and Cooling

(Credit: Thornton et al. 2009)



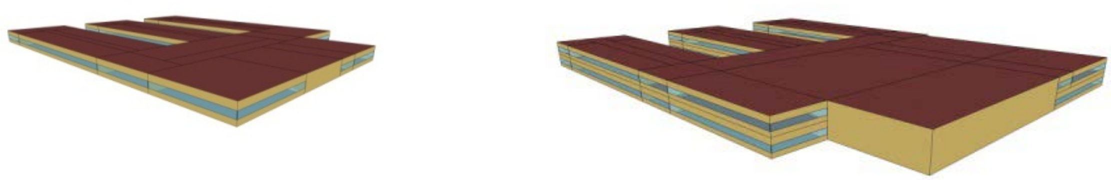
A review of the energy simulation results shows that, on average, the prescriptive design recommendations result in about 73% heating energy savings and about 34% cooling energy savings. The percentage of heating and cooling energy savings varies significantly with climate. Fan energy is reduced by about 84%, mainly from radiant heating and cooling. The lighting-related measures eliminate about 53% of interior lighting energy and 72% of exterior lighting energy. Plug-in electric equipment energy is reduced by about 31% because of changes in equipment and associated controls. Water heater efficiency improvement leads to about 16% energy reduction for SWH.

K-12 School Buildings

This 50% AEDG defines a K-12 school as one that has administrative and office areas; classrooms, hallways, and restrooms; gymnasiums with locker rooms and showers; assembly spaces with either flat or tiered seating; food preparation spaces; and libraries or media centers.

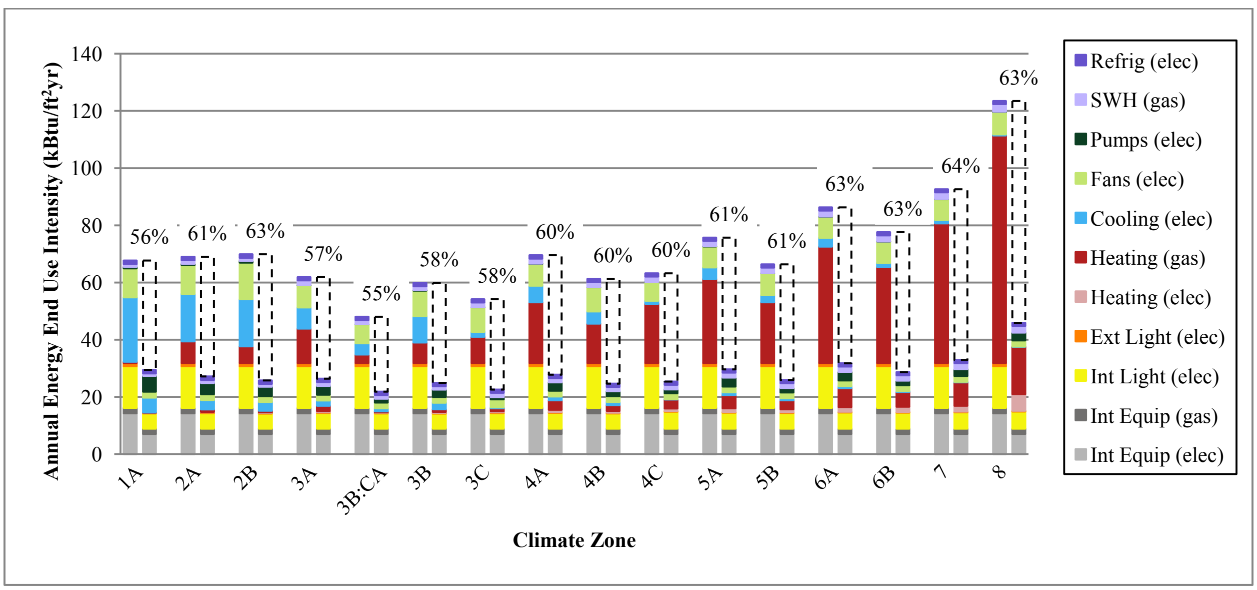
This guide does not consider atypical specialty spaces such as indoor pools, wet labs (e.g., chemistry), "dirty" dry labs (e.g., woodworking and auto shops), or other unique spaces that generate extraordinary heat or pollution. This AEDG applies to all sizes and classifications (elementary, middle, and high schools) of new construction K-12 schools. Recommendations are based on two designs: a 74,500-ft^2 elementary school and a 205,000-ft^2 high school. Renderings of the two designs are shown in Figure 4.

Figure 4 Primary and Secondary School Energy Model Renderings
(Credit: Bonnema et al. 2011)



This AEDG includes recommendations for three HVAC system types; Figure 5 demonstrates an example of the energy modeling results for the primary school with ground source heat pumps.

Figure 5 Primary School Model with Ground Source Heat Pumps
(Credit: Bonnema et al. 2011)



A review of the energy simulation results shows that, on average, the prescriptive design recommendations result in about 82% heating energy savings and about 77% cooling energy savings. The percentage of heating and cooling energy savings varies significantly with climate.

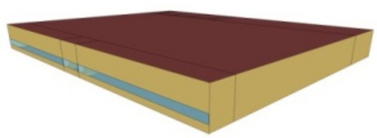
Fan energy is reduced by about 74%, mainly from zone-level ground source heat pumps and a DOAS. The lighting-related measures eliminate about 62% of interior lighting energy and 75% of exterior lighting energy. Electric equipment energy is reduced by about 50% and natural gas equipment by about 3% because of changes in equipment and associated controls. Water heater efficiency improvement leads to about 11% energy reduction for SWH.

Medium to Big Box Retail Buildings

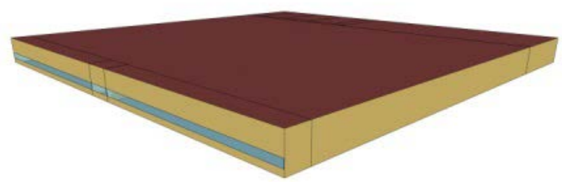
This 50% AEDG defines a medium to big box retail building as one that has sales areas; administrative and office areas; meeting and dining areas; hallways and restrooms; and storage spaces and mechanical/electrical rooms.

This AEDG applies primarily to retail buildings with 20,000 ft^2 to 100,000 ft^2 of floor area; however, many of the recommendations apply to smaller and larger retail buildings as well. Recommendations are based on three designs: a high and low plug load version of a 40,000-ft^2 medium box store and a low plug load version of a 100,000-ft^2 big box store. Renderings of the two energy models are shown in Figure 6.

Figure 6 Medium and Big Box Store Energy Model Renderings
(Credit: Hale et al. 2009)



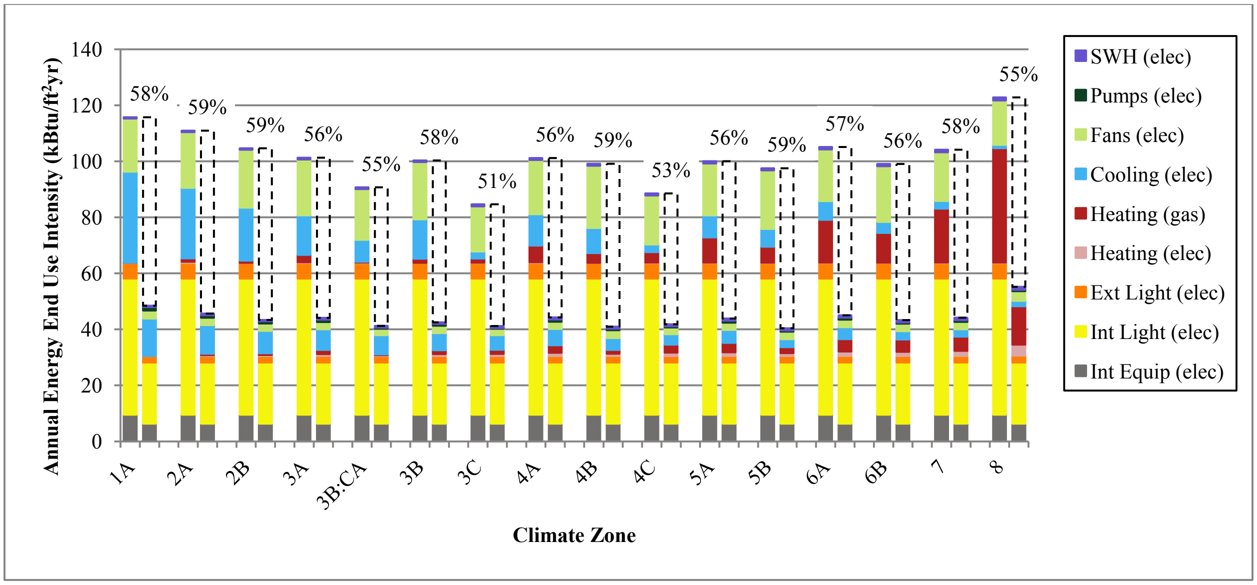
Medium Box Store



Big Box Store

This AEDG includes recommendations for five HVAC system types; Figure 7 demonstrates an example of the energy modeling results for the medium box retail store with water source heat pumps.

Figure 7 Medium Box Retail Store Model with Water Source Heat Pumps
(Credit: Hale et al. 2009)



A review of the energy simulation results shows that, on average, the prescriptive design recommendations result in about 26% heating energy savings and about 22% cooling energy savings. The percentages of heating and cooling energy savings vary significantly with climate. Fan energy is reduced by about 86%, mainly from zone-level water source heat pumps and a DOAS. The lighting-related measures eliminate about 55% of interior lighting energy and 58% of exterior lighting energy. Electric equipment energy is reduced by about 34% because of changes in equipment and associated controls.

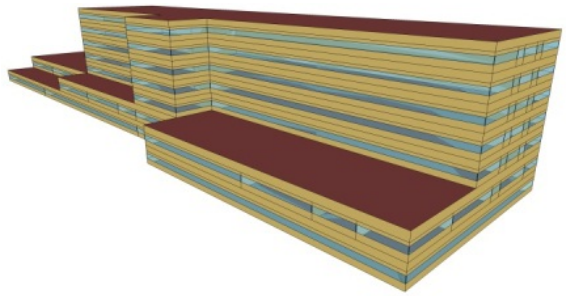
Large Hospitals

This 50% AEDG defines a large hospital as one that has cafeterias, kitchens, and dining facilities; administrative, 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, hallways, lockers, and restrooms; operating rooms, procedure rooms, recovery rooms, and sterilizer equipment areas; pharmacies, medication rooms, laboratories; triage, trauma, and emergency rooms; physical therapy and imaging/radiology rooms; and storage, receiving, laundry, and mechanical/electrical/telecomm rooms.

This AEDG applies to all new construction hospital buildings larger than 100,000 ft^2. Recommendations are based on a 427,000-ft^2 hospital design. A rendering of the modeled design is shown in Figure 8.

Figure 8 Large Hospital Energy Model Rendering

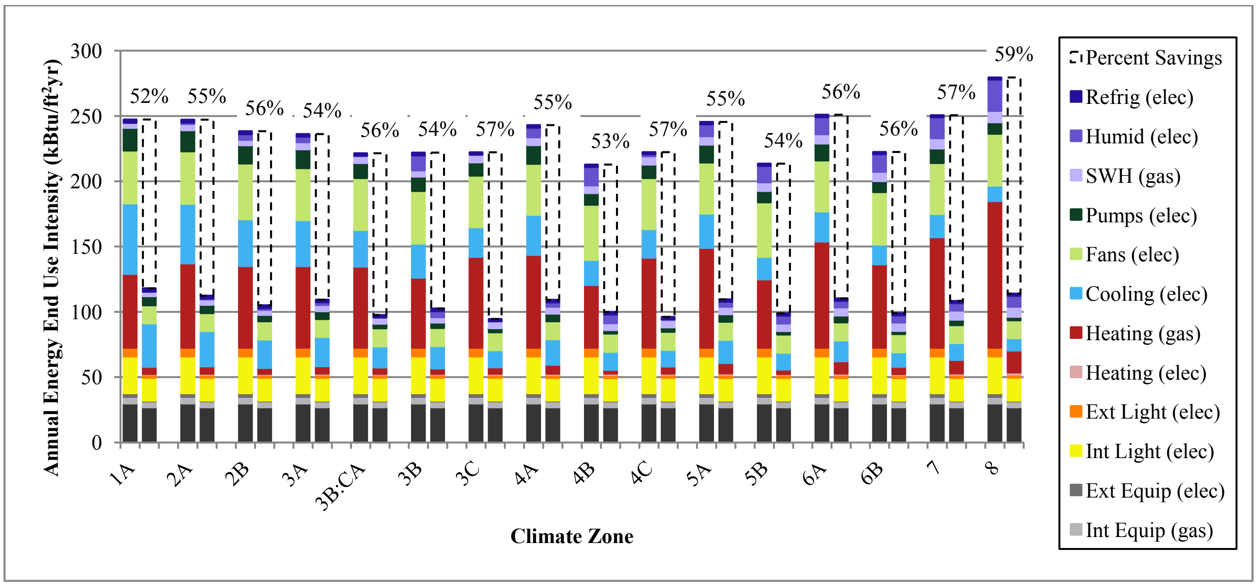
(Credit: Bonnema et al. 2010)



This AEDG includes recommendations for three HVAC system types; Figure 9 demonstrates an example of the energy modeling results for the large hospital with water source heat pumps.

Figure 9 Large Hospital Model with Water Source Heat Pumps

(Credit: Bonnema et al. 2010)



A review of the energy simulation results shows that, on average, the prescriptive design recommendations result in about 90% heating energy savings and about 34% cooling energy savings. The heating savings are fairly consistent across climate zones as they result mostly from the elimination of reheat. Fan energy is reduced by about 66%, mainly from zone-level ground source heat pumps and a DOAS. The lighting-related measures eliminate about 39% of interior lighting energy and 64% of exterior lighting energy. Electric equipment energy is reduced by about 10% and natural gas equipment by 10% because of changes in equipment and associated controls. Water heater efficiency improvement leads to about 11% energy reduction for SWH. Elevator energy use is reduced 75% with better equipment; pumping and humidification energy are reduced 64% and 58%, respectively.

Recommendation Summary

Most aspects of designing and constructing a high-performance commercial building, including the building envelope, lighting and daylighting, plug loads, SWH, HVAC, and quality assurance, are covered by recommendations in the AEDGs. In general, the 50% AEDGs recommend a building envelope that is approximately 45% more insulated than Standard 90.1-2004. The guides also contain space-by-space interior and exterior LPD recommendations that result in significantly lower whole-building LPD than required by Standard 90.1-2004. Exterior lighting recommendations reduce lighting power for parking lots and drives by more than 33% over Standard 90.1-2004. The guides recommend ENERGY STAR® exclusive plug-in equipment, best-in-class plug-in equipment where ENERGY STAR does not apply, and best-in-class commercial kitchen equipment. In general, the HVAC recommendations decouple the space conditioning load from the ventilation load, either with a DOAS and zone-level conditioning equipment or advanced variable air volume with separate OA treatment, resulting in significant energy savings over standard equipment. Additional HVAC recommendations include best-in-class equipment efficiencies, demand controlled ventilation, and airside energy recovery. SWH recommendations result in savings of 13% over Standard 90.1-2004, on average. The following subsections highlight a few of the building type specific recommendations that are in each 50% AEDG.

Small to Medium Office Buildings

- Interior lighting recommendations that result in a 25% reduction in whole-building LPD.
- Guidance for improving energy efficiency in perimeter zones as part of façade zone optimization.
- Daylighting recommendations for open-plan offices, private offices, conference rooms, and public spaces (lobbies, reception/waiting areas).
- Sample lighting layouts for open offices, private offices, conference/meeting rooms, corridors, storage areas, and lobbies.
- Radiant floor heating and cooling strategies.

K-12 School Buildings

- Interior lighting recommendations that result in a 42% reduction in whole-building LPD.
- Daylighting strategies for a number of space types, including top- and sidelighting of classrooms and toplighting of gymnasiums.
- Numerous tips to conserve energy in K-12 kitchens and cafeterias.
- Cost control strategies and best practices related to high-performance schools, as well as key design strategies for controlling capital costs.
- Tips for using the building as a teaching tool.

Medium to Big Box Retail Buildings

- Interior lighting recommendations that result in a 38% reduction in whole-building LPD.
- Strategies for reducing energy use across a portfolio of retail stores.
- Tips on successful daylight integration in a retail setting.

- Perimeter wall accent and light-emitting diode display lighting tips.
- Parking lot lighting energy use reduction and control strategies.
- Sales floor and security system plug load recommendations.

Large Hospitals

- Interior lighting recommendations that result in a 25% reduction in whole-building LPD, including light-emitting diode surgery light recommendations that save 60% of the energy used for surgery lighting and significantly reduce the energy demands of cooling the surgeons and warming their patients.
- Install traction elevators exclusively throughout the building. Install regenerative traction elevators for high use.
- Aggressive reduction in reheat resulting from decoupling space conditioning loads and ventilation loads; recommending a heat recovery chiller, aggressive supply air temperature reset, and zone airflow setback; airside pressure drop and coil face velocity reductions; elimination of steam boilers; and high delta T chilled water loops.

Conclusion

The 50% AEDGs provide simple, easy-to-use guidance to help the building designer, contractor, and owner identify a clear path to 50% energy savings over Standard 90.1-2004. In many ways, the AEDGs are a simple interface with a complex background analysis performed using EnergyPlus. The combination of a comprehensive set of recommendations contained within a single table, along with numerous how-to tips to help the construction team execute the project successfully, result in increased energy efficiency in new buildings. Case studies of actual facility applications add to the comprehension of energy efficiency opportunities. The ultimate goal of the AEDG partner organizations is to achieve net-zero (Torcellini et al. 2006) energy buildings, and the 50% savings guides represent a step towards reaching this goal. To date, there are over 425,000 AEDGs in circulation. AEDGs are available as a free download from http://www.ashrae.org/aedg.

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