Strategies to Cut Energy Use by 50% in Commercial Buildings

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There will be a Q&A session at the end. Questions will be submitted electronically and answered verbally. Submit your questions by selecting "Q&A" on the menu at the top, click in the top box, type your question and click "Ask."

Today's Speakers

Lut Tang Jerome Lam is an Energy Technology Program Specialist for the U.S. Department of Energy's (DOE) Commercial Building Integration and Deployment Team. Mr. Lam manages commercial building research and development projects for DOE and has more than 10 years experience as a project manager/architect in national and international architecture firms**.**

Shanti Pless is a Senior Research Engineer, LEED AP, at the National Renewable Energy Laboratory (NREL). He brings 10 years of experience in commercial building energy efficiency research to the Commercial Building Research Team, where he focuses on integrating energy efficiency and renewable systems and design processes. He helped develop the 50% energy savings strategies for medium box general merchandise stores, grocery stores, and large office buildings.

Adam Hirsch is a Senior Mechanical Engineer at the National Renewable Energy Laboratory (NREL). He helped develop 50% energy savings strategies for medium box general merchandise stores, grocery stores, and large office buildings. He coordinates new construction and retrofit projects for the DOE Commercial Building Partnerships program to develop stores that cut energy use by 50% in new buildings and 30% in retrofits.

Brian Thornton, P.E., LEED AP, is a Senior Mechanical Engineer at Pacific Northwest National Laboratory (PNNL). He is the lead author for Technical Support Document: 50% Energy Savings for Small Office Buildings and Technical Support Document: 50% Energy Savings Design Technology Packages for Medium Office Buildings. Before joining PNNL in early 2009, he provided more than a decade of energy efficiency analysis for building design and regulatory programs including four years as the owner of his own business . In 2006 he received a Better Bricks Award (Northwest Energy Efficiency Alliance) for energy efficiency design support.

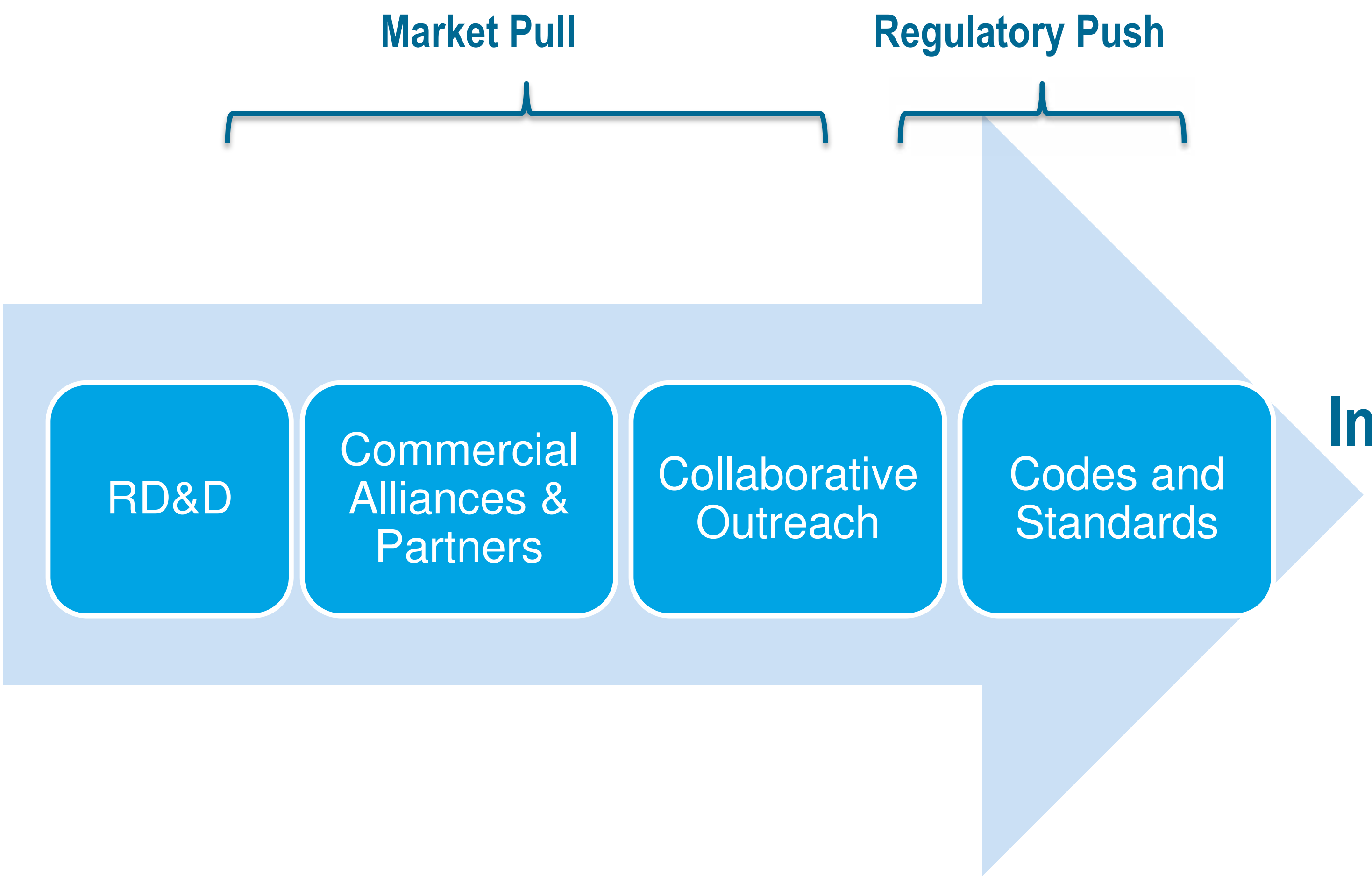
Jian Zhang is a Research Engineer in the Building Energy Systems and Technologies Group at Pacific Northwest National Laboratory (PNNL). He provides technical support to DOE's Retailer Energy Alliance – Restaurant Project Team. He has also worked on research projects for DOE's Building Energy Codes Program and Commercial Building Partnerships Program with focus on design and analysis of energy-efficient commercial buildings.

Commercial Building Integration and Deployment

Jerome Lam
U.S. Department of Energy
October 28, 2010

Speed Technology Innovation and Energy Savings

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Impact 3 billion ft^2 each year

Deployment Programs

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Commercial Building Energy Alliances

Retailer Energy Alliance

Hospital Energy Alliance

Commercial Real Estate Energy Alliance

Commercial Building Partnerships

Fitzmartin Consulting Retrofit Project

Energy-Saving Measures	Approximate Energy Savings
Increase thermostat deadband from ±1°F to ±3°F	3%
Install variable speed fans on air handling units combined with supply air temperature reset	9%
Right-size corridor lighting	5%
Install occupancy sensors (also addresses nighttime lighting)	9%
Upgrade downlighting from incandescent to fluorescent	7%
Reduce nighttime plug loads from 50% to 20%	4%
Estimated Total Energy Savings Compared with Existing Energy Use	**37%**

In addition to saving energy, the EEMs have to make business sense.

"We modeled new variable air volume air handling units and daylight harvesting in detail, and both strategies would have saved energy," says Greg Stark, NREL project lead. "But we couldn't justify the cost of these EEMs based on the client's business model, so we eliminated them from consideration."

The EEMs that the team agreed upon are relatively inexpensive and are replicable in a large number of high-rise office buildings throughout the United States. The impacts of widespread deployment would be impressive. If the identified EEMs were applied throughout this building alone, the energy and carbon savings per year would be almost 7 million kilowatt-hours of electricity and 9 million pounds of carbon. NREL will publish its methods and analysis for all to use.

The Fitzmartin Consulting retrofit project involves renovating one floor of the five-floor HRO law offices in the Wells Fargo Center in downtown Denver, Colorado. *Photo courtesy of Downtown*

Commercial Technology Solutions

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES PROGRAM

Technology Specification Project: LED Site (Parking Lot) Lighting

The U.S. Department of Energy (DOE), its national laboratories, and alliance members are working to support the market introduction of light-emitting diode (LED) parking lot lighting. A Commercial Building Energy Alliance (CBEA) Project Team is focused on making reliable, energy-efficient, and competitively priced outdoor LED luminaires more widely available in the marketplace.

A Walmart in Leavenworth, Kansas, has the first retail parking lot designed from inception to meet the CBEA LED parking lot site lighting specification. The superstore is serving as a test site to determine the viability of expanding LED parking lot lights throughout Walmart stores nationwide.

LED technology has advanced into new categories of "white light" applications, including parking lot lighting, where early indications suggest a high-quality light and long life. At present, however, tested products are available from a limited number of suppliers, performance in the later years of the product's life-time can only be estimated, and LED luminaires are relatively expensive on a first-cost basis. Nonetheless, there are many benefits for LED lighting in parking lots. Refer to Table 1 on page 2.

DOE's CBEAs are focusing on reducing commercial building energy costs and consumption by working with a host of industry suppliers, including appliance, heating, cooling, and lighting manufacturers, to meet members' energy-efficiency needs. One area in particular that offers immediate returns is lighting, because the performance of high-efficiency lighting systems using solid-state lighting (SSL) technology is rapidly improving and gaining market acceptance. A CBEA Project Team is investigating the use of LED parking lot lighting for commercial buildings with the goal of accelerating the market availability of LED parking lot lighting products that meet CBEA members' performance requirements. To date, the Project Team has:

- Identified candidate luminaires and are investigating their field and laboratory performance, as well as life and reliability issues
- Developed product performance specifications and evaluation procedures based on CBEA members' needs.

DOE Support

This DOE-sponsored effort is implemented by the Pacific Northwest National Laboratory (PNNL) in coordination with CBEA members. DOE actively supports research and commercialization of LED lighting through its SSL program, which includes research and development, product testing, technical information development, product demonstrations, and outreach to energy-efficiency program administrators. Visit ssl.energy.gov for more information on DOE's SSL portfolio.

DOE provides technical assistance in support of this specification project, including:

- Product performance testing
- Product demonstration technical support
- Analysis of energy cost savings
- Analysis/quantification of maintenance cost savings
- Investigations into life measurements and other performance indicators
- Development of a CBEA product performance specification
- Technology specification technical assistance as needed.

Resources developed in support of this effort are available at www1.eere.energy.gov/buildings/alliances/rea_subcommittees.html (see Lighting and Electrical).

Commercial Building Initiative

Advanced Energy Design Guides

commercialbuildings.energy.gov

AEDGs and TSDs Overview

Shanti Pless

Senior Research Engineer

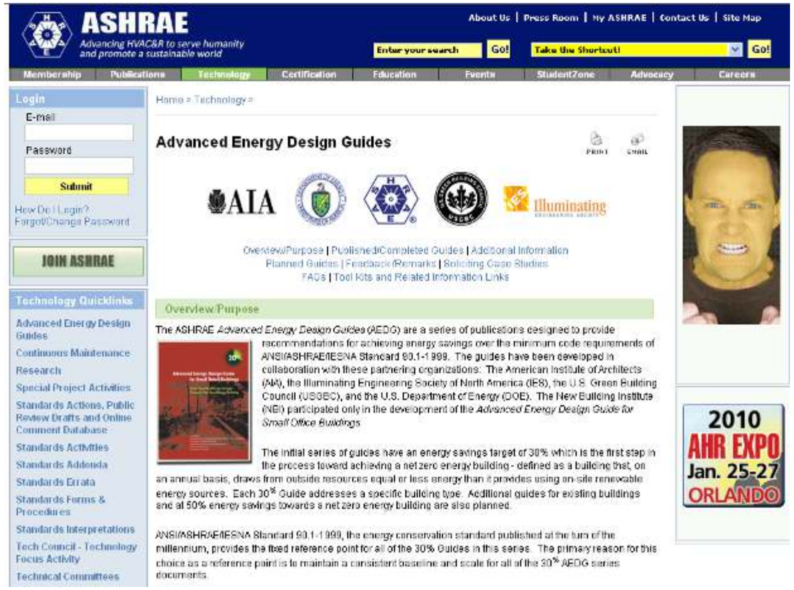
NREL Commercial Buildings Research Group

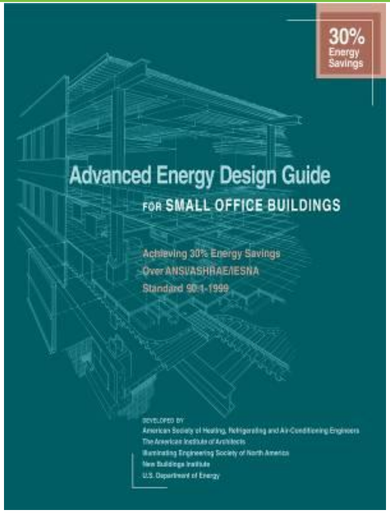
October 28, 2010

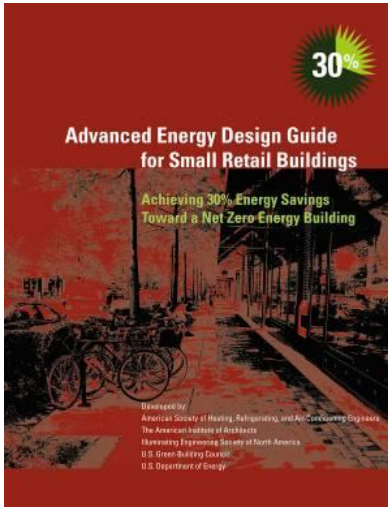
What is an Advanced Energy Design Guide?

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Packages of energy efficiency recommendations to help owners and designers achieve *30% energy savings*
  - *30% site energy use savings over ASHRAE 90.1 – 1999*
  - *But also looked at 90.1-2004 and 2007*
- Present recommendations for *some ways, but not all or the only way* to build energy efficient buildings
  - Provide climate specific recommendations
  - Not a code or Standard
- Recommendations provided by a Committee of Industry Professionals
  - Developed by ASHRAE, AIA, USGBC, IES, and DOE
- Applies to new construction and major renovation
- Alternative compliance path in LEED
- Download for free or soft cover purchase at: www.ashrae.org/aedg




30% Energy Savings
Advanced Energy Design Guide
FOR SMALL OFFICE BUILDINGS
Achieving 30% Energy Savings
Over ANSI/ASHRAE/IESNA
Standard 90.1-1999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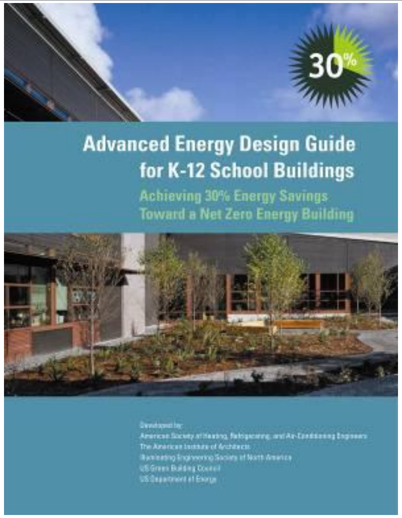
Advanced Energy Design Guide
for Small Retail Buildings
Achieving 30% Energy Savings
Toward a Net Zero Energy Building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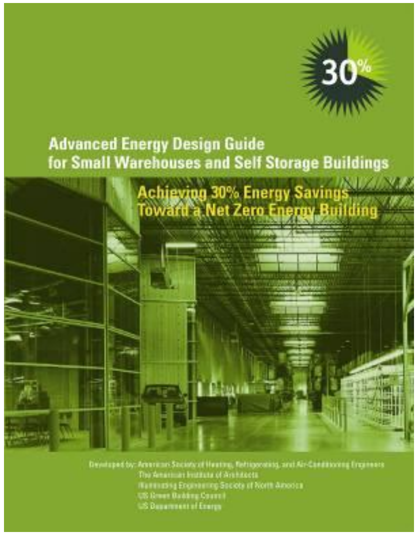
Advanced Energy Design Guide
for K-12 School Buildings
Achieving 30% Energy Savings
Toward a Net Zero Energy Building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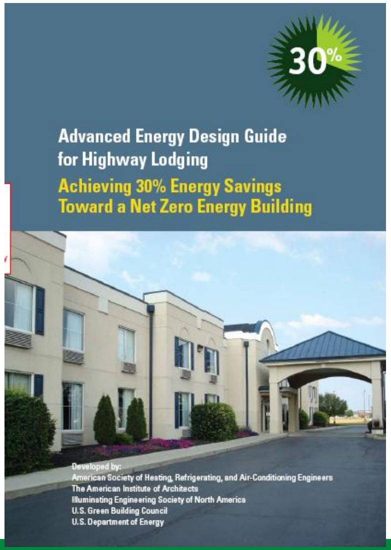
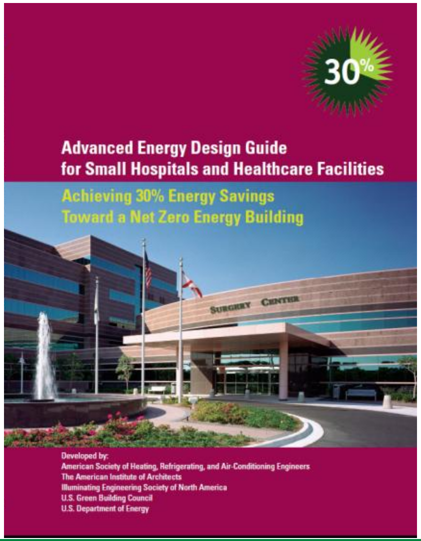
Advanced Energy Design Guide
for Small Warehouses and Self Storage Buildings
Achieving 30% Energy Savings
Toward a Net Zero Energy Building


30%
Advanced Energy Design Guide
for Highway Lodging
Achieving 30% Energy Savings
Toward a Net Zero Energy Building
Developed by:
American Society of Heating, Refrigerating, and Air-Conditioning Engineers
The American Institute of Architects
Illuminating Engineering Society of North America
U.S. Green Building Council
U.S. Department of Energy

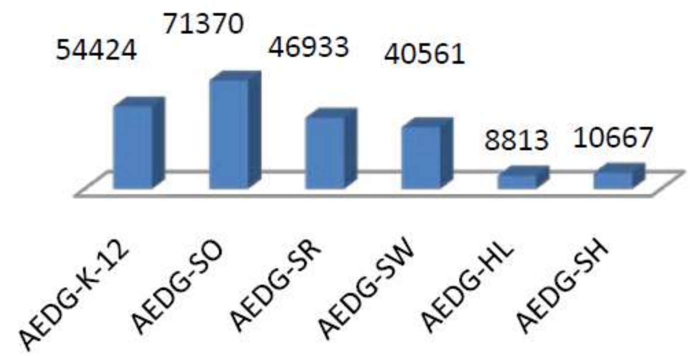

30%
Advanced Energy Design Guide
for Small Hospitals and Healthcare Facilities
Achieving 30% Energy Savings
Toward a Net Zero Energy Building
Developed by:
American Society of Heating, Refrigerating, and Air-Conditioning Engineers
The American Institute of Architects
Illuminating Engineering Society of North America
U.S. Green Building Council
U.S. Department of Energy

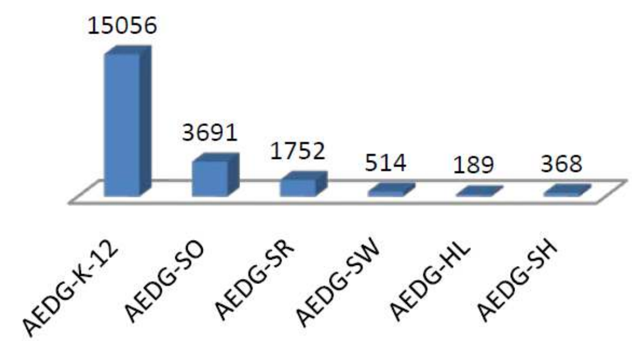
Recommendation Development Process

- Collaboration of partner organizations
  - Volunteer project committee members
- Focus on “good” design practices for
    - Envelope
    - Daylighting and lighting
    - HVAC
    - Service hot water
- Recommendations available from multiple manufactures
- At least as stringent as ASHRAE 90.1-2007
- 65% and 90% peer review process, focus group
  - Leverage Commercial Building Energy Alliance membership
- Energy modeling to develop Recommendations by climate zone and verify savings
  - Some analysis to determine optimal levels of insulation
  - Energy is independent variable & cost-effectiveness (e.g. payback) is dependent variable

30% AEDGs – Deployment Examples

- Over 275,000 guides in circulation
- Commissioned market impact analysis
  - Part of tool kit for A/Es
- Influenced ASHRAE 90.1-2010 and 189.1 development and market acceptance for beyond code strategies
- Proven to be easy to use with readily available efficiency targets
  - A key tool for rebuilding in Greensburg, KS
    - Integrated into Master Plan
    - All commercial projects used the AEDGs and have meet or exceeded 30%



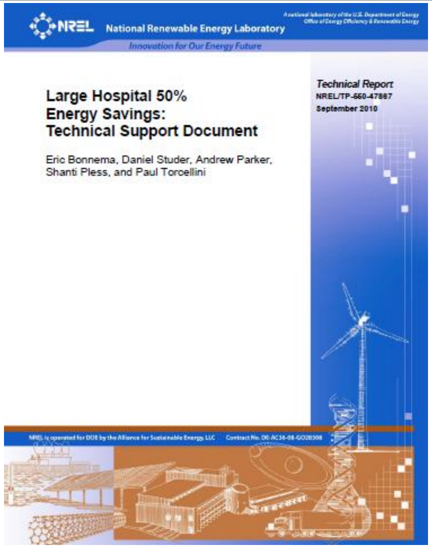





50% Savings Technical Support Documents

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Analysis documentation of 50% savings strategies by building type
  - General Merchandise
  - Grocery Stores
  - Small Office
  - Medium Office
  - Highway Lodging
  - Large Hospitals
  - Large Offices
  - Quick Service Restaurant



- Small/Medium Office and K-12 50% AEDG in development

- http://www.commercialbuildings.energy.gov/guides.html

Large Office TSD: 50% Energy Savings

Shanti Pless and Adam Hirsch

October 28, 2010

Link to TSD PDF:
www.nrel.gov/docs/fy10osti/49213.pdf

Large Office TSD: Scope of Analysis

Climate Selection:

Climate Type	Representative City	ASHRAE Climate Zone
Hot and Humid	Miami, FL	1A
Hot and Dry	Las Vegas, NV	3B
Marine	Seattle, WA	4C
Cold and Humid	Chicago, IL	5A
Cold and Dry	Boulder, CO	5B
Very Cold	Duluth, MN	7

Prototype Overview:

Characteristic	Low-Rise Prototype	High-Rise Prototype
Total Floor Area (ft^2)	460,800	460,800
Number of Floors	4	12
Floor Plate Area (ft^2)	115,200	38,400
Aspect Ratio	1.5	1.5
Floor Types Modeled	Ground, Interior, Top	Interior

Large Office TSD: Baseline and Low-Energy Models

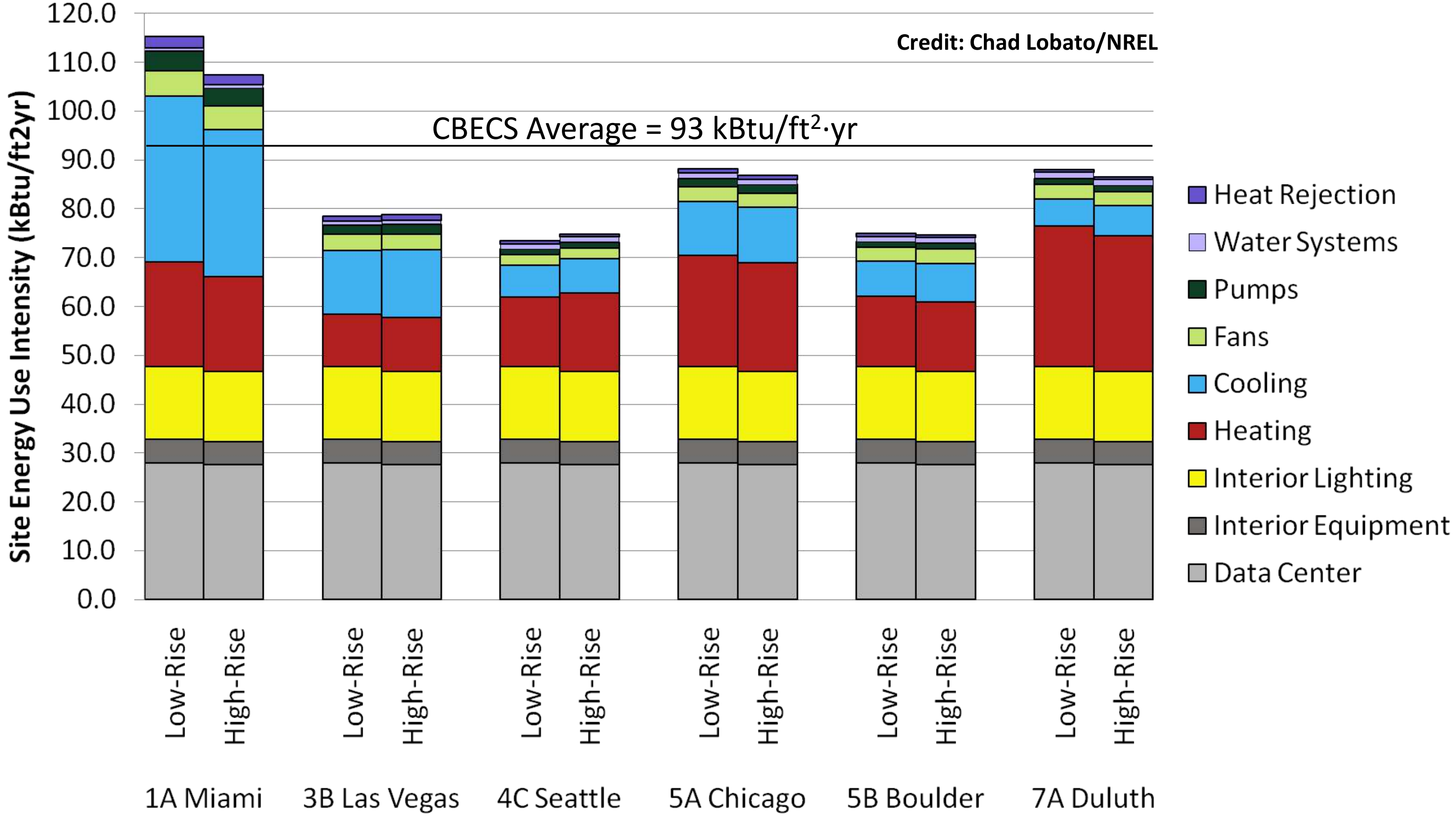
Baseline Model:

- **Lighting power density:** 1.1 W/ft^2
- **Office equipment load density:** 0.40 W/ft^2
- **Total data center load density:** 0.9 W/ft^2
- **Exterior wall insulation:**
  - low-rise: no c.i. to R-11.4 c.i.
  - high-rise: R-13.0 to R-13.0 + R-7.5 c.i.
- **Roof insulation:** R-15.0 c.i.
- **Windows:**
  - U-factor: 0.57 to 1.21
  - SHGC: 0.25 to 0.64
  - VLT: 0.25 to 0.64
- **HVAC:**
  - Hydronic VAV
  - Centrifugal water-cooled chiller (6.1 COP)
  - Natural gas boiler (80% efficient)
  - Enthalpy-controlled economizers
  - Variable volume terminal boxes with hot water reheat

Low-Energy Model:

- **Lighting power density:** 0.63 W/ft^2
- **Office equipment load density :** 0.32 W/ft^2
- **Total data center load density:** 0.42 W/ft^2
- **Exterior wall insulation:**
  - low-rise: R-5.7 c.i. to R-19.5 c.i.
  - high-rise: R-13.0 to R-22.5 c.i.
- **Roof insulation:** R-15.0 c.i.
- **Windows:**
  - U-factor: 0.24 (low-rise), 0.29 (high-rise)
  - SHGC: 0.42 (low-rise), 0.28 (high-rise)
  - VLT: 0.75 (low-rise), 0.55 (high-rise)
- **HVAC:**
  - Radiant ceilings with DOAS
  - Centrifugal water-cooled chiller (7.0 COP)
  - Natural gas condensing boiler (>90% efficient)
  - Water-side economizing
  - Energy recovery

Large Office TSD: Baseline Energy Usage



- Low-rise and high-rise energy use intensities (EUIs) are comparable
- Electrical and lighting equipment consume 56% of total energy
- Data center consumes 33% of total energy

Large Office TSD: Low-Energy Energy Usage

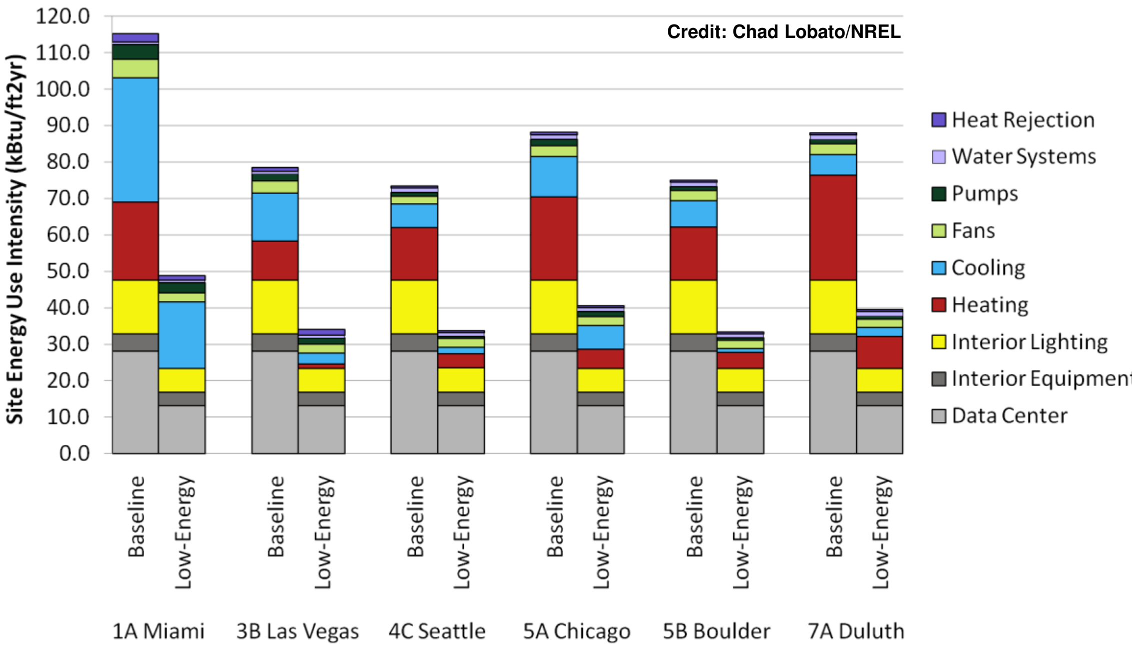
50% energy savings achievable **without the use of renewables** in all cases

Lighting power reduced via high efficiency equipment, occupancy sensors, and daylighting (by approximately 60%)

Data center loads reduced by 54%

Other plug loads reduced by 20% via high-efficiency equipment and smart control strategies

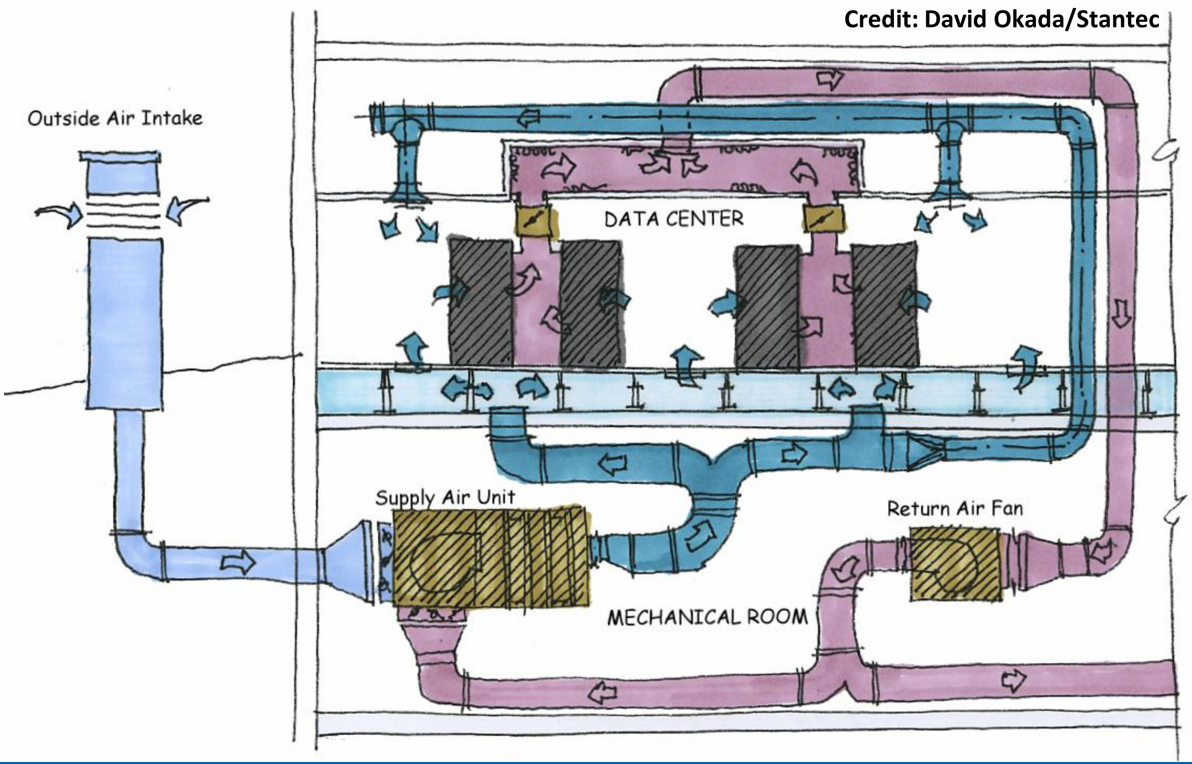
Heating load reduced significantly by eliminating reheat at the zone level



Large Office TSD: Data Center Load Reduction

IT Load Reduction: 65W to 48W per person
- Replace standard servers with blade servers
- Virtualize to run up to 20 jobs on a single blade server

HVAC and Lighting Load Reduction: 1.9 to 1.2 power usage effectiveness (PUE)
- Hot and cold aisle containment
- Effective cable management



Large Office TSD: Plug Load Reduction

Office Equipment Load Reduction: 0.4 W/ft² to 0.32 W/ft²

Large Office TSD: Radiant Heat/Cool with DOAS

- **Decouples ventilation from conditioning**
- **Decouples latent load from sensible load**
- **Drastically reduces air system size**

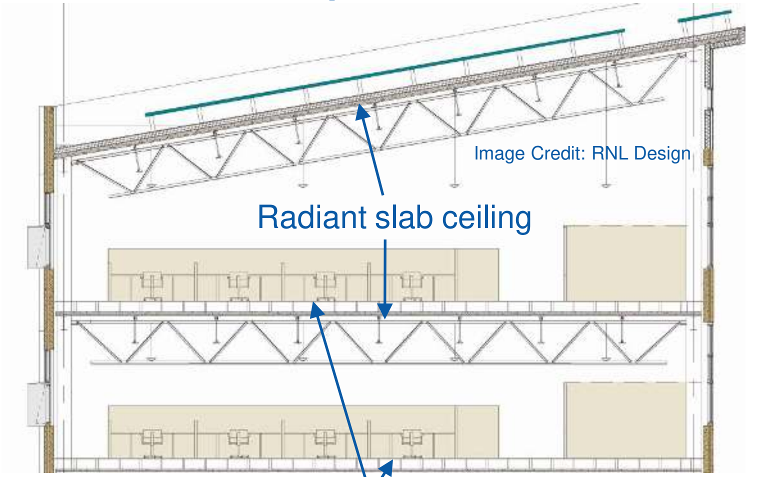
DOAS:

- Sized for ventilation load
- Conditions outdoor air to meet latent load
- Eliminates reheat at zone level
- Assists radiant heating in high load cases

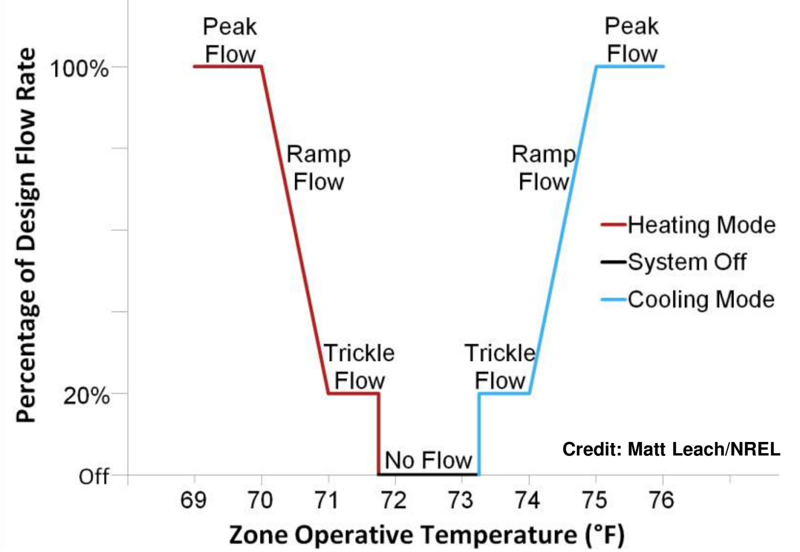
Radiant Ceiling Slab Heating and Cooling:

- Sized for sensible load
- High thermal mass dampens load fluctuations and allows for load shifting
- "Trickle and Ramp" control strategy tailored to thermal mass characteristics

RSF Implementation



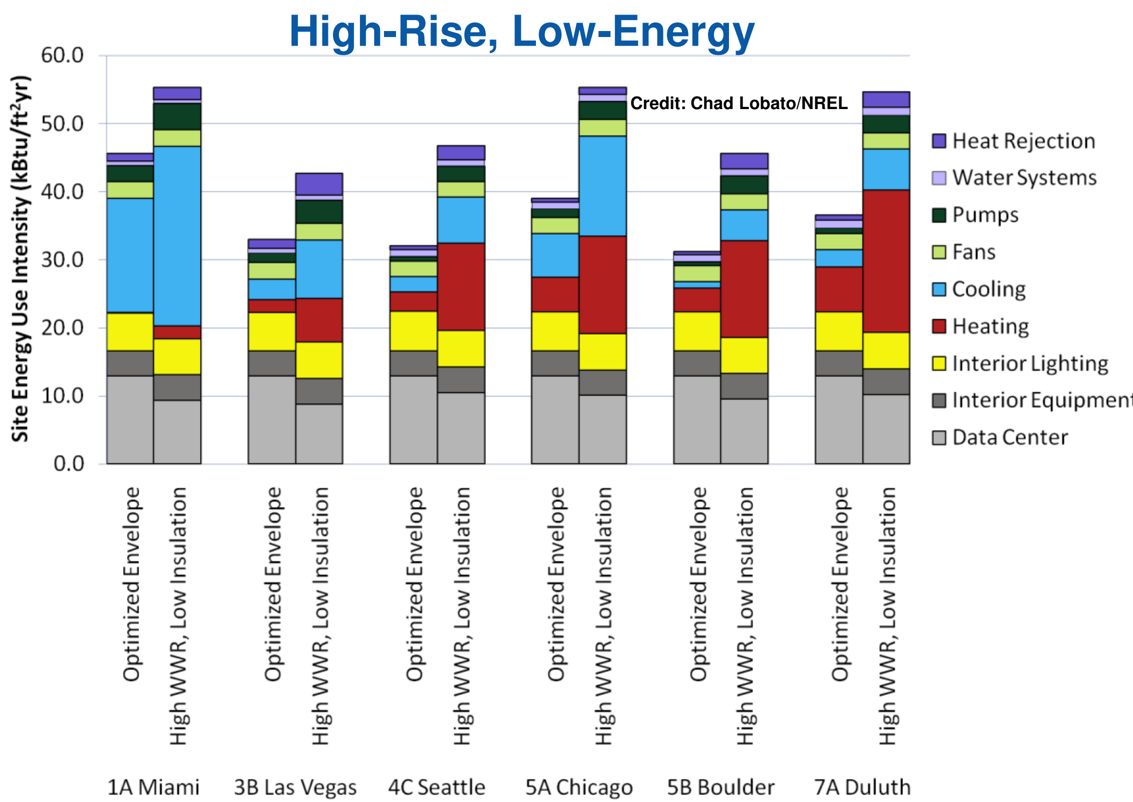
"Trickle and Ramp" Radiant Flow Control



Large Office TSD: Envelope Energy Analysis

Purpose: analyze energy implications of glass curtain exterior construction with high window-to-wall ratio (WWR) and low envelope insulation

- Envelope does not meet 90.1 requirements
- Severely limits potential energy savings
- 50% goal not achievable without substantial addition of renewables (90% - 300% PV roof coverage)
- Poorly insulated envelope significantly increases heating and cooling loads
- Increased equipment part load and run time results in increased pump and heat rejection energy



Note: Glass Box data center loads offset by generation from 60% roof coverage PV

Large Office TSD: Simple Payback Analysis

– **Low-rise:**
  - First cost increase: \$10-\$17/ft^2
  - Energy cost savings: \$0.88-\$1.25/(ft^2·yr)
  - Payback: 10.8-15.6 years

– **High-rise, optimized envelope:**
  - First cost increase: \$3.82-\$10.54/ft^2
  - Energy cost savings: \$0.88-\$1.15/(ft^2·yr)
  - Payback: 3.9-9.2 years

– **High-rise, high WWR, low insulation:**
  - First cost increase: \$14.41-\$20.47/ft^2
  - Energy cost savings: \$0.59-\$0.96/(ft^2·yr)
  - Payback: 18.5-30.2 years*

* 19.5-35.6 years if enough PV added to achieve 50% energy savings goal

NREL Research Support Facility (RSF)

- Projected to use ~33 kBtu/(ft^2·yr) **= 50% less than code**
- 822 occupants
- 220,000 ft^2 of floor area
- LEED™ Platinum
- **Produces as much energy as it consumes**

- Daylighting, low lighting power density, and occupancy sensors
- Well-insulated envelope
- Radiant heating/cooling in ceiling slab with DOAS
- Ventilation air energy recovery
- Evaporative cooling of ventilation air and data center
- Efficient data center and equipment
- Heat recovery from data center and transpired solar collectors
- Natural ventilation and night purging

Modeled in TSD

Not Modeled in TSD

Large Office TSD: Acknowledgments

- NREL colleagues **Matt Leach**, **Chad Lobato**, **Shanti Pless**, and **Paul Torcellini**
- **John Priebe** of The Abo Group and **Stefan Coca** of Cumming Corporation
  - Envelope cost estimation
- **Bob Stahl**, **Phil Kocher** and **Jim Bradburn** of RMH Group
  - HVAC configuration and cost estimation
- **Steve Taylor** of Taylor Engineering and **Fiona Cousins** of Arup Engineering
  - Review of analysis assumptions and overall approach
- **David Okada** of Stantec Engineering
  - Review of energy efficiency measures

Large Hospital TSD: 50% Energy Savings

Shanti Pless and Adam Hirsch

October 28, 2010

Link to TSD PDF:
www.nrel.gov/docs/fy10osti/47867.pdf

Large Hospital TSD: Prototype Model

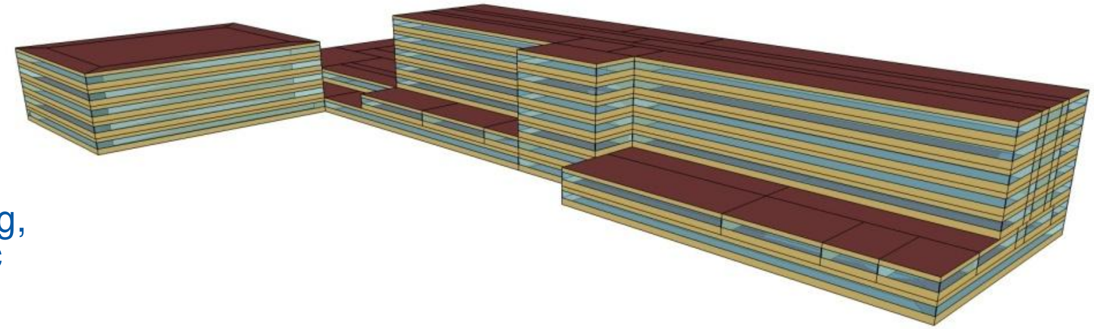
Form
- 527,000 ft^2
- 40% window-to-wall ratio

Space Types
- Floor 1: offices, laboratories, dining, mechanical, support spaces, clinic
- Floor 2: emergency department, surgery suite, imaging,
- Floor 3: birthing center
- Floor 4-7: patient tower
- 5-story attached medical office building

Envelope
- Slab-on-grade
- Steel framed exterior walls
- Insulation above deck roof
- Double pane fixed windows

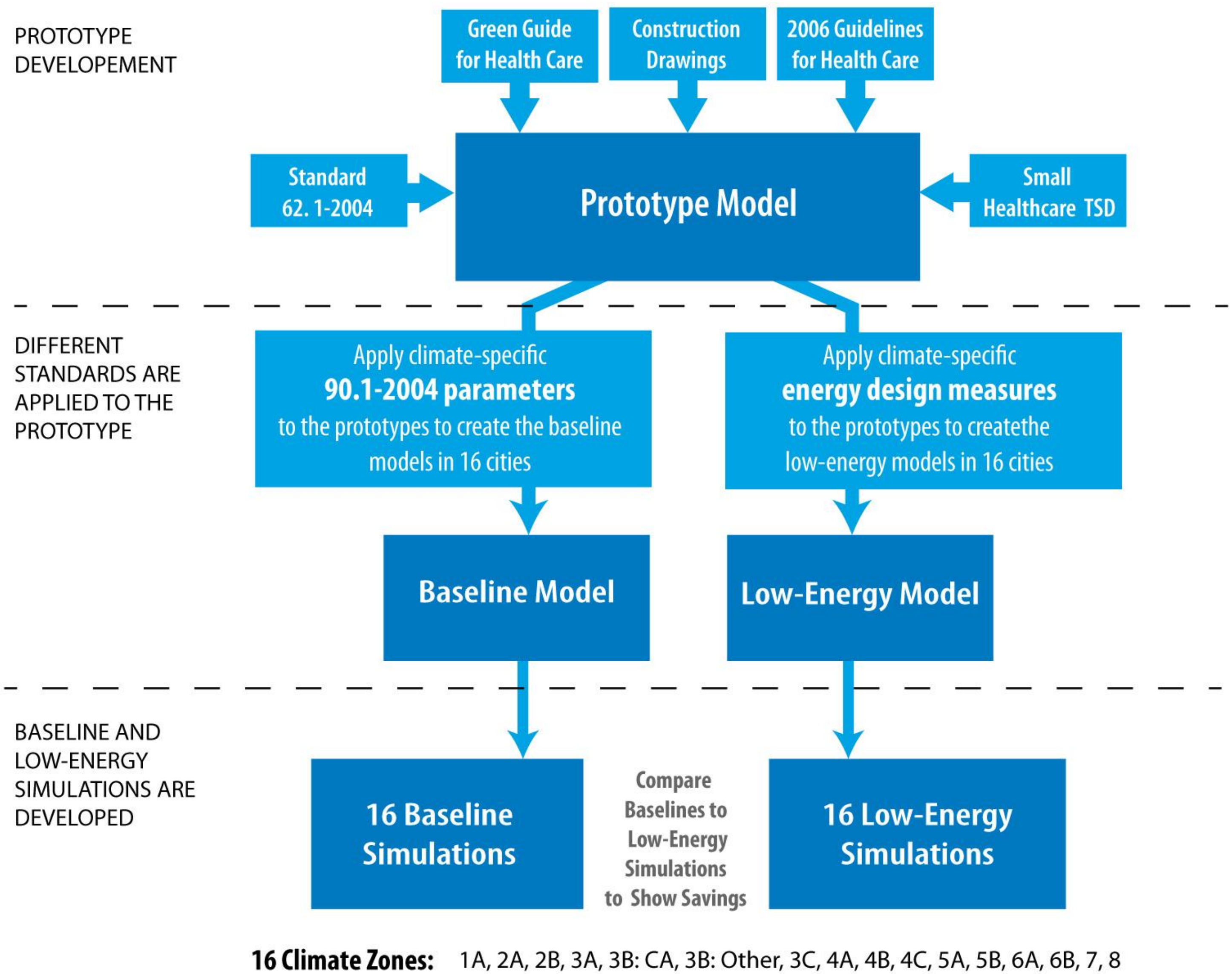
Internal Loads
- Plug load density: 2.6 W/ft^2
- Occupant density: 136 ft^2/person

Ventilation/Airflow Standards
- Healthcare spaces
  - 2006 AIA Guidelines
  - Standard 170-2008
- Administrative spaces
  - Standard 62.1-2004



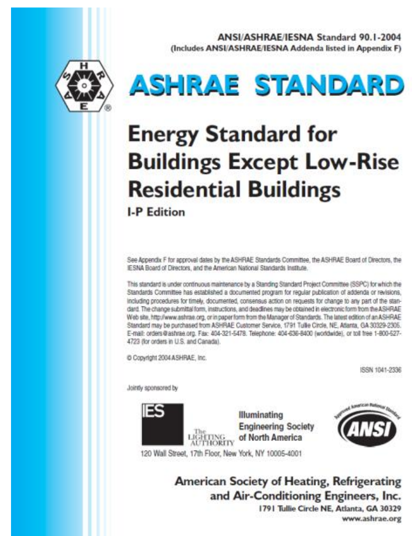
Credit: Eric Bonnema/NREL

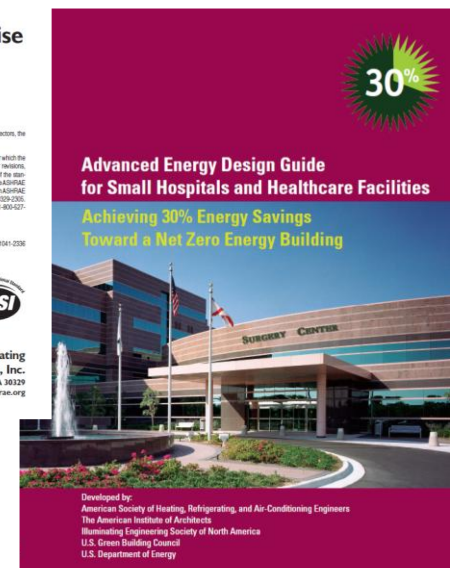
Large Hospital TSD: Modeling Process



Large Hospital TSD: Lighting

Space Type	Baseline Lighting Power Density (W/ft^2)	Low-Energy Lighting Power Density (W/ft^2)
Anesthesia gas storage	0.90	0.80
Cafeteria	0.90	0.90
Clean workroom/holding	1.10	0.80
Conference room	1.30	1.10
Corridor/transition	1.00	0.70
Dining room	0.90	0.90
Examination/treatment room	1.50	1.10
Food preparation center	1.20	1.20
Laboratory	1.40	0.90
Laundry	0.60	0.60
Lobby area	1.30	0.80
Locker	0.60	0.60
Lounge	0.80	0.80
Mechanical/electrical/telecomm	1.50	0.80
Medical supply/medication room	1.40	1.10
Nurse station	1.00	1.00
Nursery	0.60	0.60
Office	1.10	0.80
Operating suite	2.20	2.00
Patient room	0.70	0.70
Pharmacy	1.20	1.20
Physical therapy	0.90	0.90
Procedure room	2.70	2.00
Radiology/imaging	0.40	0.40
Reception/waiting	1.30	0.90
Recovery room	0.80	0.80
Restroom	0.90	0.80
Soiled workroom/holding	1.10	0.80
Sterilizer equipment room	0.90	0.90
Storage/receiving	0.90	0.70
Trauma/emergency room	2.70	1.20
Triage	2.70	2.00
Whole Building	**1.12 W/ft^2**	**0.88 W/ft^2**





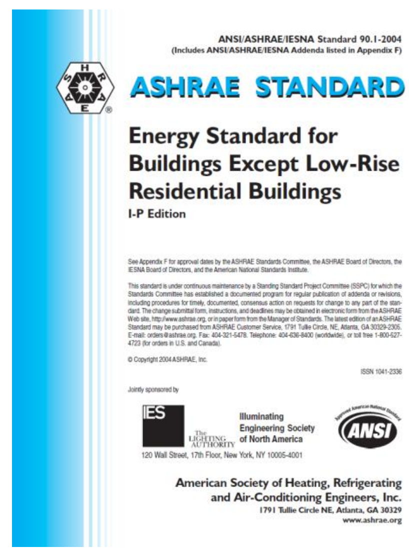
Large Hospital TSD: Envelope

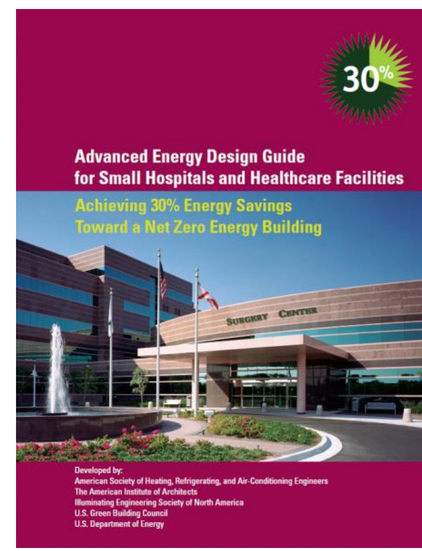
Baseline Model:

- **Exterior wall insulation:**
  - R-13 to R-13+R-7.5
- **Roof insulation :**
  - R-15 to R-20
- **Windows:**
  - U-factor: 0.46 to 1.22
  - SHGC: 0.25 to 0.64
  - VLT: 0.25 to 0.50

Low-Energy Model:

- **Exterior wall insulation:**
  - R-13+R-7.5 to R-13+R-21.6
- **Roof insulation :**
  - R-25 to R-35
- **Windows:**
  - U-factor: 0.29 to 0.43
  - SHGC: 0.26 to 0.34
  - VLT: 0.63 to 0.69





Large Hospital TSD: HVAC

Baseline Model:

Central air handler with chilled and hot water coils serving constant air volume boxes (CAV) with hot water reheat and a central plant containing a natural gas atmospheric boiler and a water-cooled chiller

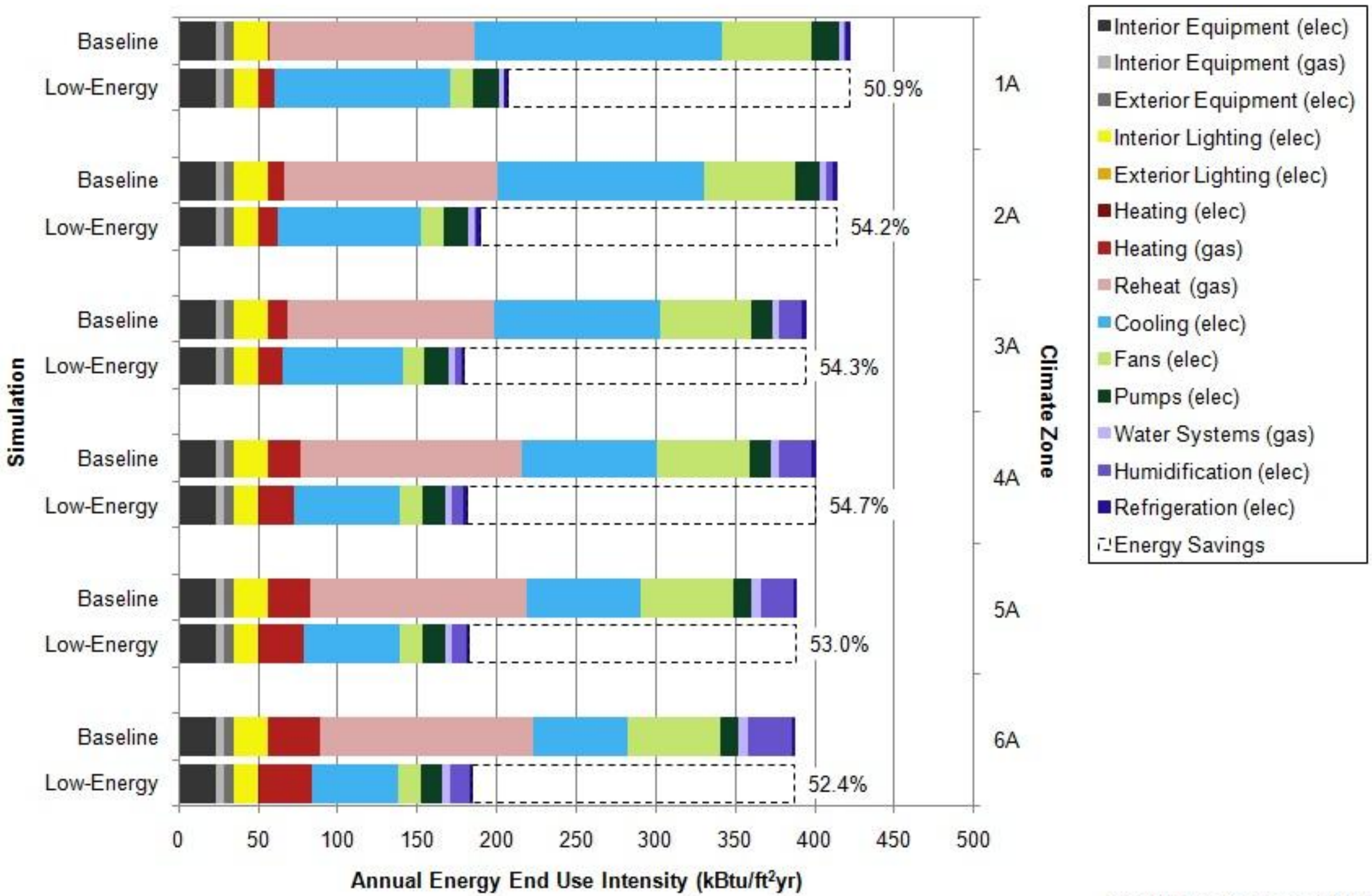
- Centrifugal water-cooled chiller
  - Variable flow, 6.1 COP
- Natural gas fired boiler
  - Atmospheric, 80% efficient
- Differential enthalpy controlled air-side economizers
- Variable speed pumps
  - 75% efficient
- Steam humidifiers
- Terminal boxes
  - Constant air volume
  - Hot water reheat

Low-Energy Model:

Zone-level water-to-air heat pumps with a common condenser loop and a variable air volume (VAV) dedicated outdoor air system (DOAS) with a CAV air handler and a low temperature chiller in the operating suite

- Centrifugal water-cooled chiller
  - Variable flow, 7.0 COP
- Natural gas fired boiler
  - Condensing, 90% efficient
- Counterflow waterside economizer
- Variable speed pumps
  - 80% efficient
- Steam humidifiers
- Zone-level heat pumps
  - Heating COP: 5.0 @ 68 F
  - Cooling COP: 4.5 @ 86 F

Large Hospital TSD: Annual Energy Savings



Credit: Eric Bonnema/NREL

Case Studies: Heat Pumps in Hospitals

Great River Medical Center

- Located in West Burlington, IA
- Greenfield replacement hospital
- Completed 04/01/2000
- 190-bed 700,000 ft^2 hospital with 2,000-ton lake-coupled geothermal system
- 800 water-to-air heat pumps
- 37% energy savings

Sherman Hospital

- Located in Elgin, IL
- Greenfield replacement hospital
- Completed: 10/15/2009
- 255-bed 650,000 ft^2 hospital with 2,400-ton lake-coupled geothermal system
- 750 water-to-air heat pumps
- 30-40% savings estimated

Large Hospital TSD: Acknowledgments

- NREL colleagues **Eric Bonnema**, **Daniel Studer**, **Andrew Parker**, and **Paul Torcellini**

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    - Assistance and data to inform energy modeling

- **Donald Wojtkowski** of SSM Health Care
    - Assistance and data to inform energy modeling

Strategies to Cut Energy Use by 50% in Commercial Buildings

Technical Support Documents:

50% Energy Savings for Small and Medium Offices

and Quick Service Restaurants

October 28, 2010

Presented

by

Brian Thornton and Jian Zhang

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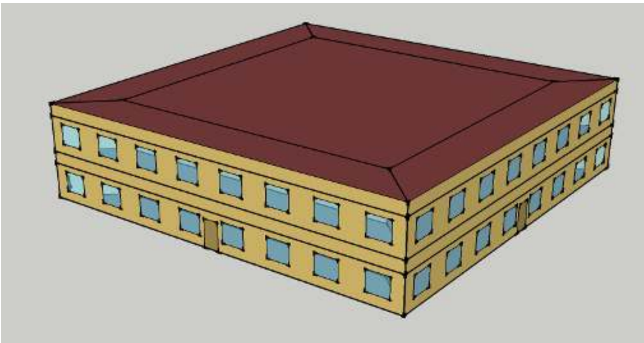
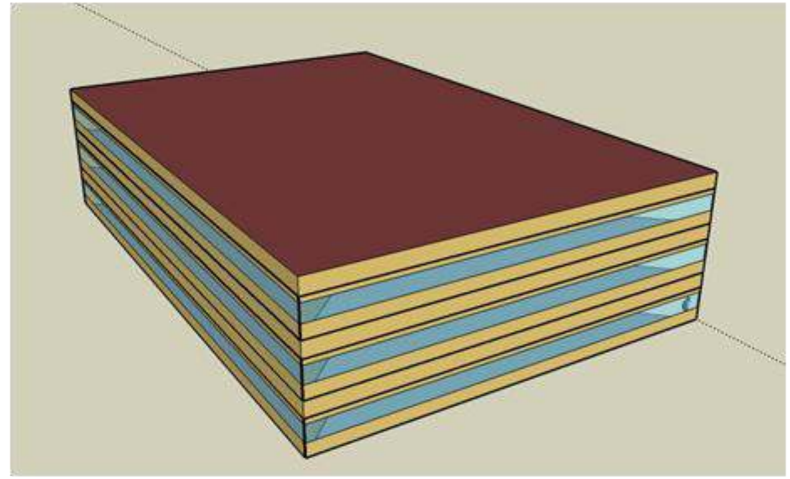
Small and Medium Office - Baselines



Small Office

- 20,000 ft^2, 100 ft by 100 ft
- 2 floors, 12 ft floor-to-floor height
- CMU block construction
- 20% window-to-wall ratio
- Constant air volume DX, gas heat



Medium Office

- 53,600 ft^2, 164 ft by 109 ft
- 3 floors, 13 ft floor-to-floor height
- Steel frame construction
- 33% window-to-wall ratio
- Variable air volume DX, gas furnace, electric reheat

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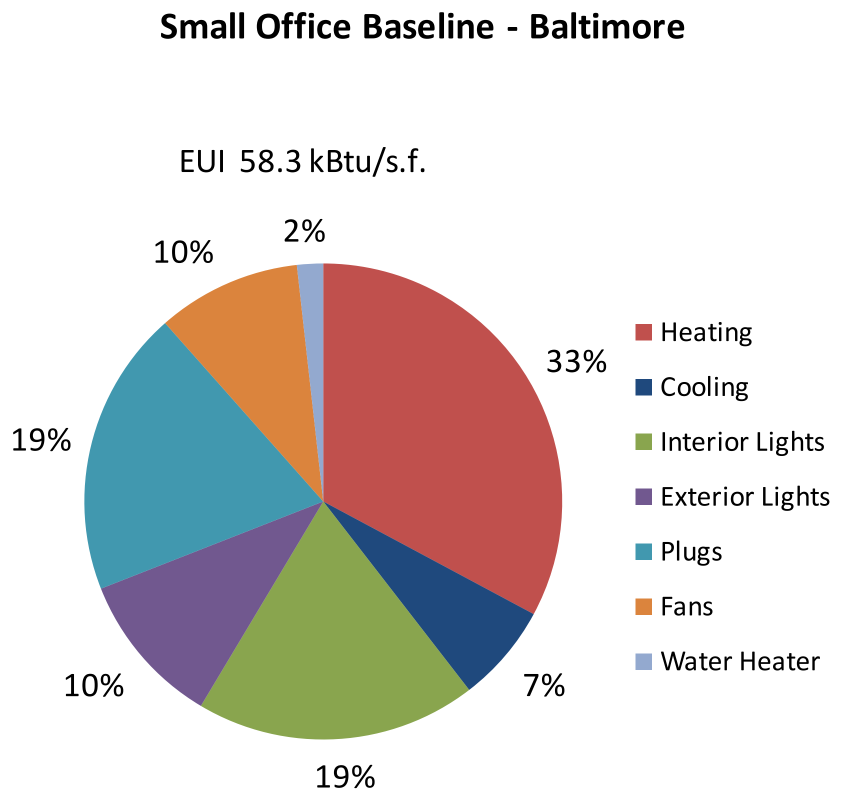
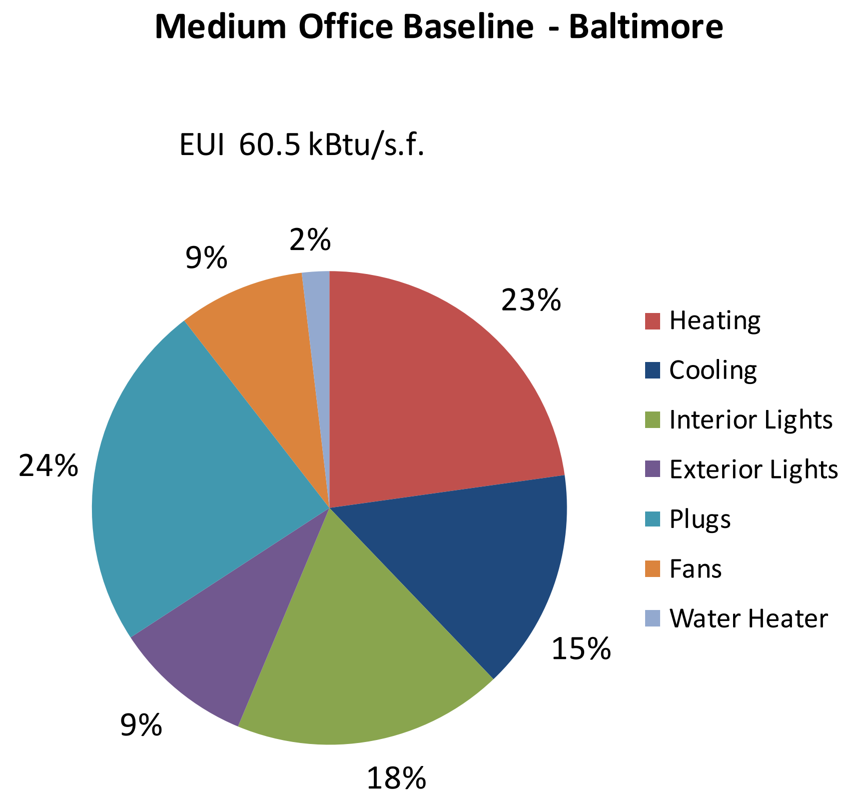
Baseline Energy Usage





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Building Envelope

Item	Component	Unit		Climate Zone								
				1	2	3A[1], 3B	3A[1], 3C	4	5	6	7	8
Walls-Exterior	Mass wall, continuous insulation	R-value ft^2·°F·h/Btu	Advanced	5.7	7.6	11.4	11.4	13.3	13.3	19.5	19.5	19.5
			Baseline	*NR*	*NR*	*NR*	*5.7*	*5.7*	*5.7*	*7.6*	*9.5*	*11.4*
	Steel framed	R-value ft^2·°F·h/Btu	Advanced	13+7.5 c.i.	13+7.5 c.i.	13+7.5 c.i.	13+7.5 c.i.	13+7.5 c.i.	13+15.6c.i.	13+18.8c.i.	13+18.8c.i.	13+18.8c.i.
			Baseline	*13*	*13*	*13*	*13*	*13*	*13+3.8 c.i.*	*13+3.8 c.i.*	*13+7.5 c.i.*	*13+7.5 c.i.*
Roof	Insulation entirely above deck	R-value ft^2·°F·h/Btu	Advanced	20	25	25	25	30	30	30	35	35
			Baseline	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*20.0*
	Cool Roof		Advanced	yes	yes	yes	yes	NR	NR	NR	NR	NR
Slab-on-grade floor	Unheated, insulation vertical, 24 in. at slab edge	R-value ft^2·°F·h/Btu	Advanced	NR	NR	NR	NR	NR	NR	10	10	10
			Baseline	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*5*
Vertical glazing	Manufactured Windows	U-factor Btu/h·ft^2·°F	Advanced	0.56	0.45	0.41	0.41	0.38	0.35	0.35	0.33	0.25
		SHGC		0.25	0.25	0.25	0.25	0.26	0.26	0.35	0.4	0.4
	Site-built Windows	U-factor Btu/h·ft^2·F	Advanced	0.65	0.65	0.6	0.6	0.44	0.44	0.42	0.34	0.34
		SHGC		0.25	0.25	0.25	0.25	0.26	0.26	0.35	0.4	0.4
	Both types	U-factor Btu/h·ft^2·F	*Baseline*	*1.2*	*1.2*	*0.6*	*1.2*	*0.6*	*0.6*	*0.6*	*0.6*	*0.5*
		SHGC		0.25	0.25	0.25	0.39	0.39	0.39	0.39	0.49	NR
	South Exterior Shading	Projection Factor	Advanced	PF>0.5	PF>0.5	PF>0.5	PF>0.5	PF>0.5	PF>0.5	NR	NR	NR

Lighting

- Interior Lighting
  - Baseline 1.0 W/ft^2, Advanced 0.75 to 0.79 W/ft^2
    - High-performance lensed fluorescent
    - High-performance instant start electronic ballasts
    - 4 foot T8 lamps all 3100 lumen lamps
  - Occupancy sensors added to open office task lighting, private offices, storage, restrooms, and electrical/mechanical spaces
  - Egress lighting reduction with security lockout
  - Perimeter daylighting – dimming
- Exterior Lighting
  - Approximately 35% reduction of exterior lighting wattage with efficient metal halides
  - Controls reduce parking and façade lighting to 10%, midnight to 6 AM.

Plug Loads Reductions

- Energy efficiency measures
  - Shift to laptops from desktop computers
  - Use Energy Star equipment wherever possible
  - Utilize additional control strategies
    - Network power management software
    - Occupancy sensor control of monitors and other desk area devices
    - Timer switch control of water coolers, coffee makers
    - Vending miser control for vending machines

Baseline	Advanced				
W/ft^2	Power reduction measures, W/ft^2	Incremental reduction from baseline, %	Controls measures, effective* power, W/ft^2	Incremental reduction from baseline, %	Total reduction from baseline, %
0.75	0.55	27%	*0.45**	*13%*	40%

* Controls reduction is from change in operating schedule, not total watts

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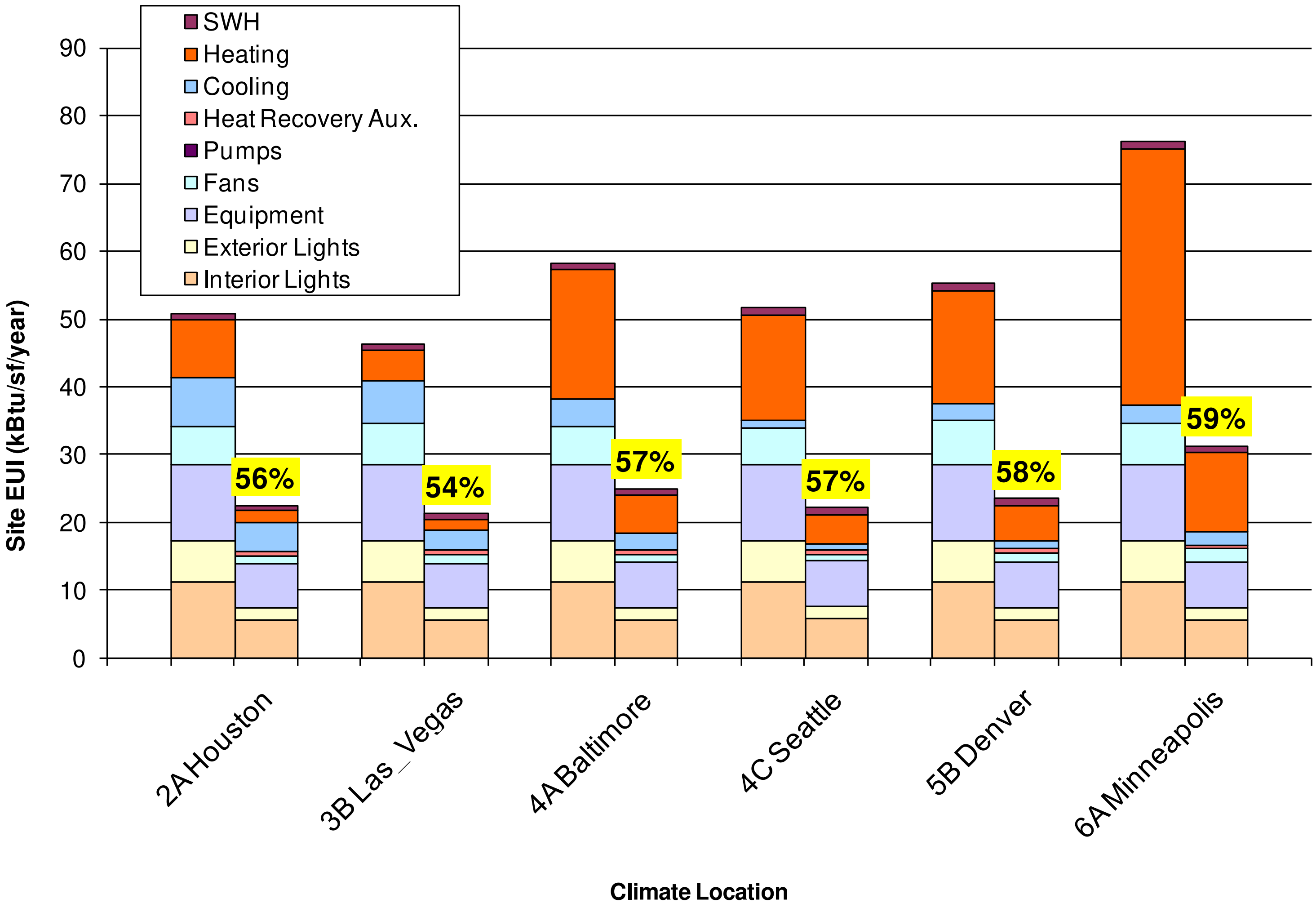
HVAC

- Small Office
  - Air source heat pumps with dedicated outside air system (DOAS)
  - DOAS DX with gas heat, energy recovery, demand controlled ventilation with variable airflow
- Medium Office
  - Radiant floor with DOAS
  - Condensing boiler and air-cooled chiller
  - DOAS DX with gas heat, energy recovery
- VAV alternative
  - VAV with premium efficiency DX, energy recovery, supply air temperature reset and demand controlled ventilation
  - In TSD not reaching 50% in all climates
- Advanced Energy Design Guide for Small and Medium Offices
  - Enhanced VAV, Fan Coils with DOAS, WSHP with DOAS

Small Office Heat Pump

Energy Usage % Reduction – Baseline Compared to Advanced



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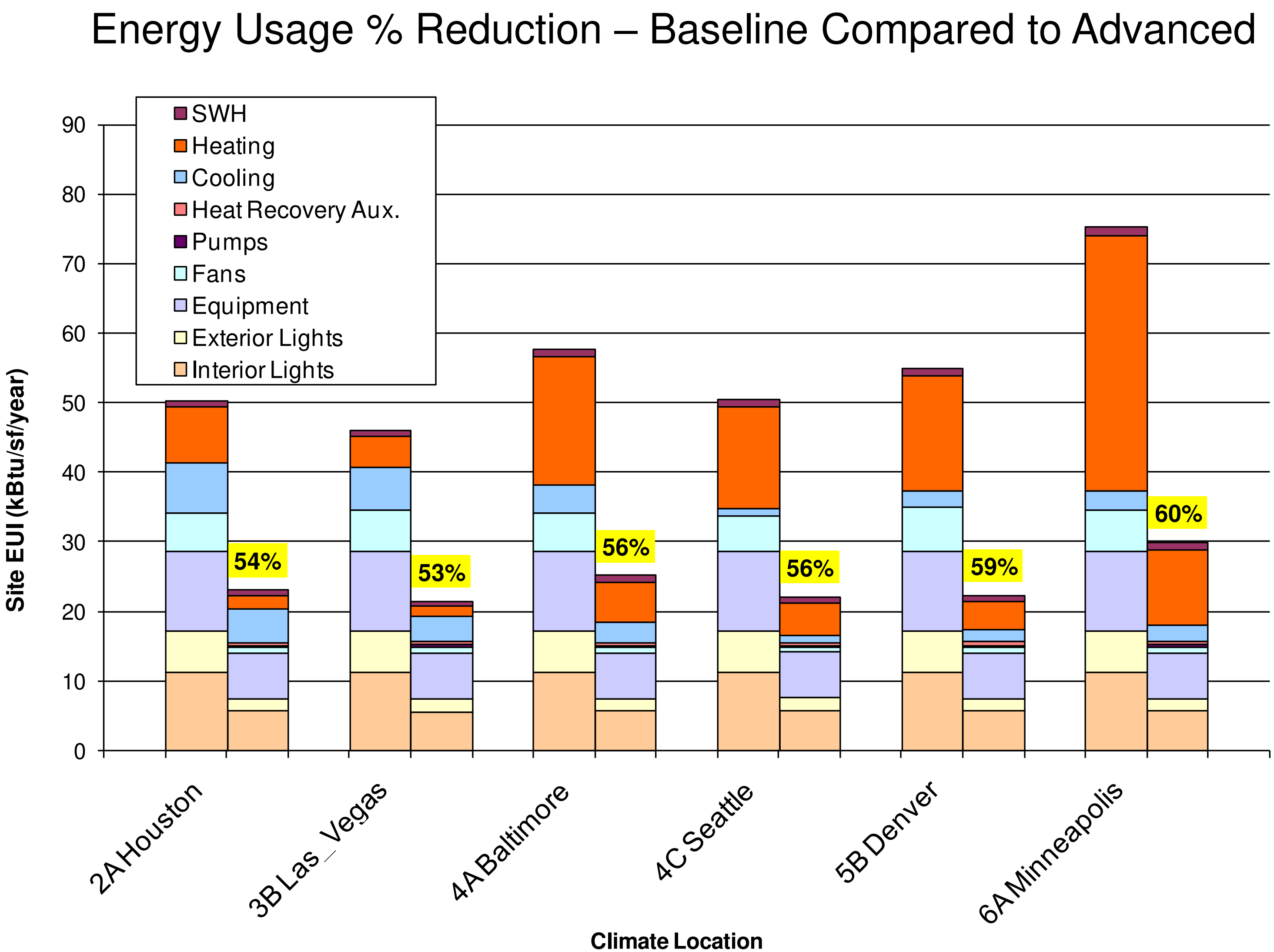
Small Office WSHP with DOAS



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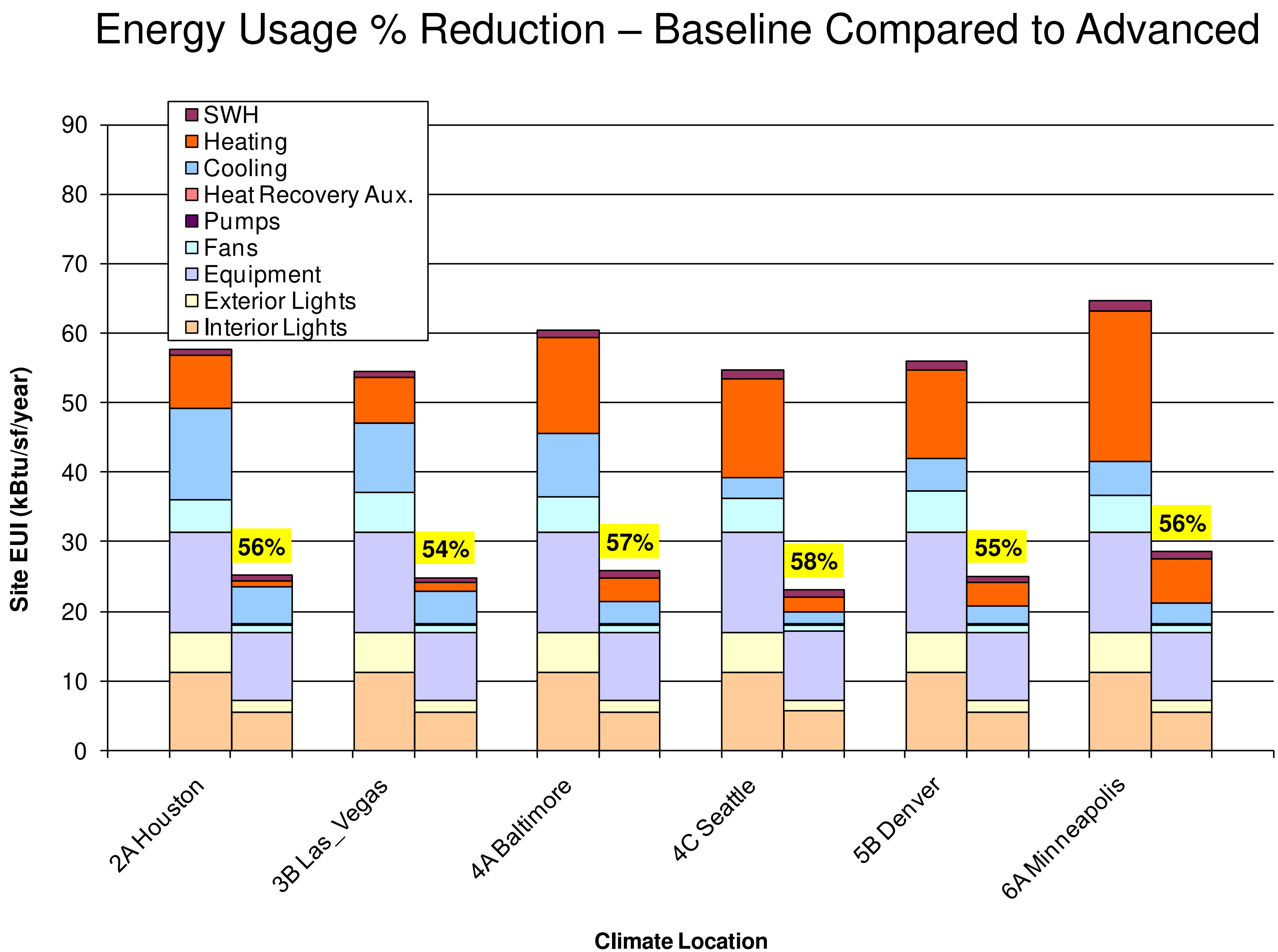
Medium Office Radiant with DOAS



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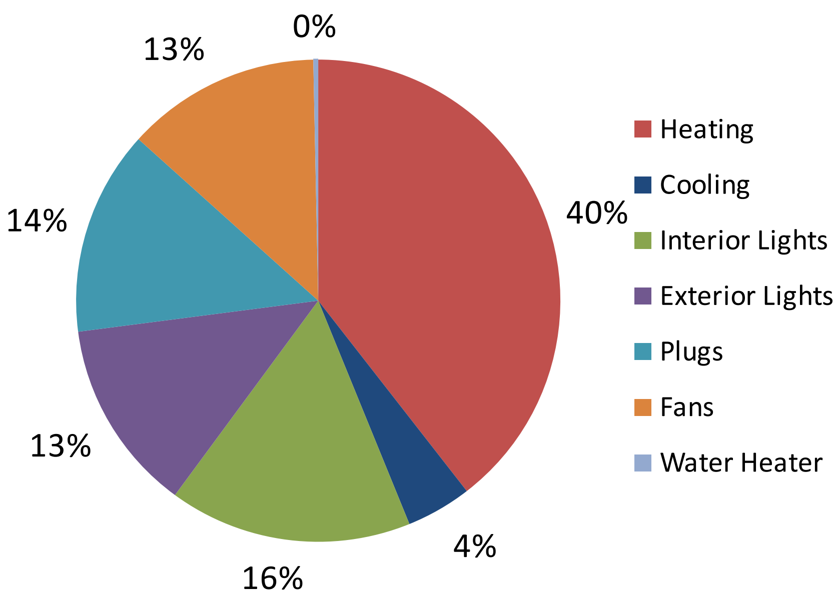
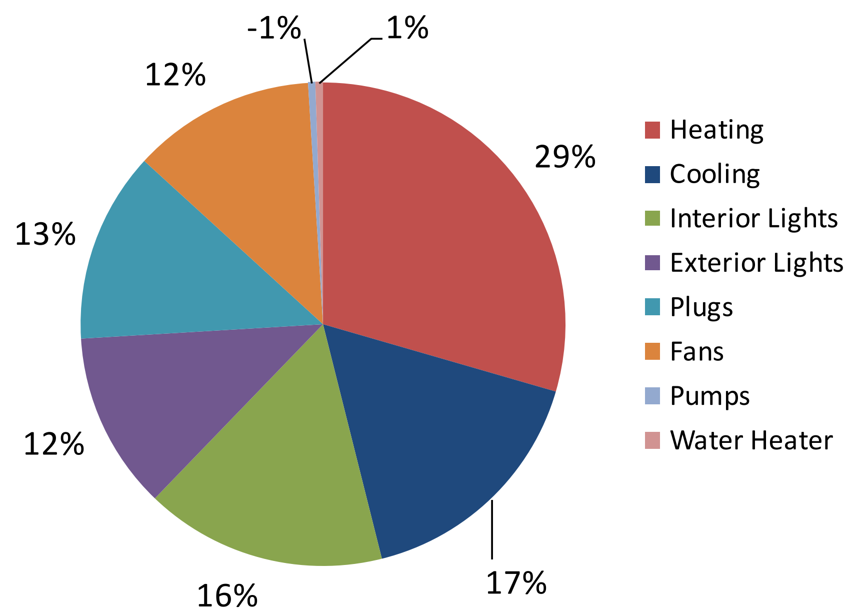
Energy Savings by End-Use Percentage

Small Office Savings Breakdown Baltimore - Heat Pumps with DOAS



Medium Office Savings Breakdown - Baltimore - Radiant with DOAS



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Energy Cost and Payback

- Small Office Heat Pumps with DOAS
  - Energy cost reduction 47% to 56%, average 51%
  - Construction unit cost increase
    - \$3.30 to \$5.60 per ft^2, average \$4.28/ft^2
  - Payback
    - 5.3 to 9.6 years, average 6.8 years
- Medium Office Radiant System with DOAS
  - Percentage energy cost reduction
    - 54% to 69%, average 61%
  - Construction unit cost increase
    - \$5.47 to \$9.03 per ft^2, average \$6.79/ft^2
  - Payback
    - 5.6 to 11.5 years, average 7.4 years

Conclusions

- Office TSDs demonstrate the feasibility of getting to 50% site energy reduction relative to an office building that meets ASHRAE 90.1-2004
- Other technologies and methods not included may also allow reaching this goal
- Design teams should consider and analyze the energy efficient design strategies for their specific site following an integrated design approach
- Site specific alternatives such as building siting, orientation and shape may provide additional savings or more cost-effective savings
- The Advanced Energy Design Guides provide more design related information than the TSDs

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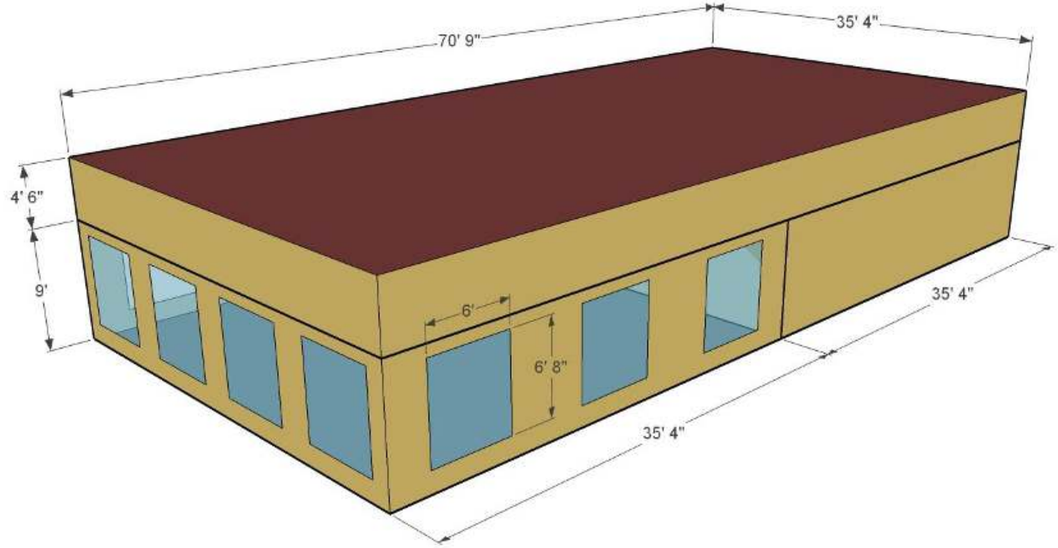
Quick Service Restaurant - Baseline



- 2500 ft^2 with kitchen and dining zones
- Wood-framed construction
- 14% window-to-wall ratio
- Two constant air volume roof top units
- “Hamburger-based” quick service restaurant, open 128 hr/week
- Full list of kitchen appliances and their schedules are defined

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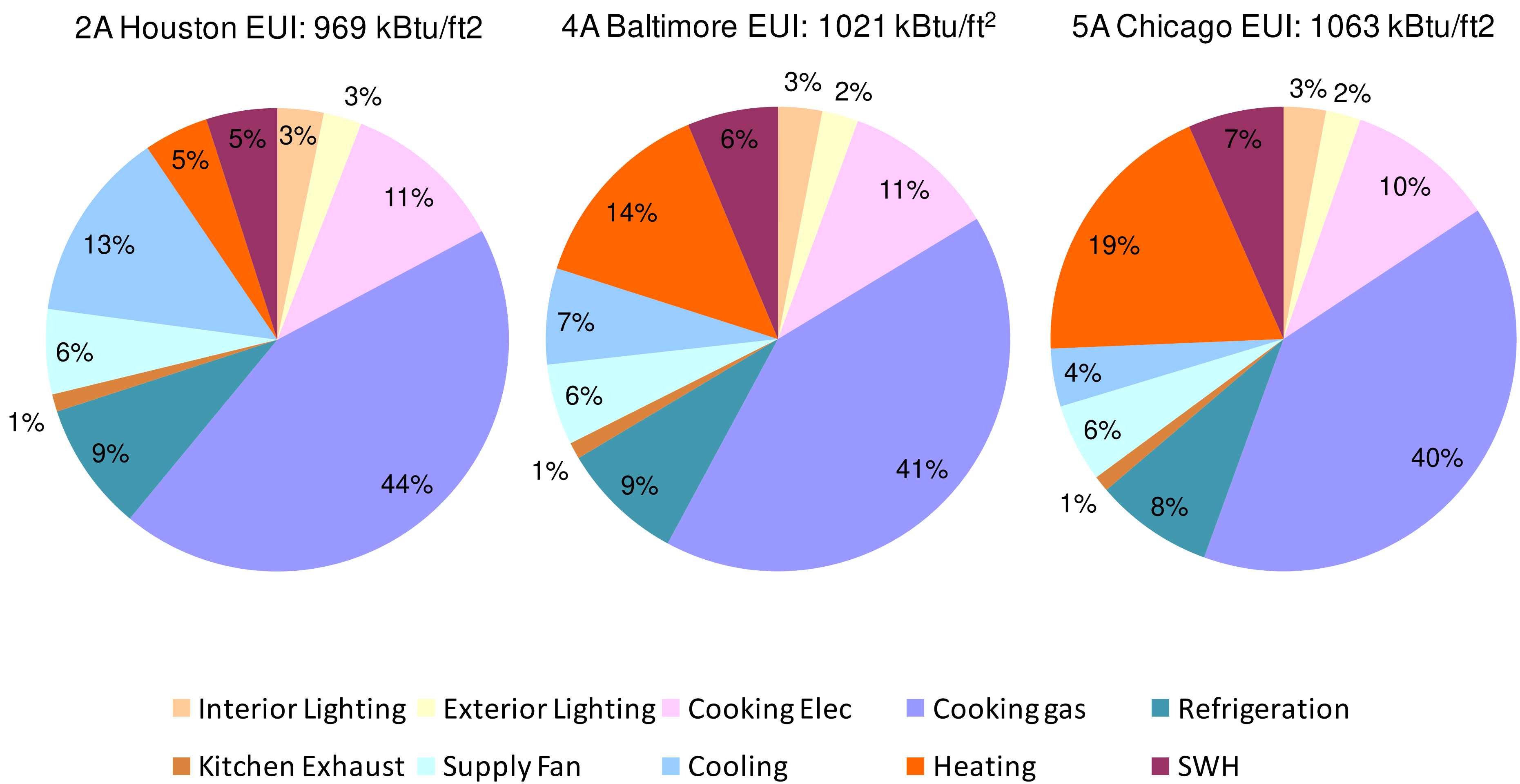
Baseline Energy Usage



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Kitchen Appliances

- Efficient kitchen appliances were identified to ensure equivalent cooking capacity
- Best-in-class Energy Star qualified appliances
  - Gas cooking - fryer and griddle: 423 (baseline) to 246 (advanced) $kBtu/ft^2$-yr
  - Electric cooking: 110 (baseline) to 83 (advanced) $kBtu/ft^2$-yr
- Refrigeration
  - Walk-in cooler/freezer: ECM motor, additional insulation, heat recovery to preheat hot water.
  - Total refrigeration: from 7.3 (baseline) to 5.5 (advanced) kW

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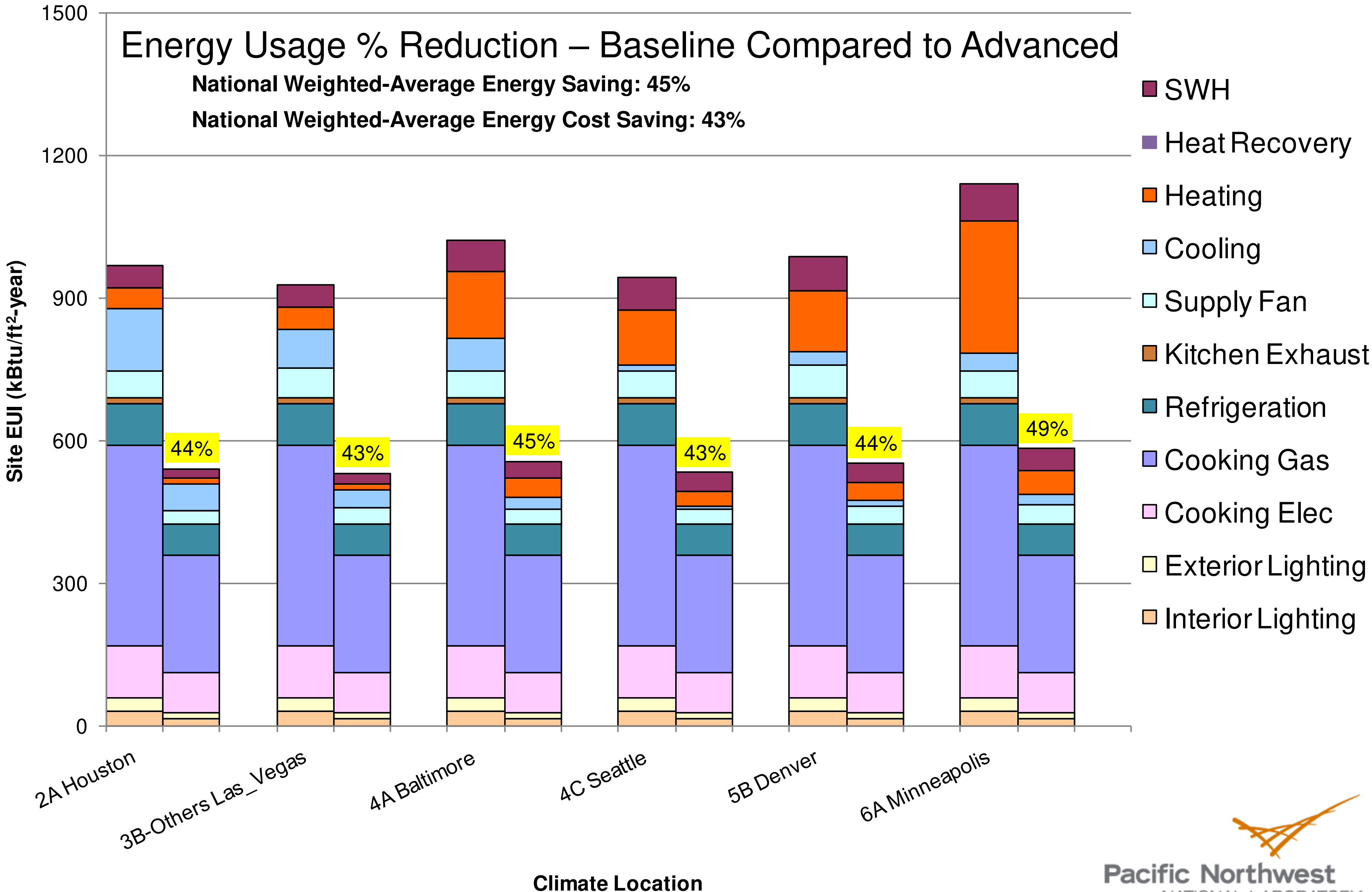
Mechanical Systems

- Reduced exhaust flow rate from constant 4600 cfm to demand-controlled flow based on cooking schedule at peak of 1830 cfm
- DOAS system with two CAV RTUs, runaround coil heat recovery to preheat outdoor air with kitchen exhaust air (cold climates only)
- Broader use of air-side economizer across climate zones and extended cooling capacity to cover 5-ton air units
- Premium efficiency cooling units
- Condensing water heater with 95% thermal efficiency

Lighting and Envelope

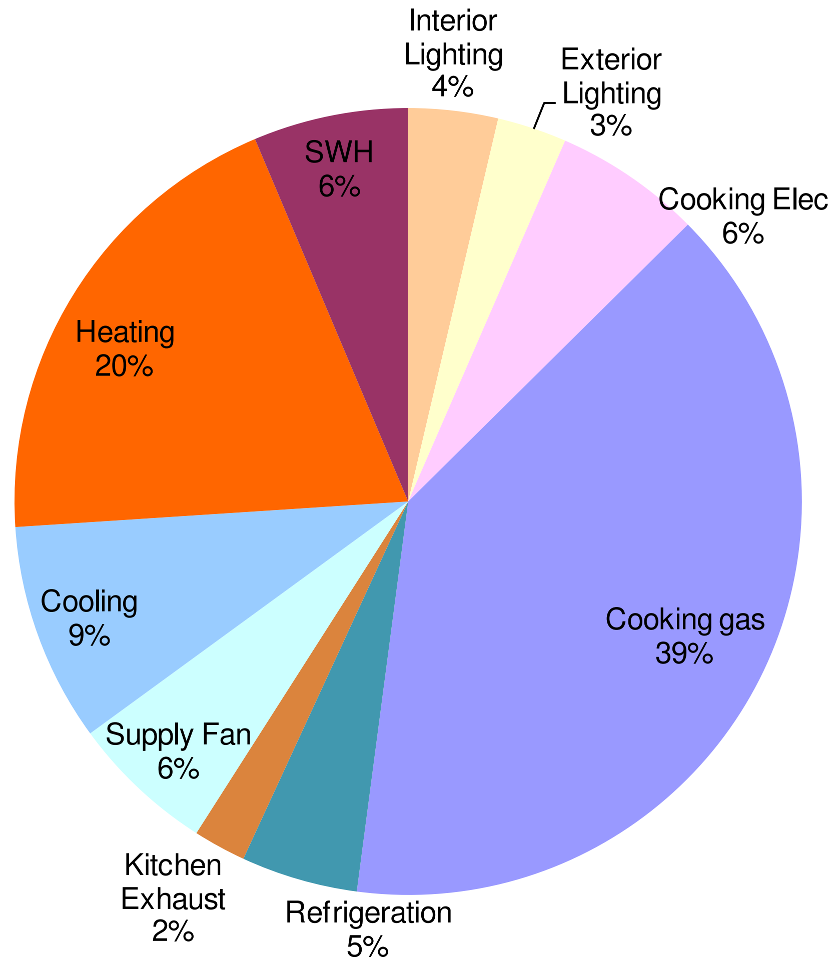
- Interior lighting
  - Efficient lamps and ballasts, LPD reduced from 1.44 to 0.83 W/ft^2
  - Occupancy sensors in office, active storage and restroom further reduce by 7.2%
- Daylight harvesting – side lighting
  - 66% lighting is dimmable in dining area
- Exterior lighting
  - Reduced lighting power from 4.3 to 2.7 kW.
  - Bi-level switching and photocell-controlled exterior lights, only on during business hours and after dark
- Enhanced building opaque insulation
- High-performance window glazing
- Cool roofs in climate zones 1 through 3

Energy Saving Results



Summary

- QSR is very energy intensive, baseline EUI: 1000 kBtu/ft^2
- Measures from kitchen appliances and mechanical systems are most effective
- Site energy savings
  - Range 41% to 52%, average 45%
- Unit construction cost increase
  - Range \$11.6 to \$29.1 per ft^2 average \$16.5 per ft^2 or 9%
- Payback
  - Range 1.5 to 3.5 years, average 2.1 years



Energy Savings by End-Use Percentage

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Michael Lane
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Derek Schrock, Andrey Livchack
Halton Company

Don Fisher, David Zabrowski
Food Service Technology Center operated by Fisher-Nickel Inc.

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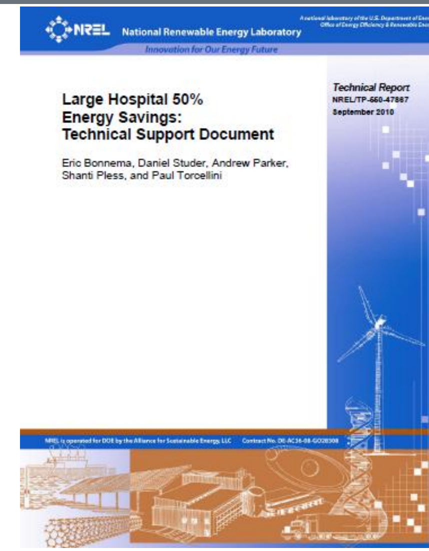
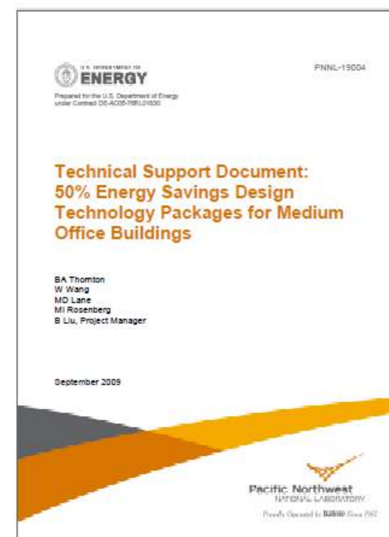
50% Savings Technical Support Documents

- Analysis documentation of 50% savings strategies by building type
  - General Merchandise
  - Grocery Stores
  - Small Office
  - Medium Office
  - Highway Lodging
  - Large Hospitals
  - Large Offices
  - Quick Service Restaurant





- Small/Medium Office and K-12 50% AEDG in development
- http://www.commercialbuildings.energy.gov/guides.html

Question and Answer Session

Questions will be submitted electronically and answers will be provided verbally

To submit a question, select Q&A on the top bar, click in the top box, type your question, click Ask

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