NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Advanced Energy Design Guides (AEDGs)

Renewable Energy and Energy Efficiency for Tribal Community Development

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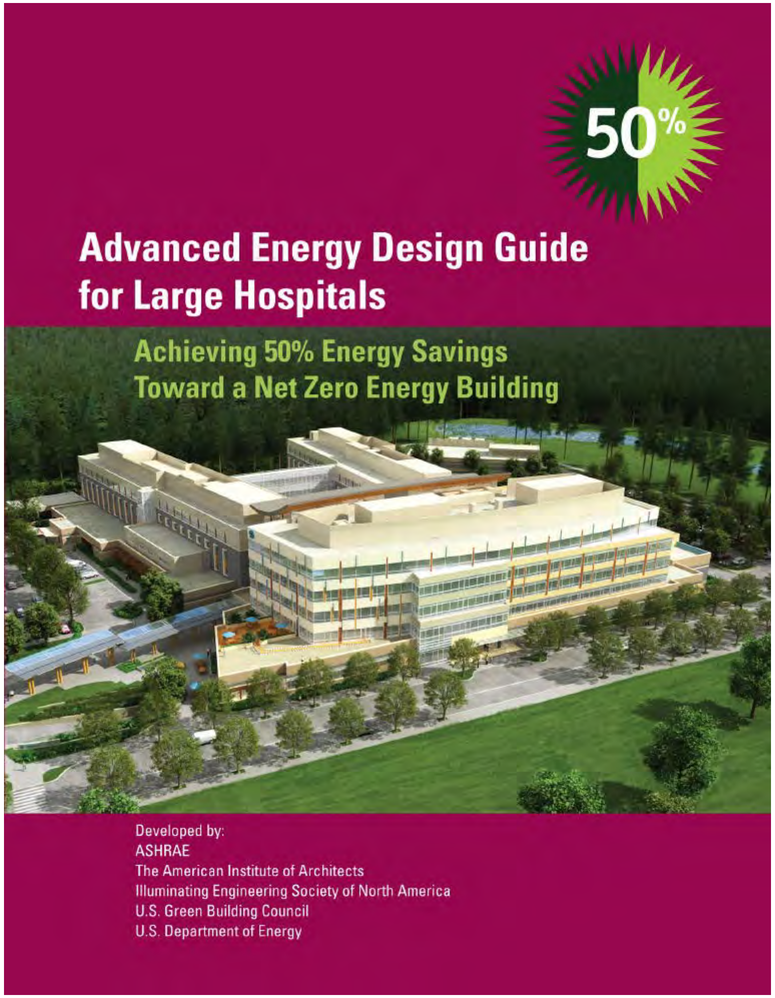
Presentation Overview

- AEDG Overview
- 50% AEDG Content Details
- 50% AEDG Recommendation Overview
- 50% AEDG Energy Modeling Analysis
- Q&A

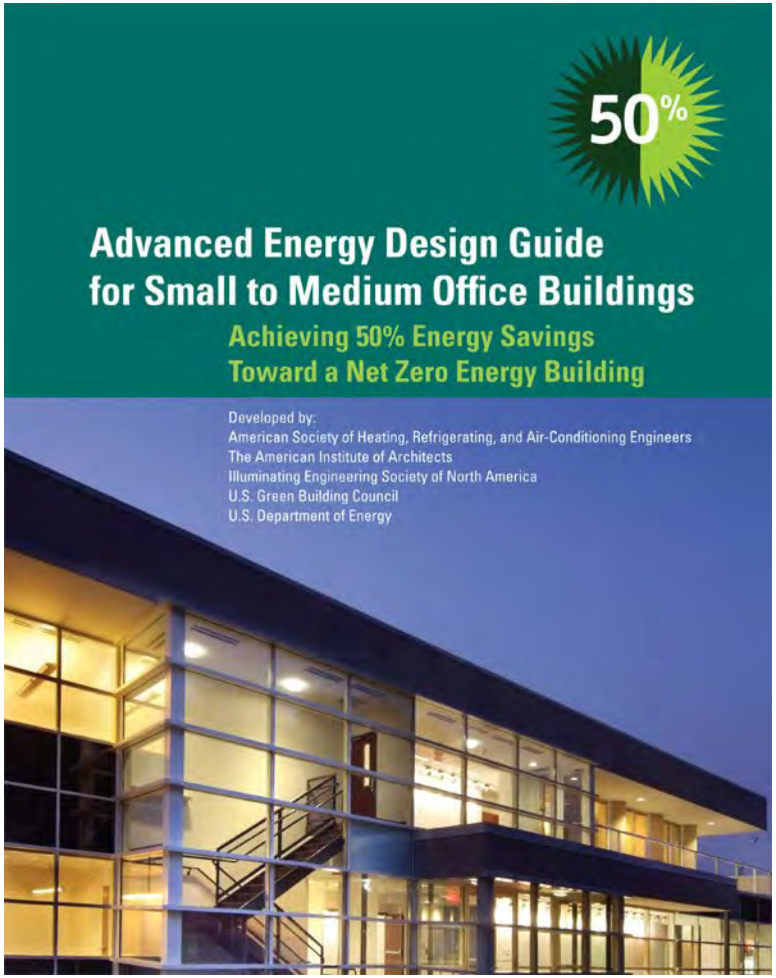
What Is an AEDG?



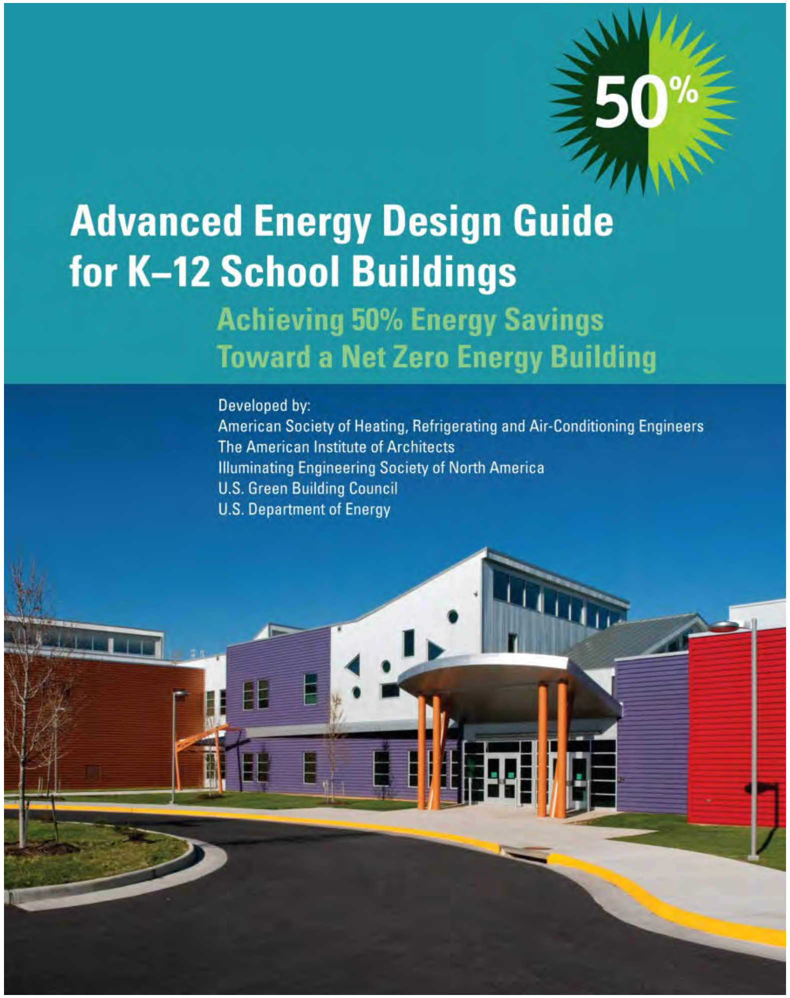
- **A series of publications that provide prescriptive energy savings guidance and recommendations by building type and geographic location**
- **The publications contain design packages and strategies to help owners and designers achieve site energy savings over Standard 90.1**

What Is an AEDG?

- **Developed in collaboration with ASHRAE, AIA, IES, USGBC, DOE**
- **Two series:**
  - Original series targeted 30% savings over 90.1-1999
  - Current series targets 50% savings over 90.1-2004
- **Educational guidance—not a code or standard**
- **Available for free as a PDF download from www.ashrae.org/freeaedg**



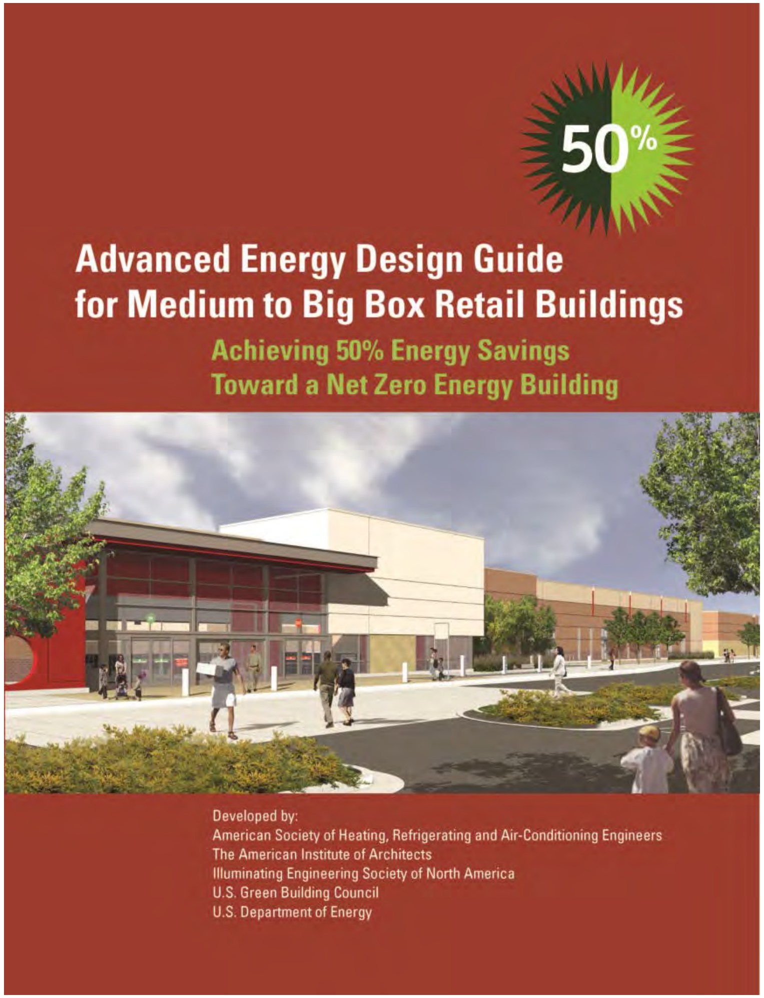
Why Are AEDGs Needed?



- **The U.S. commercial building sector is responsible for approximately 20% of the nation's energy use**
- **According to the Energy Information Agency's 2010 Annual Energy Outlook, energy consumption has been forecasted to increase by 1.4% each year from 2009 to 2035**
- **Most building designers do not have access to the resources they need to evaluate energy efficiency beyond basic code recommendations**

Why Are AEDGs Needed?

- **Easy-to-use and proven recommendations are needed that do not require users to undertake detailed calculations or analyses to reach the broadest possible audience**
- **AEDGs address this need by leveraging available analysis techniques to rapidly develop pre-engineered solution sets**
- **These prescriptive how-to guides target 50% energy savings over code that owners, architects, engineers, contractors, and facility managers can act on**

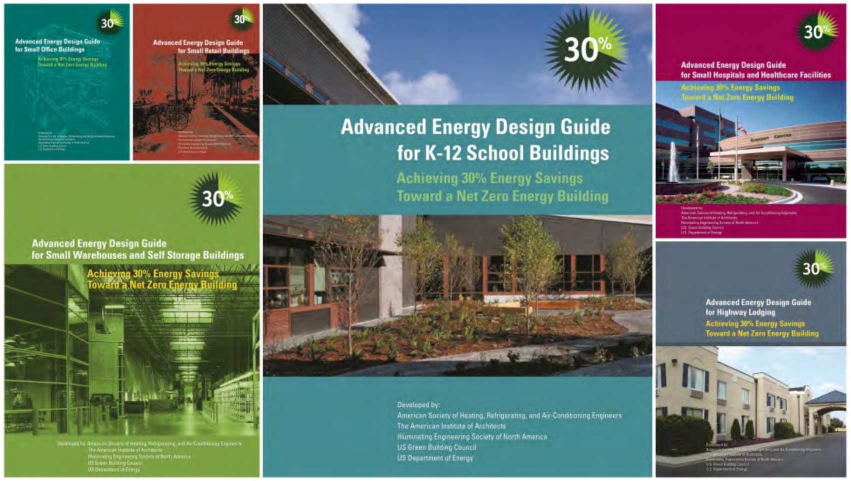


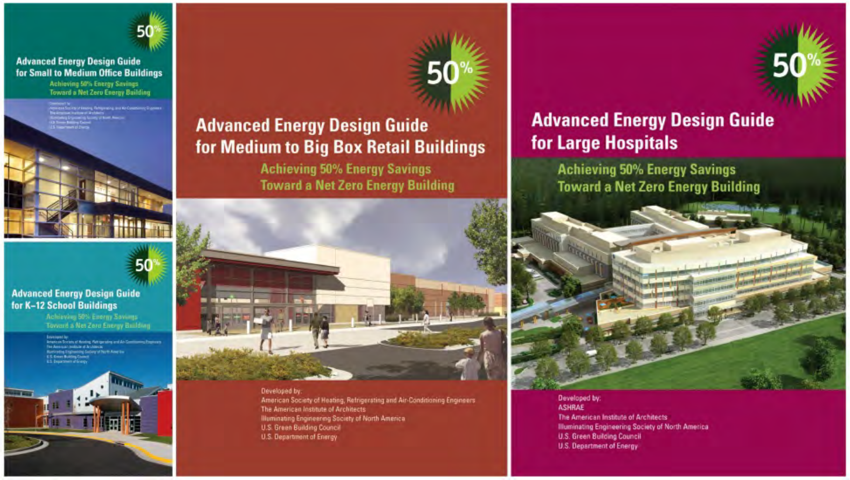
Ground Rules for Prescriptive Path (50%)

- Products must be available from at least two manufacturers
- Systems must be within first cost range of conventional systems
- Savings are determined based on modeling using Standard 90.1-2004 as the base case
- All systems and products must be compliant with Standard 90.1-2010
- Systems must provide compliance with Standard 62.1-2010 and ASHRAE 55-2010

Published AEDGs

- **30% guides**
  - o Small office buildings
  - o Small retail buildings
  - o K-12 school buildings
  - o Small warehouse and self-storage buildings
  - o Highway lodgings
  - o Small hospitals and healthcare facilities
- **50% guides**
  - o Small to medium office (SMO) buildings
  - o K-12 school buildings
  - o Medium to big box retail (MBR) buildings
  - o Large hospitals (LH)





TSDs and AEDGs

- **The national laboratories (NREL and PNNL) publish a technical support document (TSD) as a precursor to the AEDG. The TSD contains:**
  - The technical analysis and resulting design guidance to achieve energy savings
  - An analysis of cost effectiveness
- **The AEDG expands on the TSD analysis with how-to tips, case studies, and details on how to implement the design recommendations**
- **An updated TSD is then published that documents the development of the AEDG**

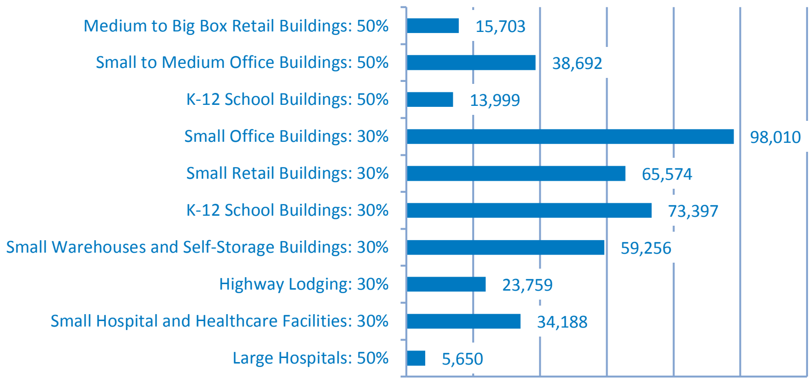
AEDG Partnership

- Collaboration of professional organizations and DOE
- Specialized Project Committee (PC) for each AEDG
- Oversight is provided via an AEDG Steering Committee (SC)
- Backed by DOE national laboratory leadership, energy simulation, technical analysis, and support
- Open peer review and commentary process

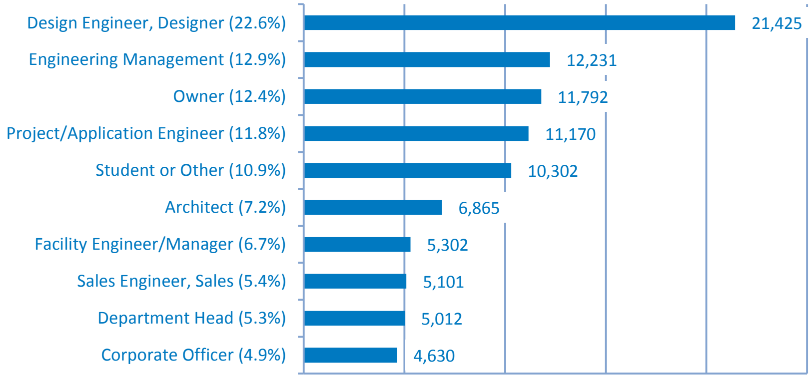
Impact and Distribution

- **As of July 5, 2012**
  - 450,578 copies in circulation
    - 428,228 electronic
    - 22,350 print
- **Promote worldwide building energy efficiency**
- **Referenced in RFP specifications**
- **Influence**
  - ASHRAE Standard 90.1
  - ASHRAE/USGBC/IES Standard 189.1
- **Alternative compliance path for LEED rating system**

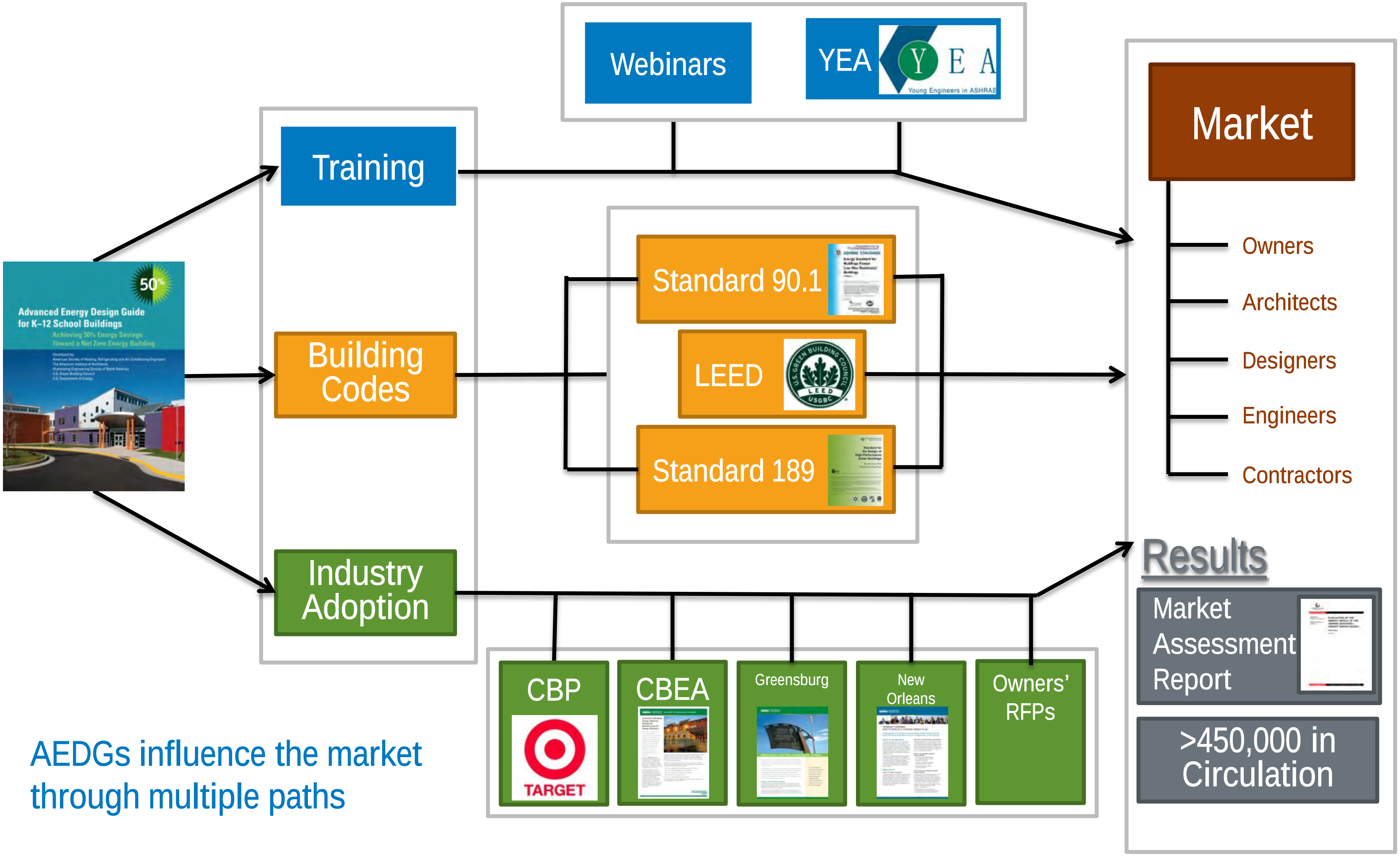
Title … Quantity in Circulation



Job Title … Percent … Quantity



AEDG Path to Market



AEDGs influence the market through multiple paths

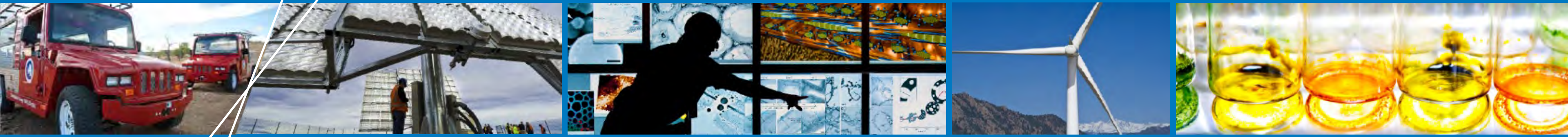
Guide Development and Contents

Development Process

- SC with members from ASHRAE, AIA, IES, USGBC, DOE
  - Oversee all AEDGs
  - Members review but do not contribute directly to the guide
- PC with members from ASHRAE, AIA, IES, USGBC, DOE
  - Leaders in their field, design or work with high-performance buildings
  - Contribute directly to AEDG (main authors)
  - Volunteers

Contents

- Foreword: Make the Non-Energy Case to Decision Makers
- Chapter 1: How to Use the Guide
- Chapter 2: Expanded Guidance on Integrated Design Process and Strategies
- Chapter 3: Performance Targets and Whole Building Case Studies
- Chapter 4: Prescriptive Recommendations by Climate Zone
- Chapter 5: How To Implement Recommendations (how-to tips) and Technical Examples



Guide Content Details

Guide Contents—Front Matter

Foreword

- Discusses other reasons to be energy efficient (makes the non-energy case)
    - Better work environment
    - Can be building type specific
        - Enhanced shopping environment for retail
        - Enhanced learning environment for K-12 schools
        - Better patient environment for hospitals
    - Life cycle costs, operating costs
    - Other sustainability issues (greenhouse gases, water, etc.)
    - Marketing, public perception

Decision Maker Flow Chart

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 in the RFP. 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 recommendations
Conceptual Design	Require design teams to implement AEDG recommendations. Learn about integrated design in Chapter 2. Review site-specific costs and benefits 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 toward 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

Guide Contents—Integrated Design

Energy Goals By Design Phase Checklist

A checklist of the energy design goals for each of the project phases discussed in this chapter may be a helpful tool for the design team.

Programming and Concept Design

Activities	Responsibilities	✓
Select the core team • Include energy goals in the RFP • Designers—including project architect, engineer, and other design consultants • Commissioning authority • Construction manager	Owner (school board members and administrators)	
Adopt energy goals	Owner and designers	
Assess the site • Evaluate centrality to the community • Evaluate access to public transportation • Identify on-site energy opportunities • Identify best building orientation	Owner, designers, construction manager	
Define functional and spatial requirements	Owner and designers	
Define energy efficiency and budget benchmarks	Owner, designers, construction manager, estimator	
Prepare the design and construction schedule	Owner, designers, construction manager	
Determine building—envelope and systems preferences	Owner, designers, construction manager	
Perform cost/benefit analysis for energy strategies	Owner and designers	
Identify applicable energy code requirements	Owner and designers	

Schematic Design

Activities	Responsibilities	✓
Identify energy conservation measures (ECMs)	Owner, designers, construction manager, CxA	
First costs investment calculation	Cost estimator	
Base case life-cycle cost assessment	Cost estimator	
First costs and LCCA comparison to OPR cost budget	Cost estimator, designers	
Anticipated annual energy costs savings	Designers	
Anticipated annual maintenance costs savings	Owner and CxA	
Simple payback period	Designers	
Return on Investment	Owner, cost estimator, designer	
kBtu/sf/yr reduction	Designer	
Carbon emissions savings	Designer	
Additional% savings compared to Standard 90.1	Designer, CxA	
Potential additional USGBC LEED points not limited to Energy and Atmosphere Credit 1	Sustainability consultant	
Range of indoor thermal comfort achieved throughout the year	Designer	
Range of lighting levels achieved throughout the year	Designer	

- **“A way but not the only way…” through the prescriptive tables**
- **A tutorial on the elements of integrated design for energy conservation**
- **A description of required design tasks for energy conservation by design phase**
- **Stresses the importance of energy modeling for design of building not amenable to tables**

Guide Contents—Cost Control Strategies

Key Design Strategies for Controlling Capital Costs

The following strategies and best practices detail key design strategies for controlling costs in high performance K-12 school projects.

Site Design

- Properly orient the school on your site—good orientation allows for significant energy savings without additional costs
- Utilize existing trees for shading
- Retain site features that can later serve as teaching tools
- If a prototype design is used, make sure the prototype is flexible enough to allow for optimal placement on the site
- Locate ground heat exchanger wells under parking lots or athletic fields to share site preparation costs

Daylight and Windows

- Use clear, double-glazing in the glass areas that are integral to your daylighting strategy to maximizing visible light transmission. High visible transmittance daylighting glass maximizes daylight transmission while minimizing daylighting aperture cost.
- Don't use any more glass in your daylighting strategy than is necessary to achieve your lighting level objective during peak cooling times. Excess glass costs more and results in higher heating and cooling energy use.
- Eliminate east and west facing glass and only utilize view glass where there is a purpose – not just to aesthetically balance the design elevation.
- Where east and west facing windows are required, select tinted glazing to help reduce peak cooling loads and, in turn, reduce installed cooling equipment.
- Understand that daylighting always contributes light to the space and because of different lighting requirements between day and night less light fixtures can be installed initially while still maintaining daytime illuminance requirements.
- Use architectural features to shade classroom projection areas, not operable window shades.

Building Shell

- Use white, single-ply roofing material to maximize daylight reflectance and minimize cooling.
- Paint interior walls light colors, select highly reflective ceiling materials, and don't pick extremely dark floor finishes. Darker surfaces can require more installed lighting power to meet illuminance levels resulting in higher costs and less effective daylighting.
- Develop the design based upon even modules for materials. It will reduce material waste and save time, in turn savings cost.
- Maximize the use of modular construction techniques and focus on simple forms that minimize complex wall detailing and curved surfaces.

Electrical Systems

- Select the more energy-efficient computers, vending machines, televisions, appliances, and kitchen equipment. Best in class efficiency plug load efficiency can be achieved with minimal additional cost.
- Consider PV lighting for remote locations where conduit and trenching costs can exceed the cost of the PV system.
- Limit exterior lighting to critical areas only.
- Don't over light hallways.
- Use multiple lamp fluorescent fixtures that can be switched and/or dimmed to provide multiple light levels in daylighted gymnasiums. They can cost less and provide an additional advantage by being able to be dimmed.

Mechanical Systems

- Analyze your seasonal and hourly loads carefully to determine full-load conditions.
- Make sure you accurately account for the benefits of daylighting in terms of cooling load reduction.
- Lay out the chilled- and hot-water piping, and ductwork, to minimize turns and reduce pressure losses.
- Optimize the mechanical system as a complete entity to allow for the interaction of various building system components.
- When sizing your mechanical equipment, investigate the unit sizes—it may make more sense to improve the energy efficiency of other design elements to help reduce the overall cooling load downward to the next unit size
- Correctly account for the impact of an energy recovery device(s) on the outdoor air cooling and heating system capacities.

Cost Control Strategies and Best Practices

This guide provides information for achieving high-performance building design in K-12 school projects. Owners should not expect energy-efficient schools to cost more. They can cost more, but they shouldn't have to. These designs can be accomplished without a serious cost premium. The following strategies and best practices detail approaches for controlling costs in high performance K-12 school projects.

Integrated Design

- Align program, budget, and energy goal at the beginning of the project.
- Have a good understanding of cost before significant design work has been done.
- Analyze costs as energy decisions are being made.
- At a minimum, integrate in cost estimators and design engineers at the 50% schematic design phase.
- Coordinate system placement (structural, mechanical, electrical, etc.) to reduce building volume costs.
- Plan for future integration of renewable energy by designing to be renewable-ready. Examples include the following:
  - Providing large, unobstructed roof area, either south facing or flat, for future photovoltaic (PV) mounting.
  - Providing electrical conduit chases to possible future renewable sites.

Life-Cycle Cost Analysis

- Include initial cost, operating cost, replacement cost, and maintenance cost over the life of the building when cost justifying low-energy systems. Previously successful examples include the following:
  - Additional first costs of ground-coupled systems can partially be offset by reduced maintenance costs of well fields, as compared to traditional cooling towers or heat-rejection condensers.
  - Additional first cost of light-emitting diode (LED) fixtures can partially be offset by reduced re-lamping and maintenance costs, as compared to traditional exterior lighting fixtures.

Cost Trade-Offs

- Include installation and labor costs with material costs when evaluating total system costs. Previously successful examples include the following:
  - Insulated concrete form (ICF) walls may be more expensive from a material standpoint, but the additional expense can be partially offset by reduced installation time and the fact that the electrical contractor does not have to be on site during wall framing.
- Focus on modular, pre-built systems to reduce installation costs and construction time.
- Re-invest first-costs savings from removing unnecessary amenities (overly glazed facades, excessive finishes, water fountains, etc.) for efficiency upgrades.

Value Added

- Create additional value beyond energy savings by considering efficiency strategies that have multiple benefits. Examples include the following:
  - Use PV systems or wind turbines as both renewable generation and curriculum.
  - Use M&V data to hold energy savings competitions among classrooms, grades, wings, etc.
  - Use M&V data as part of a science or math curriculum analyzing performance data.
  - Provide an enhanced learning environment though daylighting.
  - Use PV systems that can be integrated into an uninterruptable power supply.
  - Use computer carts in place of computer labs to save unnecessary square footage costs while also providing more efficient computing.
  - Passive survivability concepts.
  - High mass structure for disaster resistance.
  - Utilize daylighting to provide light during extended power outages.
  - Utilize natural ventilation to provide some outdoor air during extended power outages.

Hiring an Experienced Design Team

- Select a design and construction team with experience successfully and cost-effectively implementing efficiency strategies in schools. Benefits include the following:
  - Better understanding of actual costs and cost trade-offs that are available.
  - Understanding how to leverage the benefits of integrated design to ensure that all of the efficiency strategies work together.
  - Reduced subcontractor contingency costs associated with traditionally untrusted and risky systems and strategies.
  - Avoiding unnecessary and costly equipment oversizing due to system performance uncertainties by leveraging lessons learned from past projects. Applications include the following:
    - Ground heat exchanger well sizing based on seasonal loads and actual ground characteristics.
    - Ventilation system sizing based on actual occupancy patterns.

Alternative Financing

- Leverage all possible rebates from nonprofits, utilities, state energy offices, etc. for efficiency upgrades and renewable energy systems (NREL 2011).
- Team up with third-party financing to eliminate first costs for systems that exceed capital budget limitations and to leverage for-profit tax incentives not available to typical school districts.

Guide Contents—Recommendation Tables

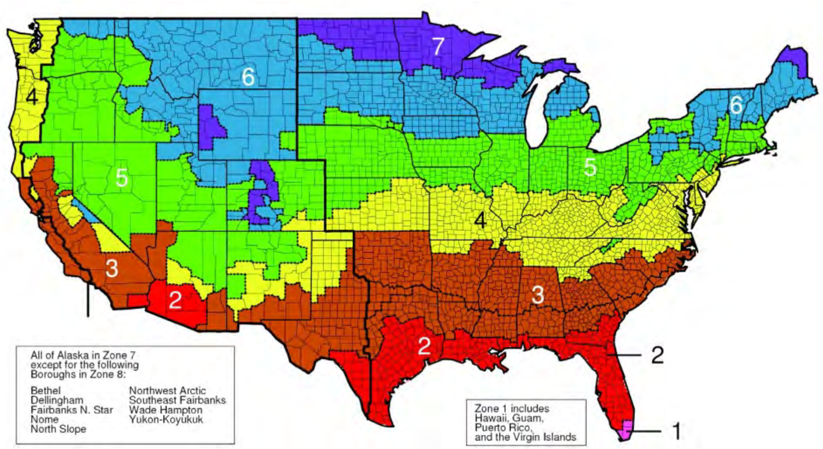
- Insulation levels for opaque envelope (roofs, walls, floors, slabs, doors)
- Fenestration performance characteristics and glazing amounts
- Interior lighting power densities (LPDs)
- Daylighting strategies
- Exterior lighting recommendations
- Plug load selection and control
- Kitchen equipment selection and operation
- Service water heating (SWH) equipment efficiencies
- HVAC equipment types and component efficiencies
- Commissioning, measurement and verification, and renewable energy
- All recommendations by climate zone in a single page for easy use

Envelope	Roofs	Insulation entirely above deck	R-30.0 c.i.
		Solar reflectance index (SRI)	Comply with Standard 90.1*
	Walls	Mass (HC > 7 Btu/ft^2)	R-13.3 c.i.
		Steel framed	R-13.0 + R-15.6 c.i.
		Below-grade walls	R-7.5 c.i.
	Floors	Mass	R-14.6 c.i.
		Steel framed	R-38.0
	Slabs	Unheated	Comply with Standard 90.1*
		Heated	R-20 for 24 in.
	Doors	Swinging	U-0.50
		Nonswinging	U-0.50
	Vestibules	At primary visitor building entrance	Comply with Standard 90.1*
	Continuous air barriers	Continuous air barriers	Entire building envelope
	Vertical fenestration (full assembly—NFRC rating)	Window-to-wall ratio	40% of net wall (floor-ceiling)
		Thermal transmittance	Nonmetal framing windows = 0.35 Metal framing windows = 0.42
		Solar heat gain coefficient (SHGC)	Nonmetal framing windows = 0.25 Metal framing windows = 0.25
		Light-to-solar gain ratio (LSG)	All orientations ≥ 1.5
		Exterior sun control	South orientation only – PF = 0.5
Daylighting/ Lighting		All spaces	Comply with LEED for healthcare credits IEQ 8.1 (daylighting) and IEQ 8.2 (views)
	Form-driven daylighting option	Diagnostic and treatment block	Shape the building footprint and form such that the area within 15 ft of the perimeter exceeds 40% of the floorplate.
		Inpatient units	Ensure that 75% of the occupied space not including patient rooms lies within 20 ft of the perimeter.
		Staff areas (exam rooms, nurse stations, offices, corridors); public spaces (waiting, reception); and other regularly occupied spaces as applicable	Design the building form to maximize access to natural light, through sidelighting and toplighting.
	Nonform-driven daylighting option	Staff areas (exam rooms, nurse stations, offices, corridors) and public spaces (waiting, reception)	Add daylight controls to any space within 15 ft of a perimeter window.
	Interior finishes	Room interior surface average reflectance	Ceilings ≥ 80% Walls ≥ 70%
	Interior lighting	Lighting power density (LPD)	Whole building = 0.9 W/ft^2 Space-by-space per Table 5-4
		Light source efficacy (mean lumens per watt)	T8 & T5 > 2 ft = 92 T8 & T5 < 2 ft = 85 All other >50
		Ballasts—4 ft T8 Lamps	Nondimming = NEMA Premium Dimming= NEMA Premium Program Start
		Ballasts—Fluorescent and HID	Electronic

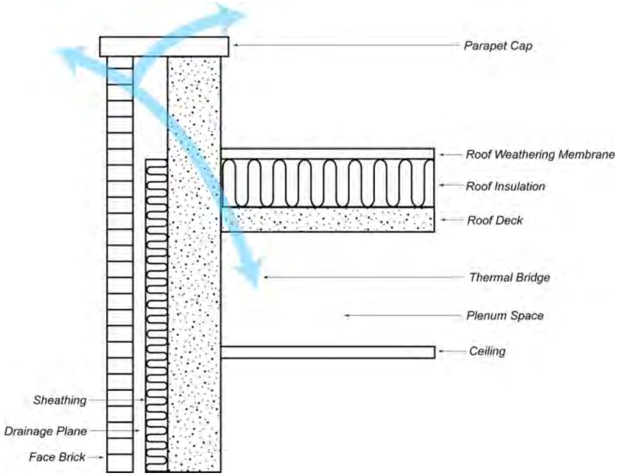
Guide Contents—Energy Targets (50%)

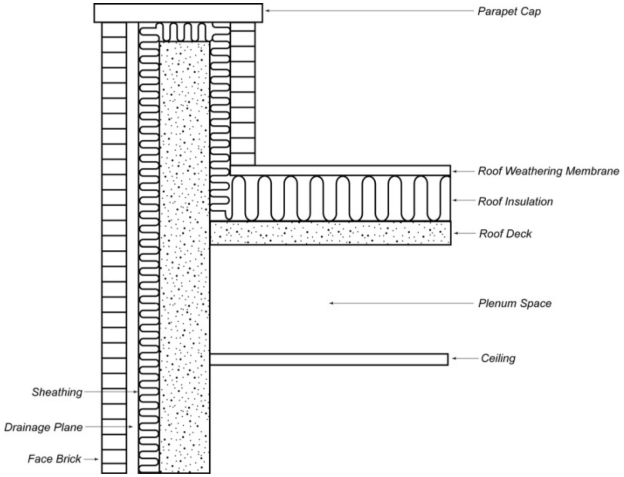
Climate Zone	Process Loads (kBtu/ft²yr)	Lighting (kBtu/ft²yr)	HVAC (kBtu/ft²yr)	Total (kBtu/ft²yr)
1A	11	6	20	37
2A			20	37
2B			20	37
3A			15	32
3B:CA			8	25
3B			14	31
3C			10	27
4A			19	36
4B			15	32
4C			15	32
5A			22	39
5B			17	34
6A			27	44
6B			22	39
7			30	47
8			45	62

- Helps with goal setting
- Performance path to 50% energy savings
- Measurable goal
- Does not rely on theoretical baseline building

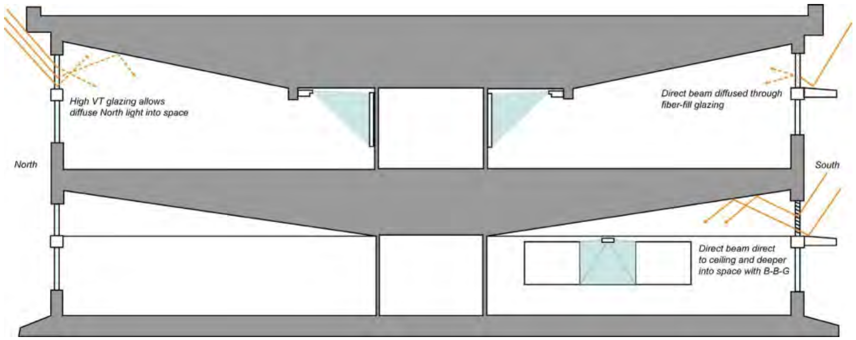


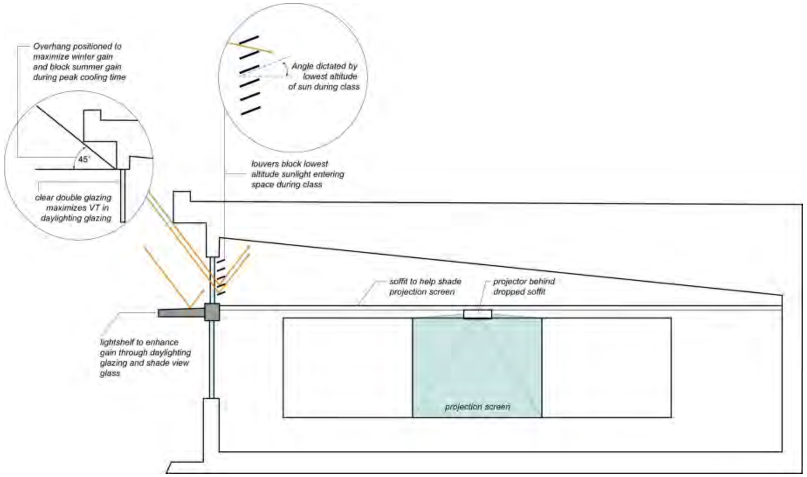
Guide Contents—Envelope How-To



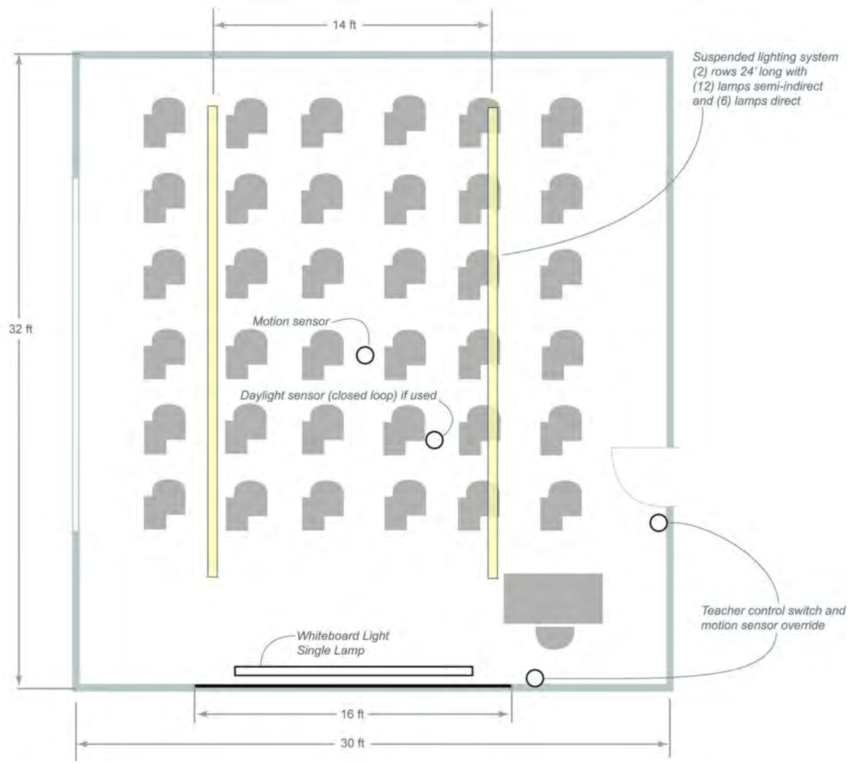


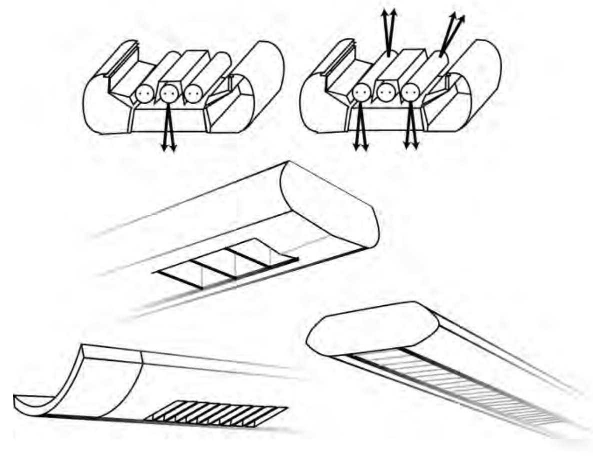
Guide Contents—Daylighting How-To

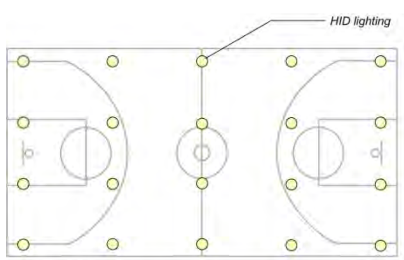




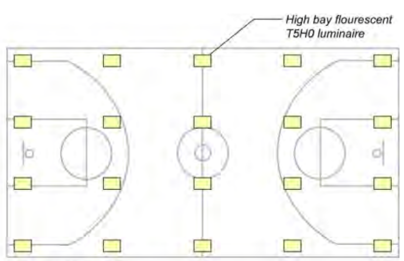
Guide Contents—Interior Lighting How-To





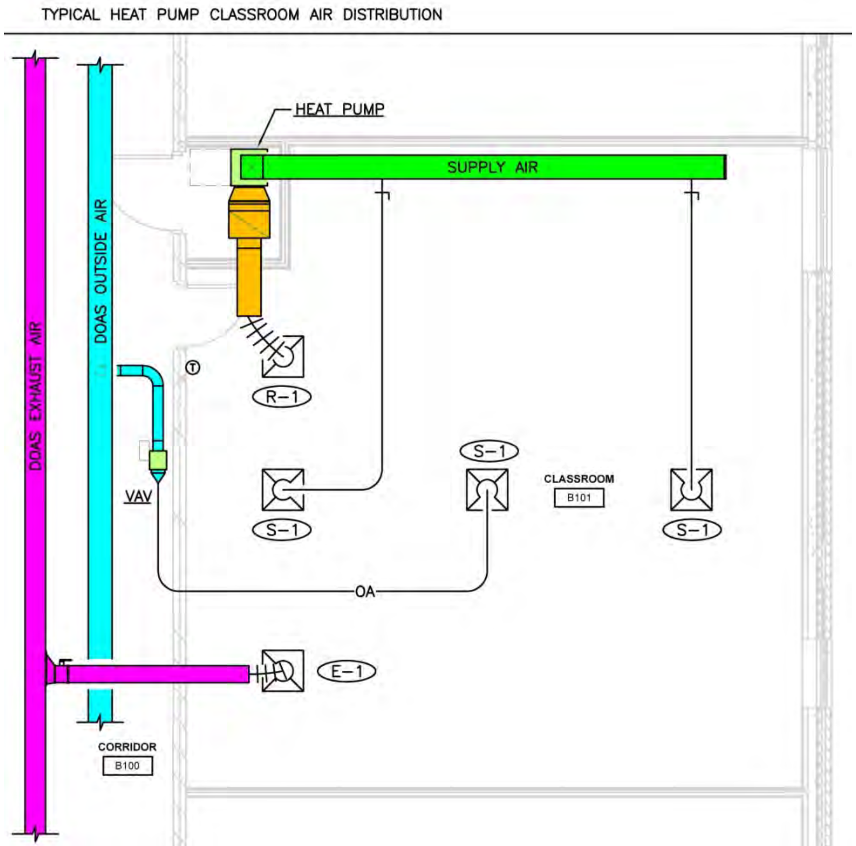


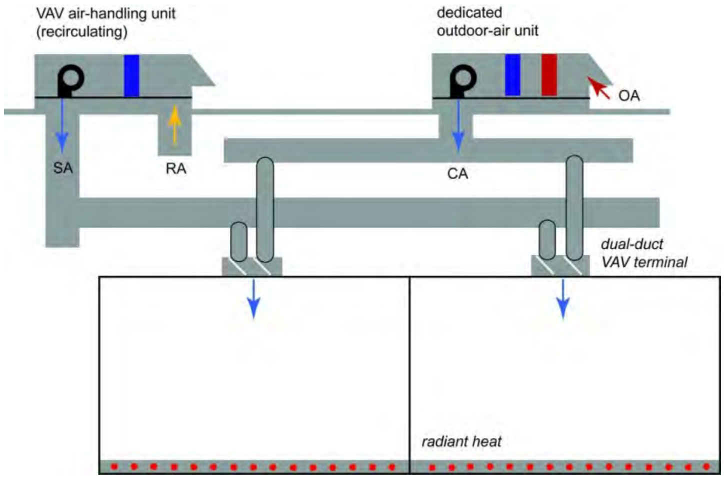
PATTERN 1 GYM
(20) 320 watt Pulse Start metal halide fixtures
Electronic ballast
50 footcandles maintained at 0.86 W/SF
60 footcandles maintained on court

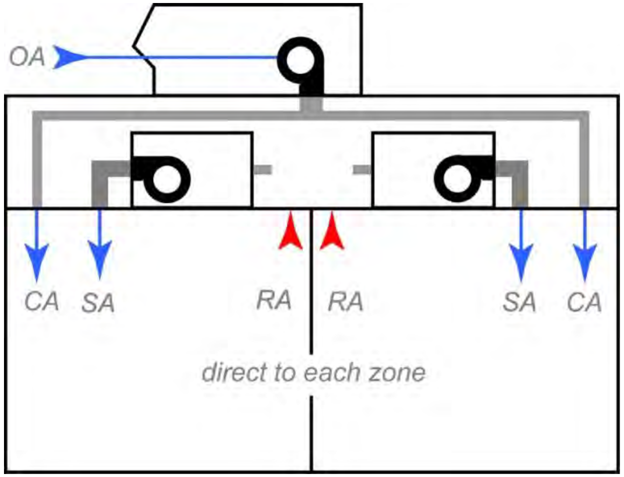


PATTERN 2 GYM
(20) Gym-rated flourescent high bay fixtures
each with (6) F54T5HO lamps
(2) or (3) electronic ballast total 360 watts
60 footcandles maintained at 0.90 W/SF
70 footcandles maintained on court

Guide Contents—HVAC How-To







Guide Contents—Case Studies

Richardsville Elementary School

- Bowling Green, Kentucky
- 74,500 ft^2, 2-story, 500 students
- R-30 white roof
- R-28.6 insulation concrete form (ICF) walls
- Daylighting with light shelf and tubular daylighting devices
- LPD of 0.68 W/ft^2
- Dual compressor water-to-water heat pump
- Dedicated outdoor air system (DOAS)
- Ground heat exchanger
- Demand controlled ventilation
- Exclusive use of laptop computers
- All electric high-performance kitchen
- Submetered HVAC, DOAS, lighting, kitchen, information technology, and plug loads
- 17 $kBtu/ft^2yr$ whole-building EUI

Guide Contents – Case Studies

<u>Great River Medical Center</u>

- **West Burlington, Iowa**
- **700,000 ft^2**
- **190 inpatient beds, 8 operating rooms**
- **Two 99,000-ft^2 medical office buildings**
- **Heated and cooled with one of the largest lake-coupled geothermal system in the United States**
    - 1800 tons of cooling
    - 85-mile long piping system
    - 800 heat pumps
- **96 kBtu/ft^2yr whole-building EUI**
    - Average hospital is at about 240 kBtu/ft^2yr
- **$0.94/$ft^2$yr in utility costs**
    - Average hospital is at about $2.39/$ft^2$yr

Guide Contents—Technology Case Studies

Daylighting Examples

Examples of Daylighting Strategies in K-12 School Spaces

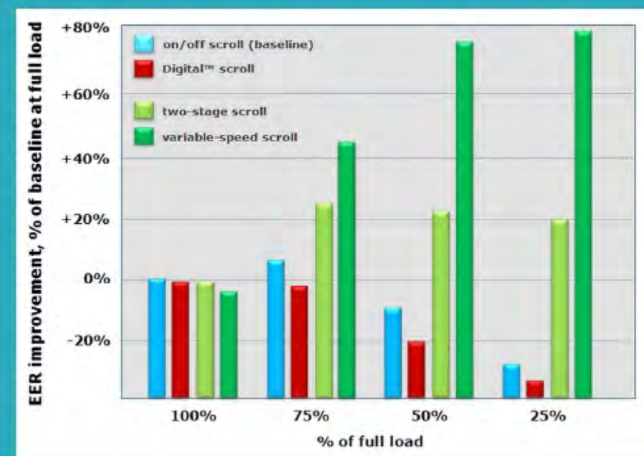
Classroom and Gymnasium with Baffles Inside South Facing Monitor

Cafeterias and Multipurpose Rooms with Roof Monitors

Libraries/Media Centers Using South-Facing Roof Monitors with Baffles

Variable-Speed Compressors

Two-Stage or Variable-Speed Compressors

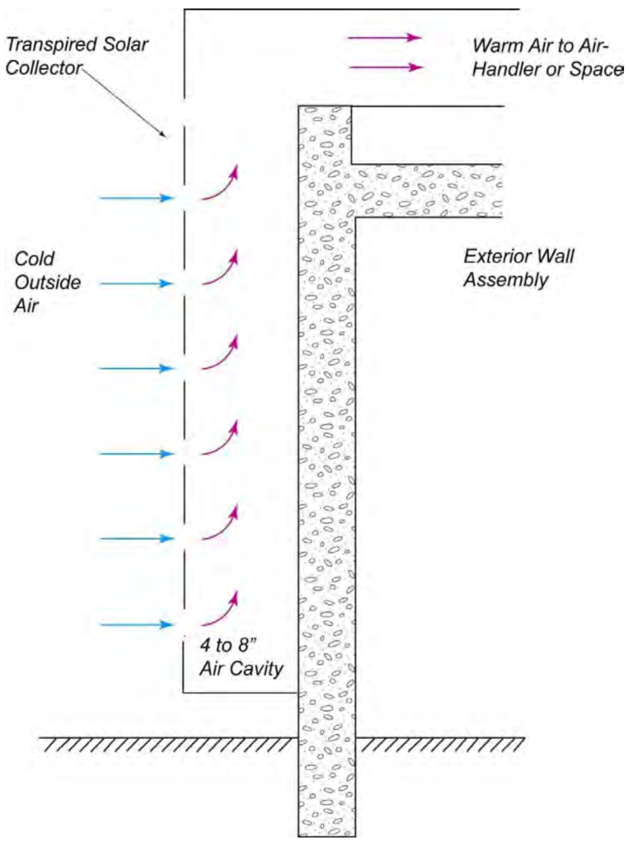


Relative performance of variable-capacity compressors
(4-ton water-source heat pump)

Recently, several equipment manufacturers have developed water-source or ground-source heat pumps that include a two-stage or variable-speed compressor. Compared to the on/off compressor that has historically been used in this type of equipment, a two-stage or variable-speed compressor is better able to match cooling or heating capacity with the changing load in the zone. This typically improves comfort and also results in reduced energy use during part-load conditions, as demonstrated in the chart showing relative performance of variable-capacity compressors.

When combined with a multiple-speed or variable-speed fan, this type of equipment can also result in better part-load dehumidification performance than a traditional heat pump with a constant-speed fan and an on/off compressor. This improvement is due to the reduction in airflow at part load, which allows the heat pump to deliver cooler and therefore drier air to the zone. This can lower indoor humidity levels.

Guide Contents—Bonus Savings



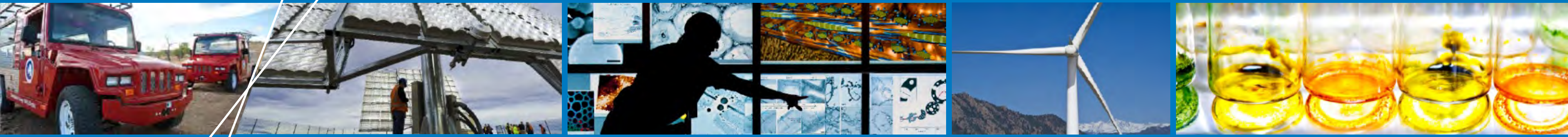
Thermal Energy Storage

Ice Storage Tanks and Air-Cooled Chiller

The Fossil Ridge High School in Fort Collins, CO, uses thermal energy storage to lower operating costs associated with cooling the building. The system consists of eight ice storage tanks and a 140 ton air-cooled chiller. The chiller is operated at night when the cost of electricity is lower, to freeze water inside the storage tanks.

Adding thermal storage to the chilled-water system reduces utility costs by shifting the operation of the chiller from periods when the cost of electricity is high (e.g., daytime) to periods when the cost of electricity is lower (e.g., nighttime). During the nighttime hours, the outdoor dry-bulb temperature is typically lower than during the day. This allows the chiller to operate at a lower condensing pressure and regain some of the capacity and efficiency lost by producing the colder fluid temperatures needed to freeze the storage tanks.

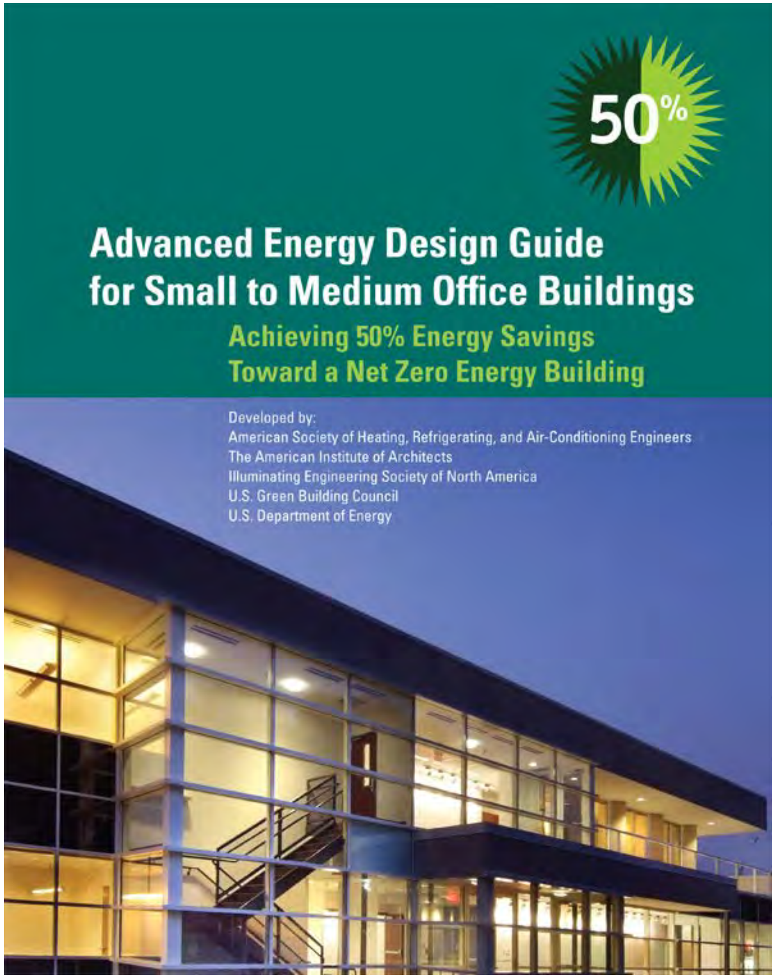
Due to the high-performance envelope and lighting system designs, the peak cooling load is only 250 tons (1050 ft^2/ton). For this project, the thermal energy storage was sized to offset a portion of peak cooling load, allowing for the installation of a downsized chiller (140 tons, or almost 1900 ft^2/ton of chiller capacity).



50% Savings AEDGs Recommendation Overview

Small to Medium Office Buildings

- SMO buildings up to 100,000 ft^2 in gross floor area
- Covers administrative, professional, government, bank/financial services, and medical offices (without medical diagnostic equipment)
- Does not cover specialty spaces such as data centers, which are more typical in large office buildings



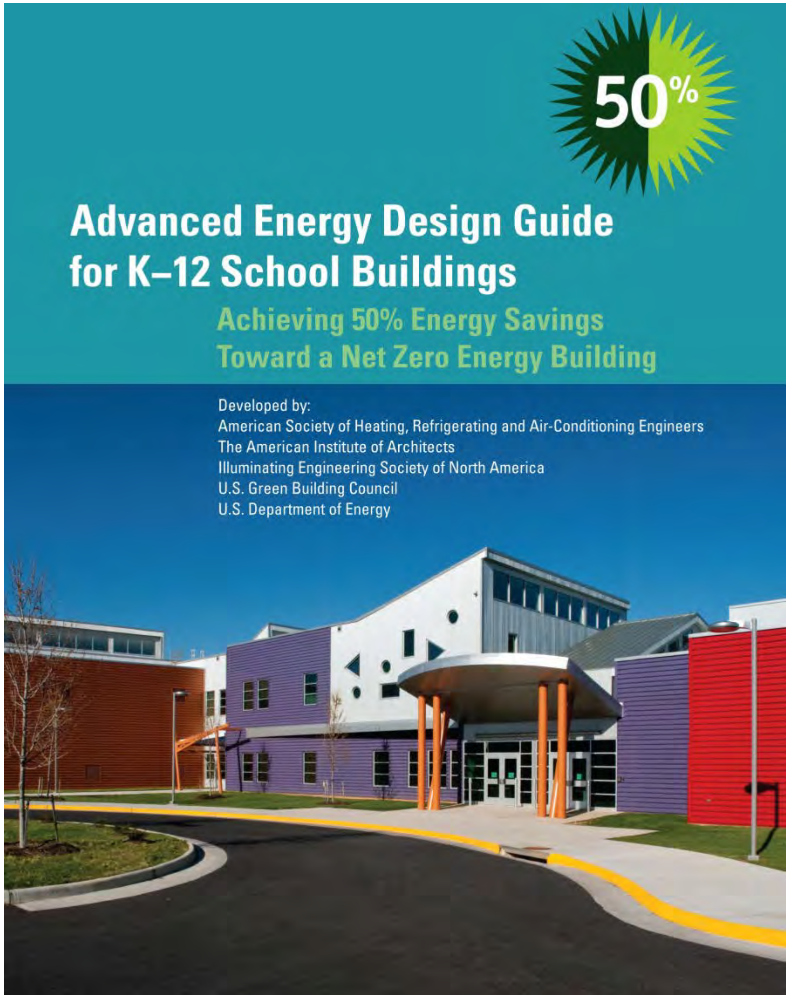
Office Recommendation Summary

- **Envelope**
  - Approximately 45% more insulated than Standard 90.1-2004
- **Façade zone optimization**
  - Guidance for improving energy efficiency in perimeter zones
- **Interior lighting**
  - Recommendations that result in a 25% reduction in whole-building LPD
  - Sample layouts for open offices, private offices, conference and meeting rooms, corridors, storage areas, and lobbies
- **Daylighting**
  - Recommendations for open-plan offices, private offices, conference rooms, and public spaces (lobbies, reception, and waiting areas)
- **Exterior lighting**
  - Recommendations that reduce lighting power for parking lots and drives by more than 33% over Standard 90.1-2004

Office Recommendation Summary

- **Plug and process loads**
  - ENERGY STAR® exclusive plug-in equipment
    - Best-in-class plug-in equipment where ENERGY STAR does not apply
  - Average SWH savings of 13% over Standard 90.1-2004
- **Six HVAC system types that result in significant energy savings over standard equipment**
  - Packaged single-zone air source heat pumps with a DOAS
  - Water source heat pumps with a DOAS
  - Variable volume air handler with DX cooling and gas-fired hydronic heating
  - Variable volume air handler with chilled water cooling and gas-fired hydronic heating
  - Four-pipe fan coils and a DOAS
  - Radiant heating and cooling with a DOAS
- **Additional HVAC recommendations**
  - Demand controlled ventilation
  - Airside energy recovery

K-12 School Buildings



- **Applies to all sizes and classifications of K-12 school buildings**
- **Defines a K-12 school as having the following common space types:**
  - 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
  - Libraries
- **Does not consider atypical specialty spaces such as:**
  - Indoor pools
  - Wet labs (e.g., chemistry)
  - "Dirty" dry labs (e.g., woodworking and auto shops)
  - Other unique spaces with extraordinary heat or pollution generation

K-12 Recommendation Summary

- **Building envelope**
  - Approximately 45% more insulated than Standard 90.1-2004
- **Interior lighting**
  - Recommendations that result in a 42% reduction in whole-building LPD
  - Sample layouts for classrooms, gymnasiums, multipurpose rooms, libraries, and corridors
- **Daylighting**
  - Numerous detailed daylighting strategies and diagrams for a number of space types, including multiple ways to top- and sidelight classrooms and toplight gymnasiums
- **Exterior lighting**
  - Exterior lighting recommendations that reduce lighting power for parking lots and drives by more than 33% over Standard 90.1-2004
- **Kitchens/cafeterias**
  - Numerous tips to conserve energy in K-12 kitchens and cafeterias

K-12 Recommendation Summary

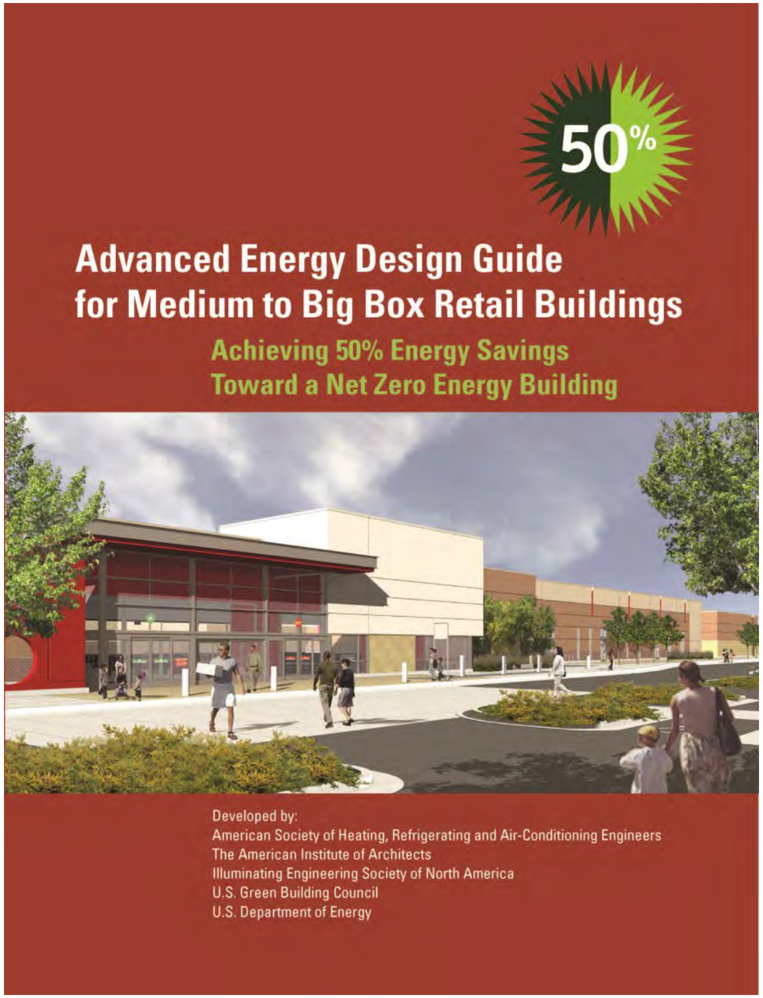
- **Plug and process loads**
  - ENERGY STAR exclusive plug-in equipment
    - Best-in-class plug-in equipment where ENERGY STAR does not apply
  - Average SWH savings of 13% over Standard 90.1-2004
- **Three HVAC system types that result in significant energy savings over standard equipment**
  - Ground source heat pumps with a DOAS
  - Four-pipe fan coils and a DOAS
  - Variable volume air handler with chilled water cooling, gas-fired hydronic heating, and a DOAS
- **Additional HVAC recommendations**
  - Demand controlled ventilation
  - Airside energy recovery
- **Value added**
  - Tips for using the building as a teaching tool

K-12 Cost Recommendations

- **Integrated design**
  - Align program, budget, and goals at project inception
  - Analyze costs as energy decisions are being made
  - Integrate cost estimators early in the design process
- **Life cycle cost analysis**
  - Include all (initial, operating, replacement, and maintenance) costs when evaluating a system
  - Ground source heat pump and light-emitting diode (LED) costs can be partially offset by reduced maintenance costs
- **Cost trade-offs**
  - Focus on modular, prebuilt systems to reduce installations costs
  - Reinvest first cost savings from removing unnecessary amenities
- **Value added**
  - Integrate building systems into the curriculum
  - Provide an enhance learning environment through daylighting
- **Hiring an experienced design team**
  - Better understand actual costs and available tradeoffs
  - Leverage lessons learned from past projects
- **Alternative financing**
  - Leverage all possible rebates for energy efficiency upgrades and renewable energy systems
  - Team with third-party financing to eliminate first costs and take advantage of tax incentives

Medium to Big Box Retail Buildings

- **Applies primarily to retail buildings with 20,000 ft^2 to 100,000 ft^2 of floor area**
- **Many recommendations also apply to smaller and larger retail buildings**
- **Defines an MBR building as having the following common space types:**
  - Sales areas
  - Administrative and office areas
  - Meeting and dining areas
  - Hallways and restrooms
  - Storage spaces and mechanical/electrical rooms
- **Does not cover specialty items such as commercial refrigeration**



Retail Recommendation Summary

- **Building envelope**
  - Approximately 45% more insulated than Standard 90.1-2004
- **Interior lighting**
  - Recommendations that result in a 38% reduction in whole-building LPD
  - Sample layouts for sales floors, back-of-house spaces, conference and meeting rooms, and stocking areas
- **Daylighting**
  - Tips on successful daylight integration in a retail setting
- **Accent lighting**
  - Perimeter wall accent and LED display lighting tips
- **Exterior lighting**
  - Recommendations that reduce lighting power by more than 33% over Standard 90.1-2004
  - Retail-specific parking lot lighting energy use reduction and control strategies
- **Portfolio energy reduction**
  - Strategies for reducing energy use across a portfolio of retail stores

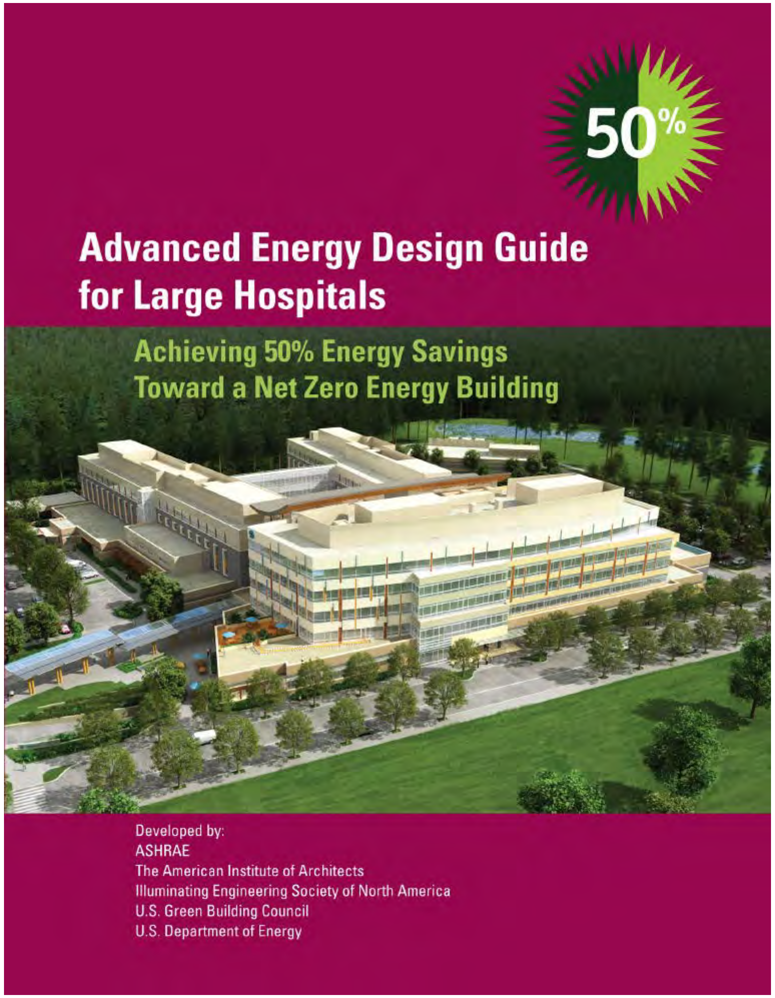
Retail Recommendation Summary

- **Plug and process loads**
  - ENERGY STAR exclusive plug-in equipment
    - Best-in-class plug-in equipment where ENERGY STAR does not apply
  - Sales floor and security system plug load recommendations
  - Average SWH savings of 13% over Standard 90.1-2004
- **Four HVAC system types that result in significant energy savings over standard equipment**
  - Packaged variable-air volume DX air conditioners with gas-fired furnaces
  - Packaged constant air volume DX air conditioners with gas-fired furnaces and a DOAS
  - Packaged single-zone air-source heat pumps with a DOAS
  - Packaged single-zone water-source heat pumps with a DOAS
- **Additional HVAC recommendations**
  - Performance-based ventilation reduction strategies
  - Airside energy recovery

Retail Cost Recommendations

- **Cost trade-offs**
  - The costs of added insulation can be offset by reducing the number of rooftop units
  - The additional investment in a high-performance lighting system can be offset with reduced cooling capacity
  - Balance and understand actual maintenance costs with energy costs
- **HVAC**
  - Consider larger rooftop units that can more cost effectively incorporate advanced HVAC recommendations such as energy recovery ventilators and economizers
  - The owner/corporation sets the expectation for peak sizing and occupancy loading; therefore, consider other stores in your portfolio (or other similar types of stores) in considering peak occupancy and internal demands when sizing equipment
- **Integrated design**
  - Lower LPDs can be achieved with careful integration with interior design while still maintaining desired illuminance levels—bright and white ceilings, walls, and floors result in better distribution of electrical lighting in the space, which can allow for less overall installed electrical lighting
- **Alternative financing**
  - Leverage purchasing power and direct purchase of specific cost-effective equipment that meets the efficiency requirements in the guide
  - Take advantage of tax and utility incentives and rebates

Large Hospitals



- **Applies to hospitals larger than 100,000 ft^2**
- **Defines an LH as having the following common space types:**
  - Cafeterias, kitchens, and dining facilities
  - Administrative, conference, lobby, lounge, and office areas
  - Reception and 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, and laboratories
  - Triage, trauma, and emergency rooms
  - Physical therapy and imaging/radiology rooms
  - Storage, receiving, laundry, and mechanical/ electrical/telecomm rooms
- **Does not cover specialty spaces such as data centers, parking garages, and campus utilities such as chilled water and steam**

Hospital Recommendation Summary

- **Envelope**
  - Approximately 45% more insulated than Standard 90.1-2004
- **Interior lighting**
  - Recommendations that result in a 25% reduction in whole-building LPD
  - Sample layouts for patient rooms, nurse stations, operating rooms, recovery rooms, treatment rooms, exam rooms, labor and delivery rooms, imaging suites, enclosed offices, and conference rooms
- **Building footprint**
  - Articulated footprint examples to maximize daylight access in the buildings
- **Exterior lighting**
  - Recommendations that reduce lighting power for parking lots and drives by more than 33% over Standard 90.1-2004
- **Task lighting**
  - LED surgery light recommendations that save 60% of the energy used for surgery lighting and significantly reduces the energy demands for cooling the surgeons and warming their patients
- **Elevators and kitchens**
  - Recommended use of traction elevators exclusively throughout the building, and regenerative traction elevators for high-use areas
  - Numerous tips to conserve energy in hospital kitchens and cafeterias

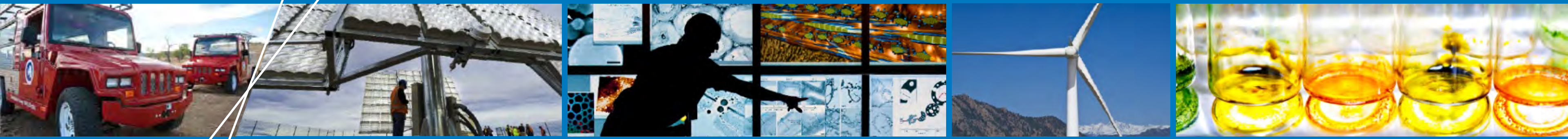
Hospital Recommendation Summary

- **ENERGY STAR exclusive plug-in equipment**
  - Best-in-class plug-in equipment where ENERGY STAR does not apply
- **Average SWH savings of 13% over Standard 90.1-2004**
- **Aggressive reduction in reheat resulting from decoupling space conditioning loads and ventilation loads**
- **A best-in-class surgery suite central air handling system**
- **Three HVAC system types that result in significant energy savings over standard equipment**
  - Water source heat pumps with a DOAS
  - Four-pipe fan coils and a DOAS
  - Mixed-air variable volume air handler with separate outdoor air treatment and a heat recovery chilled water system
- **Additional HVAC recommendations**
  - Aggressive supply air temperature reset and zone airflow setback
  - Airside pressure drop and coil face velocity reductions
  - Elimination of steam boilers
  - High ΔT chilled water loops
  - Demand controlled ventilation
  - Airside energy recovery

Hospital Cost Recommendations

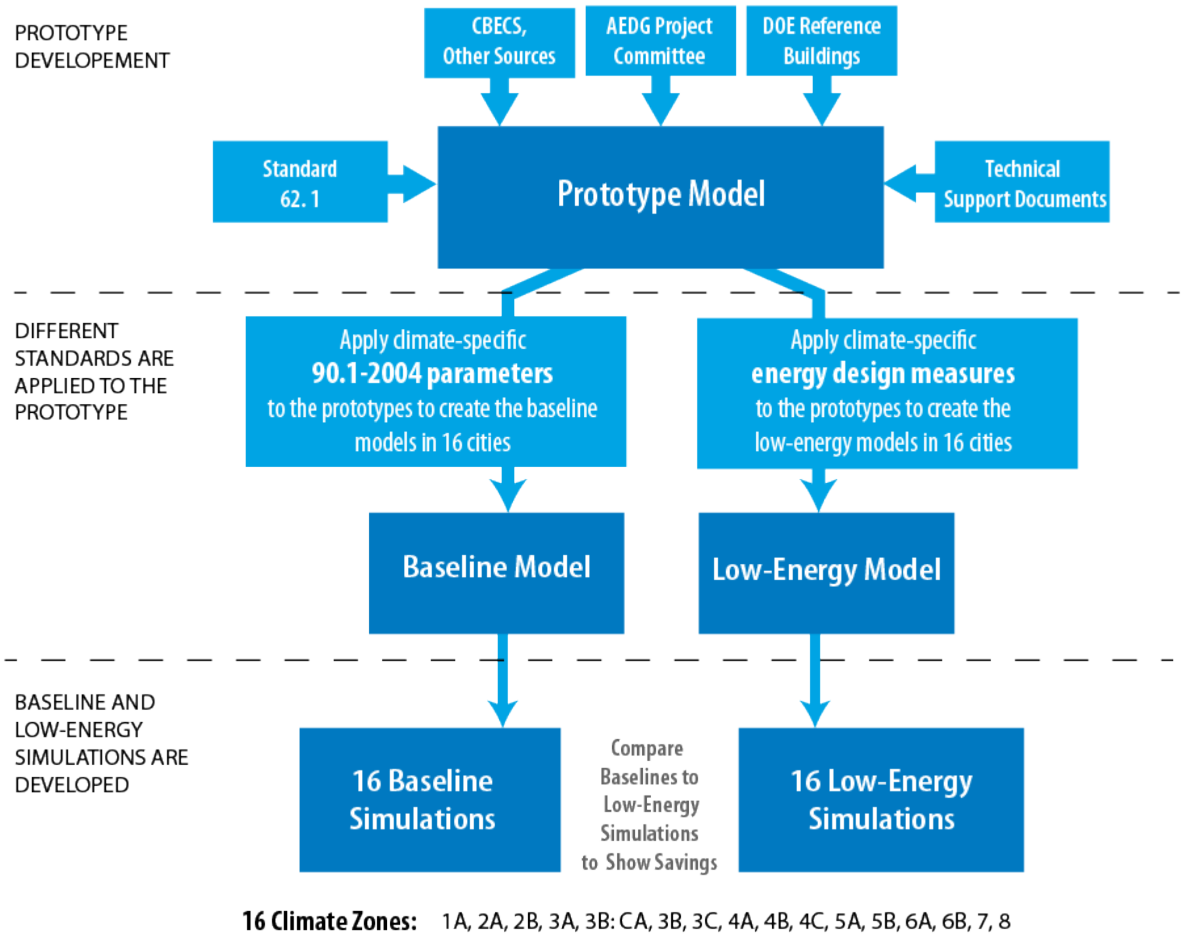
- **Relating efficiency strategies to the healthcare mission**
  - Improved environment of care and patient outcomes
  - Improved overall health of the community
  - Reduced medical errors and more satisfied caregivers
- **Integrated design**
  - Reduced errors and rework, creating savings that can be reinvested in energy efficiency
  - Well-coordinated system selection and placement can reduce building volume and lower construction costs
- **Life cycle cost analysis**
  - Include all (initial, operating, replacement, and maintenance) costs when evaluating a system
  - Ground source heat pump and LED costs can be partially offset by reduced maintenance costs
- **Cost tradeoffs**
  - Focus on modular, prebuilt systems to reduce installations costs
  - Reinvest first cost savings associated with removing unnecessary amenities
- **Value added**
  - Photovoltaic systems can be integrated into an uninterruptable power supply
  - Daylighting and operable windows can provide additional light and ventilation during power crisis
- **Alternative financing**
  - Leverage all possible rebates for energy efficiency upgrades and renewable energy systems

NATIONAL RENEWABLE ENERGY LABORATORY



50% Savings AEDGs Energy Modeling Analysis

Evaluation Approach



Energy Modeling Analysis

Baseline Models

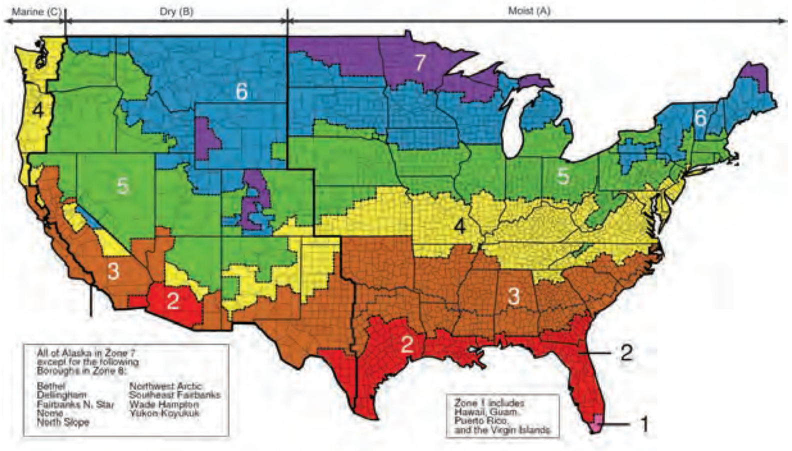
- Minimally compliant with Standard 90.1-2004 and 62.1-2004
  - Opaque envelope and fenestration
  - Space-by-space LPD
  - HVAC equipment efficiencies
  - Occupancy and ventilation requirements
- Nonregulated components
  - Plug and process loads and operating schedules
  - Determined with PC guidance

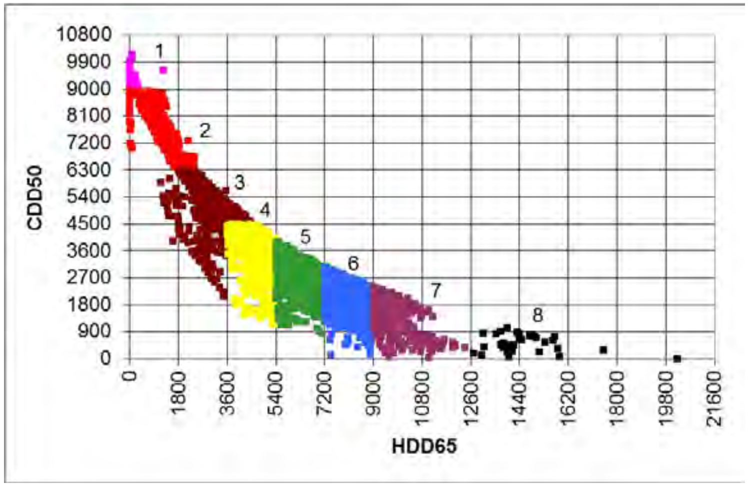
Low-energy models

- Start with baseline models
- Apply opaque envelope and fenestration criteria from AEDG
- Apply space-by-space LPDs from AEDG
- Apply plug and process load reductions and improved control determined with PC guidance
- Apply different HVAC system types with AEDG efficiencies

Climate Zones

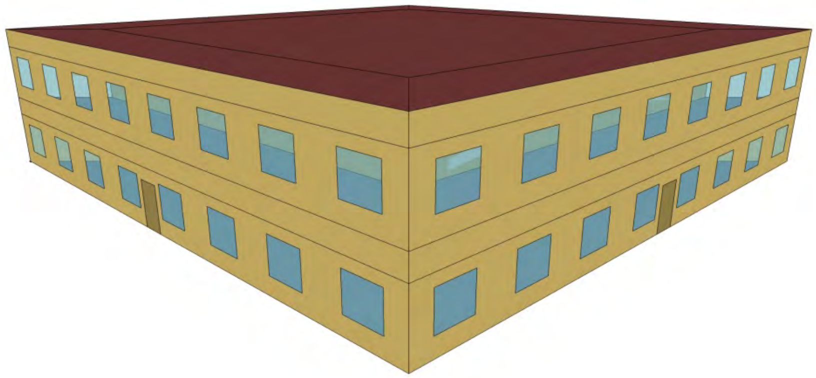
No.	Climate Zone	Representative City
1	1A	Miami, Florida
2	2A	Houston, Texas
3	2B	Phoenix, Arizona
4	3A	Atlanta, Georgia
5	3B:CA	Los Angeles, California
6	3B	Las Vegas, Nevada
7	3C	San Francisco, California
8	4A	Baltimore, Maryland
9	4B	Albuquerque, New Mexico
10	4C	Seattle, Washington
11	5A	Chicago, Illinois
12	5B	Denver, Colorado
13	6A	Minneapolis, Minnesota
14	6B	Helena, Montana
15	7	Duluth, Minnesota
16	8	Fairbanks, Alaska



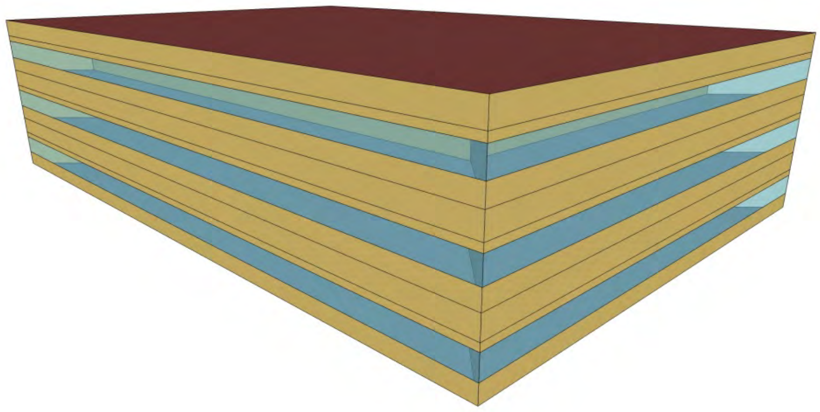


Office Energy Models

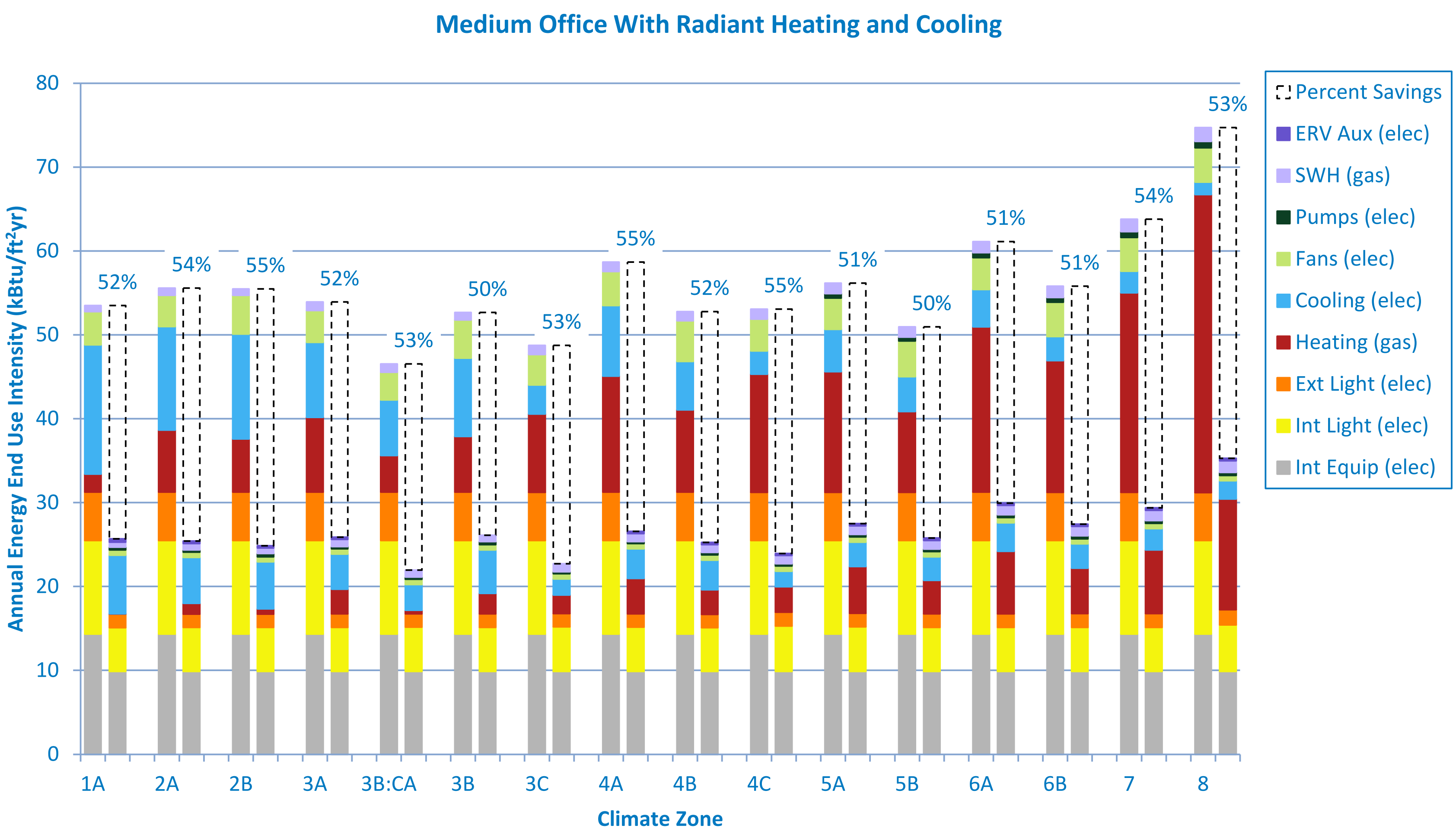
- **Small office**
  - 2 stories
  - 20,000 ft^2
  - 100-ft × 100-ft footprint



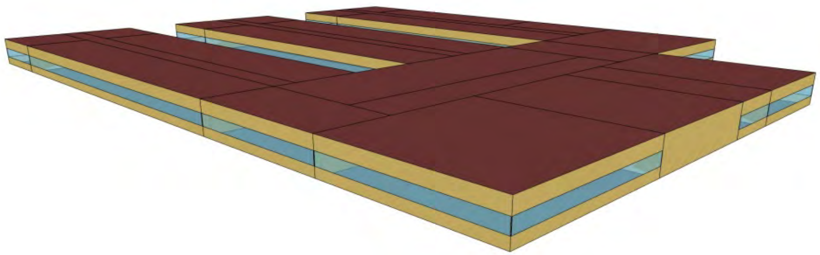
- **Medium office**
  - 3 stories
  - 53,600 ft^2
  - 164-ft × 109-ft footprint

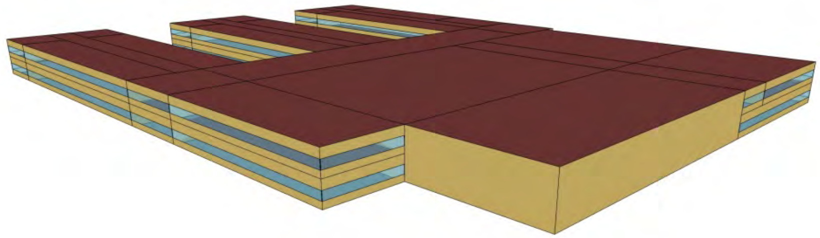


Office Energy Modeling Results



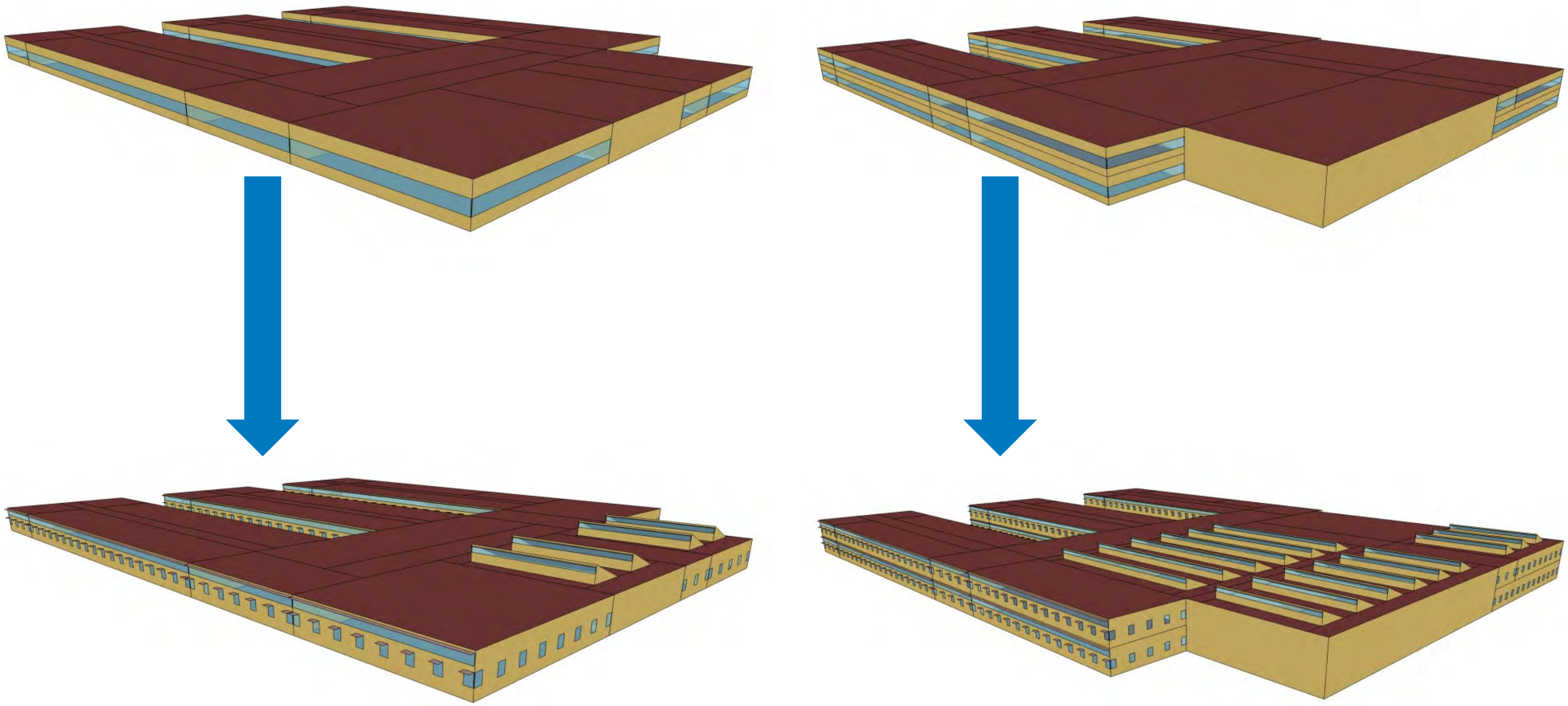
K-12 Energy Models



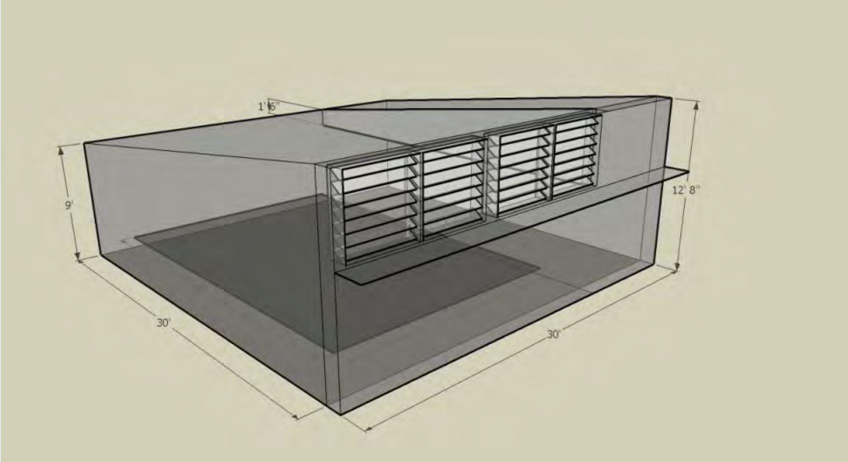


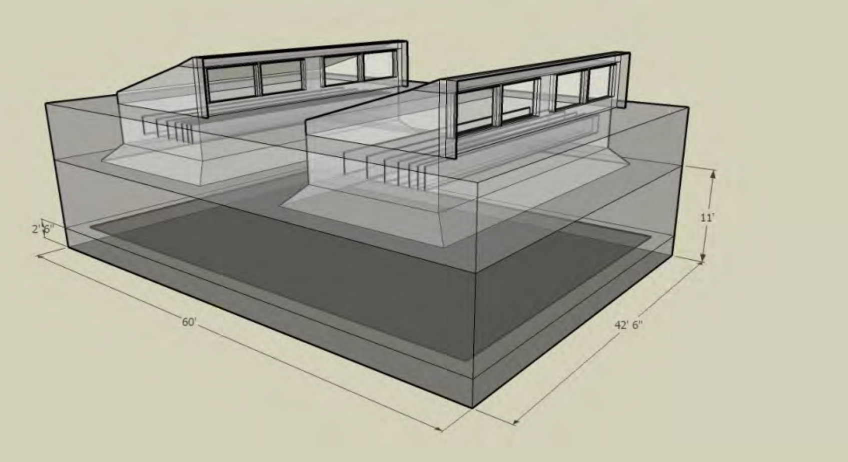
- **Primary school**
  - 1 story
  - 74,000 ft^2
  - 650 students
- **Secondary school**
  - 2 stories
  - 211,000 ft^2
  - 1200 students

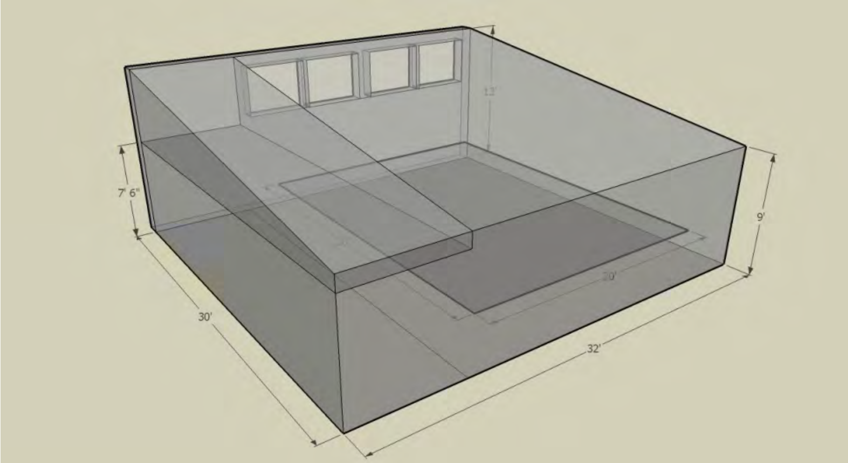
K-12 Energy Models

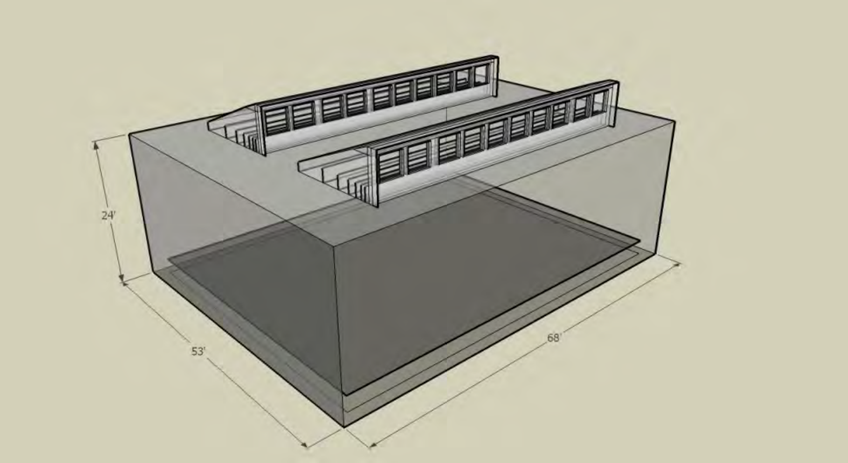


K-12 Daylight Modeling

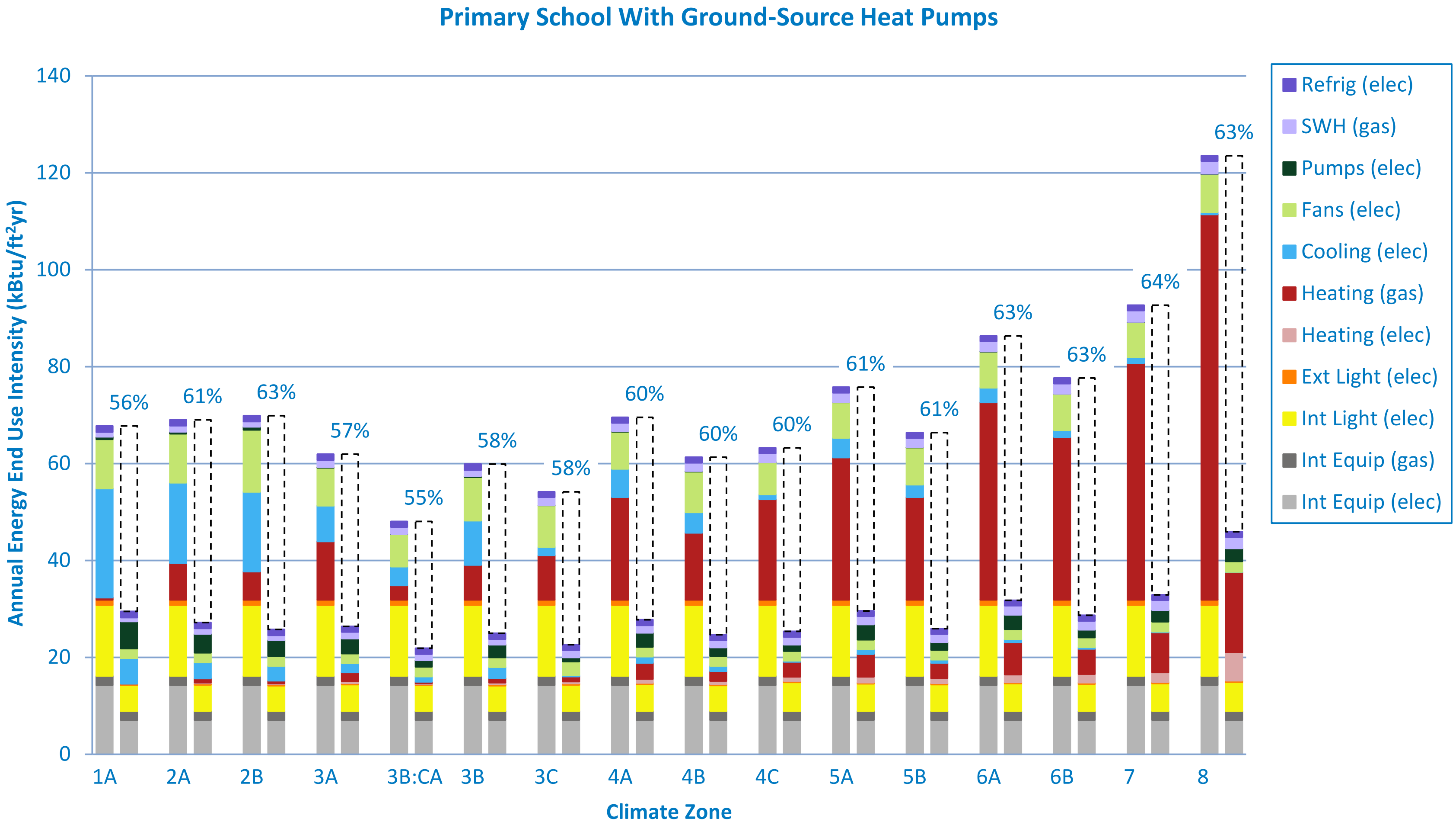






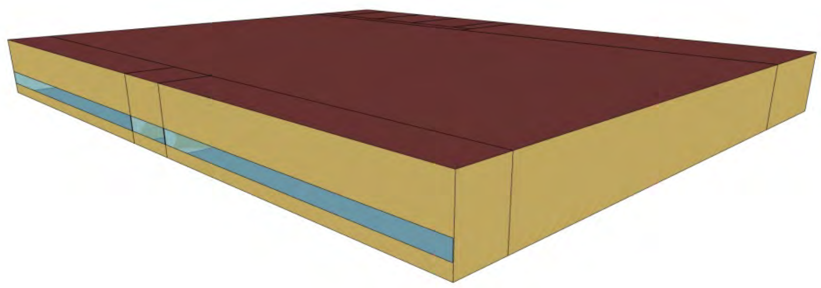


K-12 Energy Modeling Results

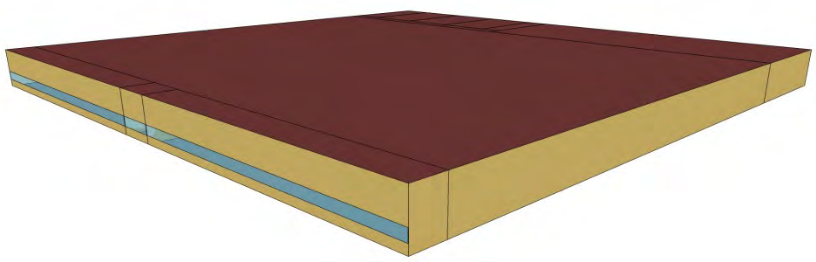


Retail Energy Models

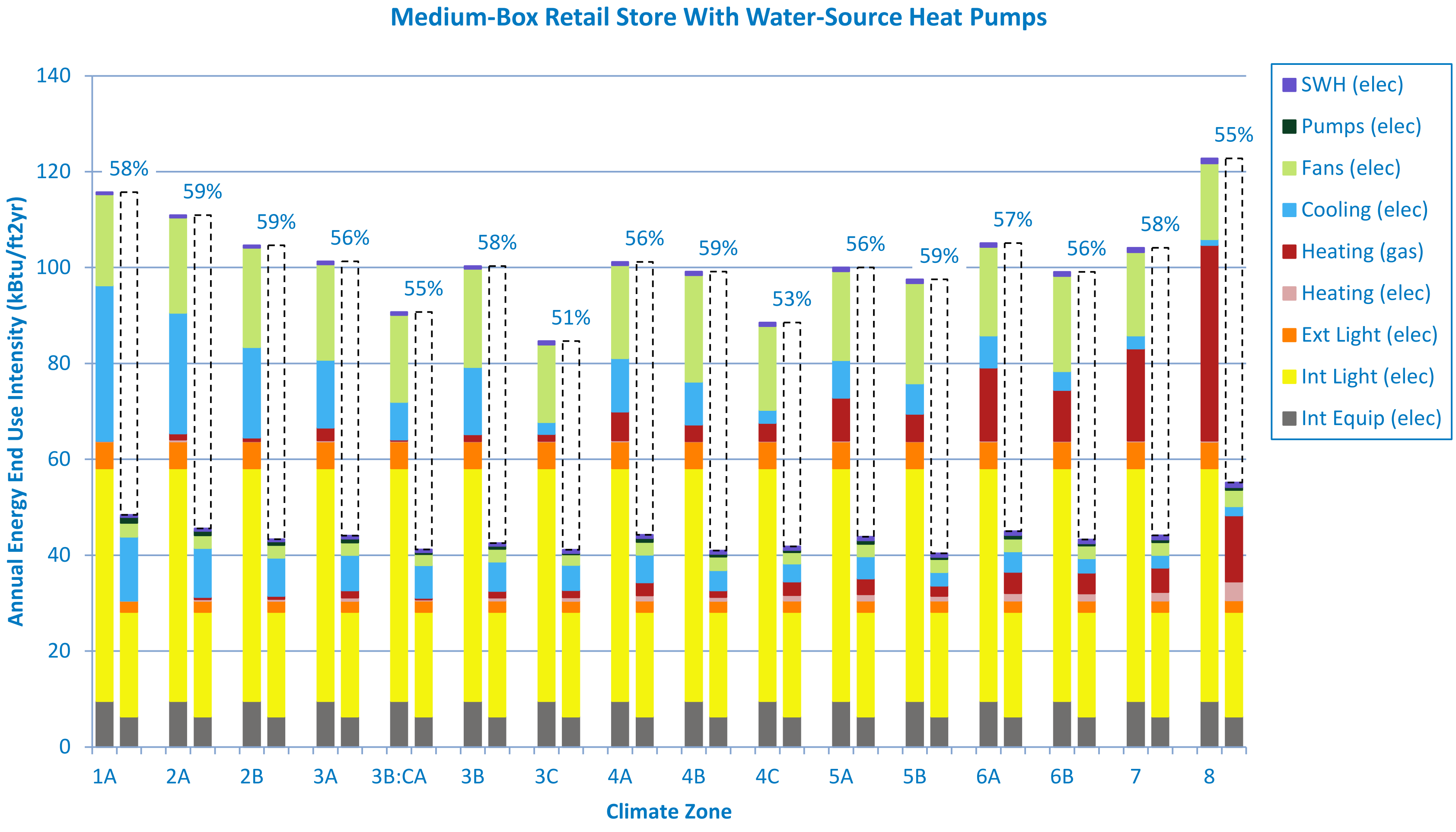
- **Medium-box store**
  - 1 story
  - 20,000 ft^2
  - High and low plug loads



- **Big-box store**
  - 1 story
  - 100,000 ft^2
  - Low plug loads

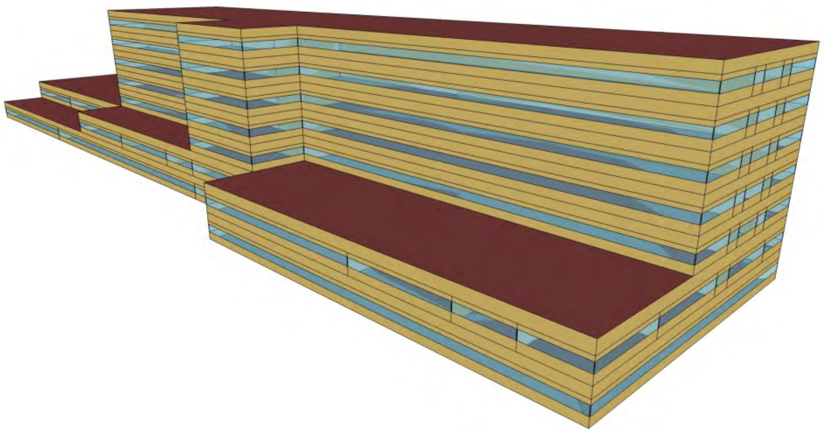


Retail Energy Modeling Results

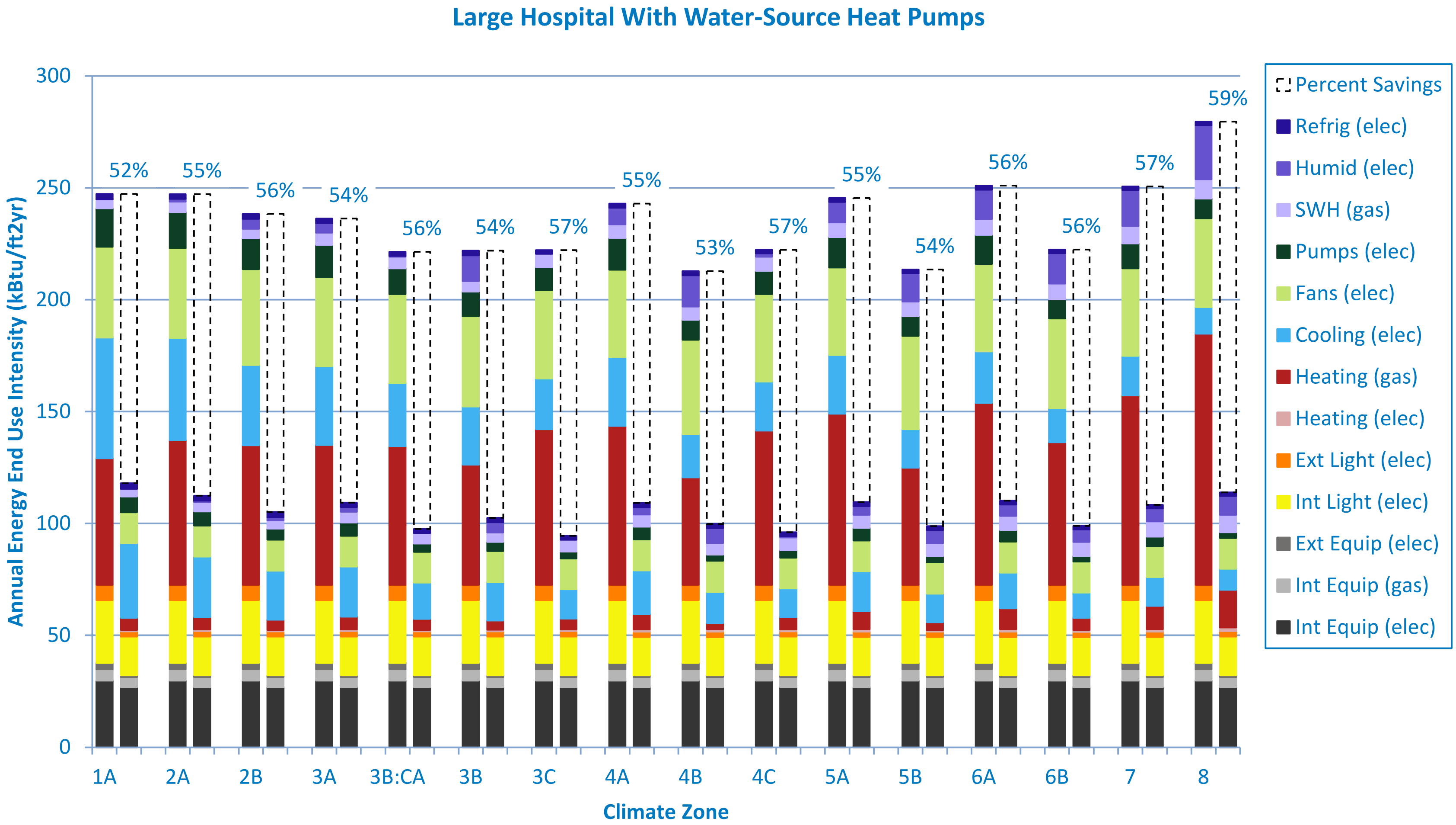


Hospital Energy Models

- **Large hospital**
  - o 7 stories
    - – 2-story diagnostic and treatment block
    - – 5-story patient tower
- **427,000 ft^2**



Hospital Energy Modeling Results

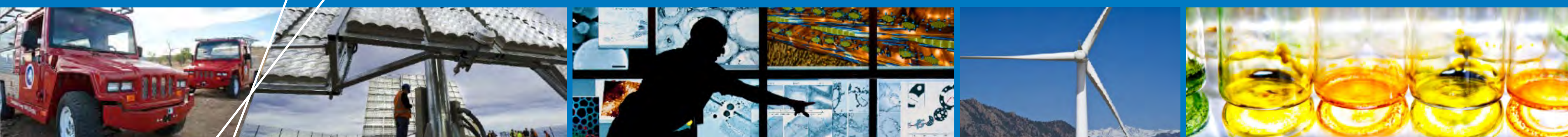


Conclusions

- **Simple, easy**
  - The AEDGs provide simple, easy-to-use guidance to help the building designer, contractor, and owner identify a clear path to significant energy savings over Standard 90.1
  - In many ways, the AEDGs are a simple interface with a complex background analysis performed using EnergyPlus
- **Concise recommendations tables**
  - The combination of a comprehensive set of recommendations contained in a single table, along with numerous how-to tips to help the construction team execute the project successfully, results in increased energy efficiency in new buildings

Conclusions

- **Case studies**
  - Case studies of actual facility applications add to the comprehension of energy efficiency opportunities
- **Step towards net zero**
  - The ultimate goal of the AEDG partner organizations is to achieve net zero energy buildings, and the AEDGs represent a step toward reaching this goal
- **More than 450,000 AEDGs are in circulation**
- **AEDGs are available for free as PDF downloads from www.ashrae.org/aedg**



Q&A

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