



Technical Support Document: Development of the Advanced Energy Design Guide for Medium to Big Box Retail Buildings – 50% Energy Savings

Eric Bonnema, Matt Leach, and Shanti Pless
National Renewable Energy Laboratory

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Executive Summary

Background

This Technical Support Document (TSD) describes the process and methodology for the development of the AEDG-MBBR (ASHRAE et al. (2011b)). The AEDG-MBBR provides recommendations for achieving 50% whole-building energy savings in retail stores over levels achieved by following *ANSI/ASHRAE/IESNA Standard 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential Buildings* (Standard 90.1-2004) (ASHRAE 2004b). The guide was developed in collaboration with ASHRAE, AIA, IES, USGBC, and DOE.

The AEDG-MBBR is the second AEDG for retail buildings; the first was targeted toward small retail buildings and is part of a series of six AEDGs targeting 30% energy savings over levels achieved by following *ANSI/ASHRAE/IESNA Standard 90.1-1999, Energy Standard for Buildings Except Low-Rise Residential Buildings* (ASHRAE 1999). The guides in the 30% energy savings series are:

- The *Advanced Energy Design Guide for Small Office Buildings: Achieving 30% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2004)
- The *Advanced Energy Design Guide for Small Retail Buildings: Achieving 30% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2006)
- The *Advanced Energy Design Guide for K-12 School Buildings: Achieving 30% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2008a)
- The *Advanced Energy Design Guide for Small Warehouses and Self-Storage Buildings: Achieving 30% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2008b)
- The *Advanced Energy Design Guide for Highway Lodging: Achieving 30% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2009a)
- The *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities: Achieving 30% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2009b)

The AEDG-MBBR is part of a series of AEDGs targeting 50% energy savings over levels achieved by following Standard 90.1-2004. The other guides in the 50% energy savings series include:

- The *Advanced Energy Design Guide for Small to Medium Office Buildings: Achieving 50% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2011c)
- The *Advanced Energy Design Guide for K-12 School Buildings: Achieving 50% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2011a)
- The *Advanced Energy Design Guide for Large Hospitals: Achieving 50% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2012)

Each guide provides user-friendly design assistance and recommendations to design, architectural, and engineering firms to achieve energy savings. The AEDG-MBBR includes prescriptive recommendations by climate zone for the building envelope; fenestration; lighting systems (including interior and exterior electrical lights and daylighting); plug, process, and phantom loads; commercial kitchen equipment; service water heating (SWH); HVAC systems; building automation and controls; outdoor air treatment; and measurement and verification.

Additional savings recommendations are also included, but are not necessary to achieve the 50% savings goal. These are provided for renewable energy systems and alternative HVAC systems.

The objectives in developing this TSD included:

- Develop baseline and low-energy retail store energy models.
- Document the modeling assumptions needed to verify 50% energy savings.
- Present the recommendations for achieving at least 50% savings over Standard 90.1-2004.
- Demonstrate through annual whole-building energy modeling that the recommendations result in 50% or greater energy savings by climate zone.
- Document the process used to develop the AEDG-MBBR.

AEDG-MBBR Development Process

The AEDG-MBBR was developed by a PC representing a diverse group of professionals. Guidance and support were provided through a collaboration of ASHRAE, AIA, IESNA, USGBC, and DOE. Publication of the AEDG-MBBR was accomplished by two separate committees: a steering committee that provided high-level guidance and a PC that developed the guide.

AEDG-MBBR Scope

This guide applies primarily to retail buildings with 20,000 ft² to 100,000 ft² of floor area; however, many of the recommendations also apply to smaller and larger retail buildings. These facilities typically include some or all of the following space types: administrative and office areas, sales areas, hallways and restrooms, meeting and dining areas, storage spaces, and mechanical/electrical rooms. It does not consider commercial refrigeration, kitchens, or other atypical specialty spaces that generate extraordinary heat or pollution. Its primary focus is new construction, but recommendations may be applicable to facilities undergoing major renovation, and in part to many other retail store renovation, addition, remodeling, and modernization projects (including changes to one or more systems in existing buildings).

The guide does not include all the components listed in Standard 90.1-2004. It focuses only on a building's primary energy systems (lighting, HVAC, etc.), so the underlying energy analysis presumes that all the other components are built according to the criteria in Standard 90.1-2004.

Certain aspects of retail store design, including commercial refrigeration equipment, domestic water well piping, and sewage disposal, were excluded, as they were too complex to include given the scope of the project. Significant energy efficiency opportunities may be available with these aspects, and AEDG-MBBR users are encouraged to take advantage of these opportunities.

The AEDG-MBBR is not intended to substitute for rating systems or references that address the full range of sustainable issues in retail store design, such as acoustics, productivity, indoor air quality, water efficiency, landscaping, and transportation, except as they relate to energy use; nor is it a design text (ASHRAE et al. 2011b). The guide contains recommendations only and is not a code or standard.

Evaluation Approach and Results

The purpose of the building energy simulation analysis presented in this TSD is to assess and quantify the energy savings potential of the set of climate-specific energy efficiency

recommendations in the AEDG-MBBR. The following steps describe how the energy savings potential of the AEDG-MBBR's recommendations were determined.

1. Develop “typical” retail store facility prototype models

For building characteristics that are not specified by Standard 90.1-2004, but that are needed to develop baseline models that represent typical operation, the retail store models from Hale et al. (2009) were used as a starting point. A “typical” prototype is an energy model that is a representative example of a retail store facility. Three prototype models were developed; two medium box and one big box. The two medium box stores were identical except for the plug loads; the low plug prototype is meant to represent a store that sells items such as clothing or books and has little plug-in merchandise; the high plug prototype is meant to represent an electronics retailer with a larger amount of plug-in merchandise. A larger big box prototype was developed to represent larger general merchandise stores. The high-level building characteristics for the three prototype models are shown in Table ES–1.

Table ES–1 AEDG-MBBR Prototype Characteristics

Building Characteristic	Medium Box Low Plug	Medium Box High Plug	Big Box
Size	40,500 ft ²	40,500 ft ²	99,225 ft ²
Aspect ratio	1.25	1.25	1.00
Sales floor area	32,400 ft ²	32,400 ft ²	79,380 ft ²
Back-of-house area	8,100 ft ²	8,100 ft ²	19,845 ft ²
Floor-to-ceiling height	20 ft	20 ft	20 ft
Space types	Sales floor, vestibule, stock room, office, meeting room, break room, restroom, corridor, mechanical room		
Wall constructions	Steel framed	Steel framed	Mass
Roof construction	Insulation entirely above deck	Insulation entirely above deck	Insulation entirely above deck
Window area	22% (south façade only)	22% (south façade only)	22% (south façade only)
Window sill height	3.6 ft	3.6 ft	3.6 ft
Window height	4.4 ft	4.4 ft	4.4 ft
Peak plug loads	0.35 W/ft ²	0.54 W/ft ²	0.36 W/ft ²
Percent conditioned	Fully heated and cooled	Fully heated and cooled	Fully heated and cooled

2. Create baseline models that are minimally code compliant with Standard 90.1-2004

The baseline models for the medium and big box retail stores were developed by applying the criteria in Standard 90.1-2004 to the prototype models. The baseline energy modeling assumptions and methods were documented, including the building envelope characteristics, building internal loads and operating schedules, ventilation rates and schedules, HVAC equipment efficiency, operation, control and sizing, fan power assumptions, and SWH. The criteria in Standard 90.1-2004 were used as the baselines to calculate energy savings for the AEDG-MBBR recommendations.

3. Create the low-energy models based on the recommended energy efficiency technologies in the AEDG-MBBR

To quantify the potential energy savings from the proposed recommended energy efficiency measures in the AEDG-MBBR, the low-energy building models were developed by implementing the energy efficiency technologies listed here.

- Enhanced building opaque envelope insulation and window glazing; and the addition of overhangs
- Reduced lighting power density and installation of occupancy controls
- Exterior lighting power density reductions
- Plug load reductions and improved controls
- Demand-controlled ventilation and energy recovery ventilators
- Dedicated outdoor air systems (DOASs)
- High-efficiency HVAC equipment
- High-efficiency SWH equipment.

4. Verify the recommendations meet or exceed the 50% energy savings goal of the AEDG-MBBR

The final recommendations included in the AEDG-MBBR were determined based on an iterative process using the PC's expertise and results from modeling proposed recommendations. Energy savings associated with the final recommendations in the AEDG-MBBR are documented in this TSD. To verify savings over a range of design options, low-energy versions of the two medium and one big box retail store were modeled with four types of low-energy HVAC systems. The low-energy HVAC system types include:

- Packaged variable air volume (VAV) direct expansion (DX) air conditioner with a gas furnace (VAV)
- Packaged constant air volume (CAV) DX air conditioner with a gas furnace and a DOAS (CAV DOAS)
- Air source heat pump (ASHP) with electric resistance supplemental heat and a DOAS (ASHP DOAS)
- Water source heat pump (WSHP) with a DOAS (WSHP DOAS).

Recommendations in the AEDG-MBBR are provided based on the type of low-energy HVAC system used. This TSD also presents energy savings results by prototype model and HVAC system type. The recommendations in the AEDG-MBBR result in more than 50% savings in all climate zones, for both medium and the one big box retail store low-energy models, for all HVAC system types. Table ES-2 and Table ES-3 summarize the percent energy savings for each low-energy model in each climate zone. Figure ES-1 shows the process applied to determine energy savings.

Table ES–2 Medium Box Percent Energy Savings Over Standard 90.1-2004

Climate Zone	Representative City	Low Plug				High Plug			
		VAV	CAV DOAS	ASHP DOAS	WSHP DOAS	VAV	CAV DOAS	ASHP DOAS	WSHP DOAS
1A	Miami, FL	58.2%	59.7%	59.3%	58.2%	57.0%	58.5%	58.1%	56.9%
2A	Houston, TX	58.7%	59.5%	59.7%	58.9%	57.8%	58.5%	58.5%	57.7%
2B	Phoenix, AZ	56.8%	58.7%	59.3%	58.6%	56.2%	57.9%	58.4%	57.7%
3A	Atlanta, GA	56.6%	56.6%	57.5%	56.5%	56.0%	56.0%	56.6%	55.7%
3B:CA	Los Angeles, CA	54.4%	54.4%	55.2%	54.6%	53.2%	53.9%	54.3%	53.8%
3B	Las Vegas, NV	57.5%	57.5%	58.9%	57.6%	57.0%	57.0%	58.0%	57.0%
3C	San Francisco, CA	54.0%	50.5%	52.9%	51.4%	53.5%	50.7%	52.3%	51.4%
4A	Baltimore, MD	56.8%	55.8%	57.2%	56.3%	56.1%	55.4%	56.3%	55.6%
4B	Albuquerque, NM	58.0%	58.1%	58.9%	58.7%	57.2%	57.6%	58.1%	57.9%
4C	Seattle, WA	54.3%	51.7%	54.4%	52.8%	53.2%	51.9%	53.8%	52.6%
5A	Chicago, IL	57.2%	55.5%	56.6%	56.1%	56.0%	55.1%	55.9%	55.5%
5B	Denver, CO	57.4%	57.8%	58.6%	58.6%	56.8%	57.4%	57.9%	57.9%
6A	Minneapolis, MN	58.1%	56.4%	56.9%	57.2%	56.8%	55.8%	56.1%	56.4%
6B	Helena, MT	56.5%	55.2%	56.3%	56.3%	55.6%	55.0%	55.7%	55.9%
7	Duluth, MN	58.5%	56.3%	56.7%	57.6%	57.5%	55.9%	56.0%	56.9%
8	Fairbanks, AK	54.2%	52.9%	53.5%	55.1%	54.1%	52.9%	53.2%	54.8%

Table ES–3 Big Box Percent Energy Savings Over Standard 90.1-2004

Climate Zone	Representative City	Big Box			
		VAV	CAV DOAS	ASHP DOAS	WSHP DOAS
1A	Miami, Florida	56.5%	58.8%	58.4%	56.9%
2A	Houston, Texas	59.3%	59.7%	59.9%	59.0%
2B	Phoenix, Arizona	57.9%	59.6%	60.2%	59.3%
3A	Atlanta, Georgia	56.5%	55.9%	56.8%	55.5%
3B:CA	Los Angeles, CA	54.0%	53.9%	54.5%	53.9%
3B	Las Vegas, Nevada	57.1%	57.0%	58.2%	56.9%
3C	San Francisco, California	53.9%	50.0%	52.1%	50.7%
4A	Baltimore, Maryland	56.2%	55.0%	56.5%	55.3%
4B	Albuquerque, New Mexico	57.7%	57.6%	58.6%	57.9%
4C	Seattle, Washington	54.0%	51.0%	53.9%	51.9%
5A	Chicago, Illinois	57.1%	55.3%	56.6%	55.7%
5B	Denver, Colorado	57.4%	57.6%	58.7%	58.2%
6A	Minneapolis, Minnesota	58.0%	56.1%	56.9%	56.8%
6B	Helena, Montana	56.4%	55.0%	56.4%	55.9%
7	Duluth, Minnesota	58.6%	56.3%	57.0%	57.4%
8	Fairbanks, Alaska	54.4%	53.0%	54.0%	55.2%

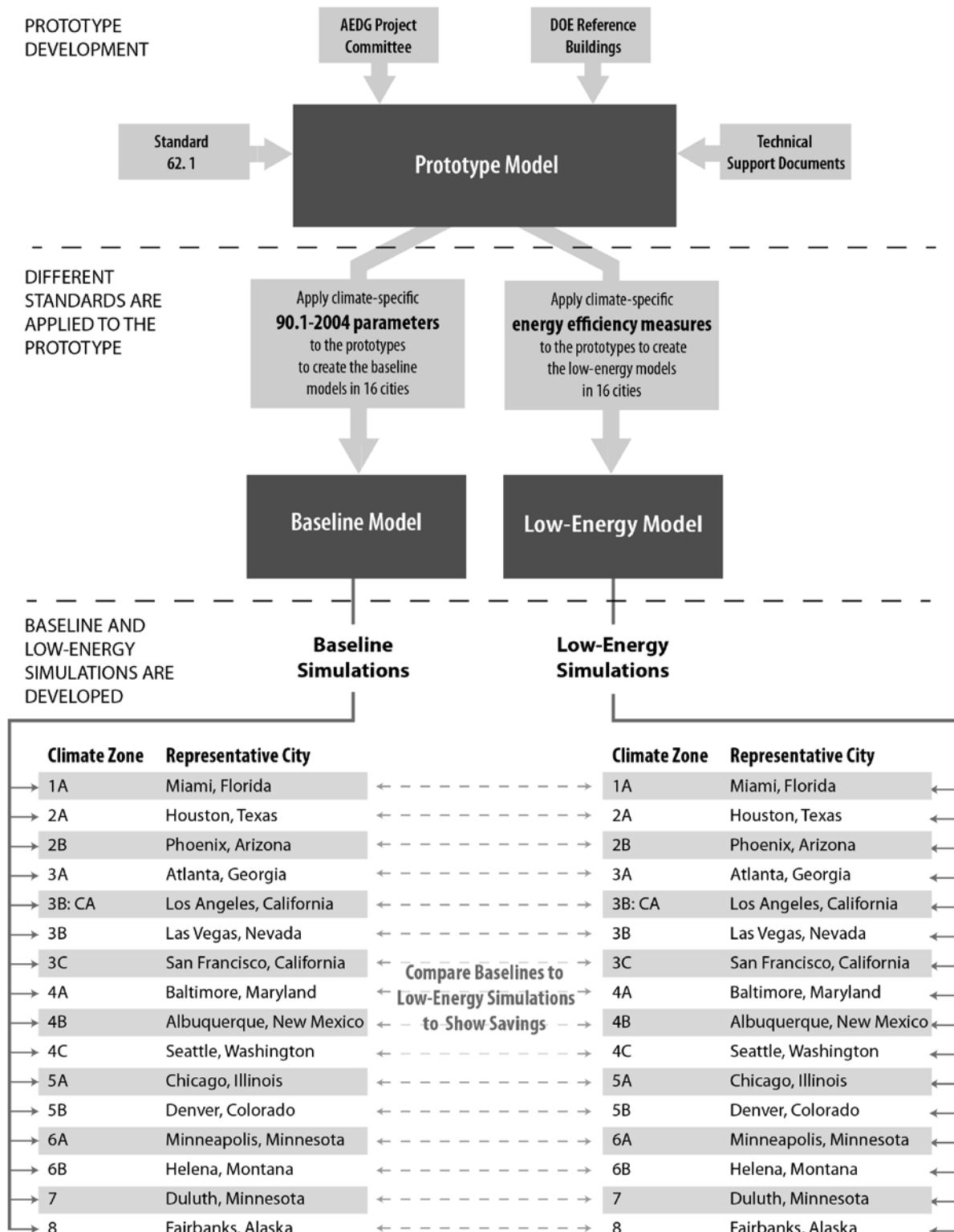


Figure ES-1 Flow diagram of modeling process
(Credit: Marjorie Schott/NREL)

Nomenclature

AEDG	Advanced Energy Design Guide
AEDG-MBBR	Advanced Energy Design Guide for Medium to Big Box Retail Buildings: Achieving 50% Energy Savings Toward a Net Zero Energy Building
AIA	American Institute of Architects
ANSI	American National Standards Institute
ASHP	air source heat pump
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
Btu	British thermal unit
°C	degree Celsius, centigrade
CAV	constant air volume
cfm	cubic foot per minute
c.i.	continuous insulation
COP	coefficient of performance
d	diameter
DCV	demand-controlled ventilation
DOAS	dedicated outdoor air system
DOE	U.S. Department of Energy
DX	direct expansion
EER	energy efficiency ratio
EF	energy factor
EMS	energy management system
ERV	energy recovery ventilator
E_t	thermal efficiency
EUI	energy use intensity
°F	degree Fahrenheit
ft	foot
ft ²	square foot
ft ³	cubic foot
gal	gallon
h	hour
hp	horsepower
HVAC	heating, ventilation, and air conditioning
IEER	integrated energy efficiency ratio
IES, IESNA	Illuminating Engineering Society of North America
in.	inch
kW	kilowatt
lb	pound
LPD	lighting power density
Ls	Linear System
LZ	lighting zone
M&V	measurement and verification
min	minute

NEMA	National Electrical Manufacturers Association
NREL	National Renewable Energy Laboratory
OA	outdoor air
O&M	operations and maintenance
Pa	Pascal
PC	project committee
QA	quality assurance
SC	steering committee
SEER	seasonal energy efficiency ratio
SHGC	solar heat gain coefficient
SWH	service water heating
TSD	Technical Support Document
USGBC	U.S. Green Building Council
V	volt
VAV	variable air volume
VFD	variable frequency drive
VLT	visible light transmittance
VOC	volatile organic compound
W	watt
w.c.	water column
WSHP	water source heat pump

Contents

Acknowledgments.....	i
Executive Summary	ii
Background.....	ii
AEDG-MBBR Development Process.....	iii
AEDG-MBBR Scope.....	iii
Evaluation Approach and Results.....	iii
Nomenclature.....	viii
Contents	x
Figures and Tables	xiii
Figures	xiii
Tables.....	xiv
1. Introduction.....	1
1.1 Objectives.....	1
1.2 Scope of the AEDG and TSD	2
1.3 AEDG-MBBR Layout and Content.....	3
1.3.1 Chapter 1 Introduction.....	3
1.3.2 Chapter 2 Integrated Design Process	3
1.3.3 Chapter 3 Applying Energy Modeling and Benchmarking Strategies.....	3
1.3.4 Chapter 4 Design Strategies and Recommendations by Climate Zone	3
1.3.5 Chapter 5 How to Implement Recommendations	4
1.4 Technical Support Document Organization.....	5
2. AEDG-MBBR Development Process.....	6
2.1 Steering Committee.....	6
2.1.1 Inclusion of Economics and Cost	7
2.2 Approval Authority	7
2.3 Project Committee Organization and Membership.....	7
2.4 Development Schedule and Process.....	8
3. Evaluation Approach	10
3.1 Determining Energy Savings	10
3.1.1 Site Energy Use.....	10
3.1.2 Whole-Building Energy Savings	10

3.1.3	Modeling Methods	12
3.2	Prototype Model Overview	14
3.2.1	Geometry	14
3.2.2	Ventilation and Occupancy	18
3.2.3	Infiltration	20
3.2.4	Thermostat Set Points	21
3.3	Baseline Model Development and Assumptions	21
3.3.1	Envelope	22
3.3.2	Electric Lighting	26
3.3.3	Plug and Process Loads	27
3.3.4	Heating, Ventilation, and Air-Conditioning	28
3.3.5	Service Water Heating	29
3.3.6	Baseline Simulation Results	29
3.3.7	All-Electric Baseline	36
3.4	Low-Energy Model Development and Assumptions	42
3.4.1	Envelope	42
3.4.2	Electric Lighting	43
3.4.3	Plug and Process Loads	45
3.4.4	Heating, Ventilation, and Air-Conditioning	46
3.4.5	Service Water Heating	50
4.	Energy Targets	51
5.	Evaluation Results	54
5.1	Recommendation Tables for 50% Energy Savings	54
5.2	Energy Savings Results	64
5.2.1	Packaged Variable Air Volume Direct Expansion	65
5.2.2	Constant Air Volume Direct Expansion With Dedicated Outdoor Air System	71
5.2.3	Air Source Heat Pump With Dedicated Outdoor Air System	77
5.2.4	Water Source Heat Pump With Dedicated Outdoor Air System	83
6.	Conclusion	89
7.	References	90
Appendix A.	Scoping Document	92
Appendix B.	Project Committee Meeting Agendas	95
B.1	Meeting 1	95

B.2	Meeting 2.....	97
B.3	Meeting 3.....	99
B.4	Meeting 4.....	101
Appendix C.	Schedule Tabular Data	103
Appendix D.	Energy Management System Code	105
D.1	VAV Supply Air Temperature Reset	105
D.2	Energy Recovery Ventilator/Evaporative Cooler Selector	108

Figures and Tables

Figures

Figure ES–1	Flow diagram of modeling process.....	vii
Figure 3–1	Flow diagram of modeling process.....	11
Figure 3–2	U.S. climate zones.....	13
Figure 3–3	Medium box zone layout	16
Figure 3–4	Big box zone layout	17
Figure 3–5	Building occupancy schedule, January–November	19
Figure 3–6	Building occupancy schedule, December	19
Figure 3–7	Infiltration schedule	20
Figure 3–8	Heating and cooling set point schedule	21
Figure 3–9	Medium box baseline models rendering	22
Figure 3–10	Big box baseline model rendering	22
Figure 3–11	Baseline lighting schedule	27
Figure 3–12	Baseline plug and process load schedule	28
Figure 3–13	Medium box low plug baseline simulation results	31
Figure 3–14	Medium box high plug baseline simulation results	33
Figure 3–15	Big box baseline simulation results	35
Figure 3–16	Medium box low plug all-electric baseline simulation results	37
Figure 3–17	Medium box high plug all-electric baseline simulation results	39
Figure 3–18	Big box all-electric baseline simulation results	41
Figure 3–19	Low-energy lighting schedule.....	44
Figure 3–20	Low-energy plug and process load schedule	46
Figure 5–1	Medium box low plug VAV simulation results.....	66
Figure 5–2	Medium box high plug VAV simulation results.....	68
Figure 5–3	Big box VAV simulation results.....	70
Figure 5–4	Medium box low plug CAV DOAS simulation results	72
Figure 5–5	Medium box high plug CAV DOAS simulation results	74
Figure 5–6	Big box CAV DOAS simulation results	76
Figure 5–7	Medium box low plug ASHP DOAS results	78
Figure 5–8	Medium box high plug ASHP DOAS results	80
Figure 5–9	Big box ASHP DOAS simulation results	82
Figure 5–10	Medium box low plug WSHP DOAS results	84
Figure 5–11	Medium box high plug WSHP DOAS results	86
Figure 5–12	Big box WSHP DOAS simulation results	88

All figures credit Eric Bonnema/NREL unless otherwise noted.

Tables

Table ES-1	AEDG-MBBR Prototype Characteristics	iv
Table ES-2	Medium Box Percent Energy Savings Over Standard 90.1-2004.....	vi
Table ES-3	Big Box Percent Energy Savings Over Standard 90.1-2004	vi
Table 2-1	AEDG-MBBR PC Organization Chart.....	8
Table 3-1	Prototype Model Summary	14
Table 3-2	Medium Box Zone Area Breakdown.....	15
Table 3-3	Big Box Zone Area Breakdown.....	15
Table 3-4	Prototype Space Type Breakdown.....	18
Table 3-5	Ventilation Rates by Space Type.....	18
Table 3-6	Baseline Exterior Wall Constructions.....	23
Table 3-7	Standard Air Film Coefficients.....	24
Table 3-8	Baseline Roof Constructions.....	24
Table 3-9	Simulated Monthly Ground Temperatures (°F), 1A-4A	25
Table 3-10	Simulated Monthly Ground Temperatures (°F), 4B-8	25
Table 3-11	Baseline Window Constructions.....	26
Table 3-12	LPD by Space Type	26
Table 3-13	Baseline Model Plug and Process Loads	28
Table 3-14	Medium Box Low Plug Baseline Simulation Results, 1A-4A	29
Table 3-15	Medium Box Low Plug Baseline Simulation Results, 4B-8	30
Table 3-16	Medium Box High Plug Baseline Simulation Results, 1A-4A	32
Table 3-17	Medium Box High Plug Baseline Simulation Results, 4B-8	32
Table 3-18	Big Box Baseline Simulation Results, 1A-4A	34
Table 3-19	Big Box Baseline Simulation Results, 4B-8	34
Table 3-20	Medium Box Low Plug All-Electric Baseline Simulation Results, 1A-4A	36
Table 3-21	Medium Box Low Plug All-Electric Baseline Simulation Results, 4B-8	36
Table 3-22	Medium Box High Plug All-Electric Baseline Simulation Results, 1A-4A	38
Table 3-23	Medium Box High Plug All-Electric Baseline Simulation Results, 4B-8	38
Table 3-24	Big Box All-Electric Baseline Simulation Results, 1A-4A	40
Table 3-25	Big Box All-Electric Baseline Simulation Results, 4B-8	40
Table 3-26	Low-Energy Steel-Framed Exterior Wall Constructions.....	42
Table 3-27	Low-Energy Mass Exterior Wall Constructions.....	42
Table 3-28	Low-Energy Roof Constructions	43
Table 3-29	Low-Energy View Window Constructions.....	43
Table 3-30	Low-Energy LPD by Space Type	44
Table 3-31	Low-Energy Model Plug and Process Loads.....	45
Table 4-1	Medium Box Retail Energy Targets	52
Table 4-2	Big Box Retail Energy Targets.....	53
Table 5-1	AEDG-MBBR Recommendations: Climate Zones 1-4	55
Table 5-2	AEDG-MBBR Recommendations: Climate Zones 5-8	60
Table 5-3	Medium Box Percent Energy Savings Over Standard 90.1-2004.....	64
Table 5-4	Big Box Percent Energy Savings Over Standard 90.1-2004	64
Table 5-5	Medium Box Low Plug VAV Simulation Results, 1A-4A.....	65
Table 5-6	Medium Box Low Plug VAV Simulation Results, 4B-8	65
Table 5-7	Medium Box High Plug VAV Simulation Results, 1A-4A	67
Table 5-8	Medium Box High Plug VAV Simulation Results, 4B-8	67

Table 5–9	Big Box VAV Simulation Results, 1A–4A	69
Table 5–10	Big Box VAV Simulation Results, 4B–8	69
Table 5–11	Medium Box Low Plug CAV DOAS Simulation Results, 1A–4A	71
Table 5–12	Medium Box Low Plug CAV DOAS Simulation Results, 4B–8	71
Table 5–13	Medium Box High Plug CAV DOAS Simulation Results, 1A–4A.....	73
Table 5–14	Medium Box High Plug CAV DOAS Simulation Results, 4B–8.....	73
Table 5–15	Big Box CAV DOAS Simulation Results, 1A–4A.....	75
Table 5–16	Big Box CAV DOAS Simulation Results, 4B–8.....	75
Table 5–17	Medium Box Low Plug ASHP DOAS Simulation Results, 1A–4A	77
Table 5–18	Medium Box Low Plug ASHP DOAS Simulation Results, 4B–8.....	77
Table 5–19	Medium Box High Plug ASHP DOAS Simulation Results, 1A–4A.....	79
Table 5–20	Medium Box High Plug ASHP DOAS Simulation Results, 4B–8.....	79
Table 5–21	Big Box ASHP DOAS Simulation Results, 1A–4A.....	81
Table 5–22	Big Box ASHP DOAS Simulation Results, 4B–8.....	81
Table 5–23	Medium Box Low Plug WSHP DOAS Simulation Results, 1A–4A.....	83
Table 5–24	Medium Box Low Plug WSHP DOAS Simulation Results, 4B–8.....	83
Table 5–25	Medium Box High Plug WSHP DOAS Simulation Results, 1A–4A.....	85
Table 5–26	Medium Box High Plug WSHP DOAS Simulation Results, 4B–8.....	85
Table 5–27	Big Box WSHP DOAS Simulation Results, 1A–4A	87
Table 5–28	Big Box WSHP DOAS Simulation Results, 4B–8	87
Table C–1	Building Occupancy Schedule, January–November, Fraction of Peak.....	103
Table C–2	Building Occupancy Schedule, December, Fraction of Peak	103
Table C–3	Infiltration Schedule, Fraction of Peak	103
Table C–4	Heating and Cooling Set Point Schedule, Degrees Fahrenheit.....	103
Table C–5	Baseline Lighting Schedule, Fraction of Peak	104
Table C–6	Baseline Electric Equipment Schedule, Fraction of Peak.....	104
Table C–7	Low-Energy Lighting Schedule, Fraction of Peak	104
Table C–8	Low-Energy Electric Equipment Schedule, Fraction of Peak	104

1. Introduction

The *Advanced Energy Design Guide for Medium to Big Box Retail Buildings: Achieving 50% Energy Savings Toward a Net Zero Energy Building* (AEDG-MBBR) (ASHRAE et al. 2011b) was written to help owners and designers of retail stores achieve 50% whole-building energy savings compared to the minimum requirements of *ANSI/ASHRAE/IESNA Standard 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential Buildings* (Standard 90.1-2004) (ASHRAE 2004b). Included in the AEDG-MBBR are prescriptive recommendations by climate zone for the design of the building envelope; fenestration; lighting systems (including electrical lights and daylighting); heating, ventilating, and air-conditioning (HVAC) systems; building automation and controls; outdoor air (OA) treatments; and service water heating (SWH). Additional savings recommendations are also included, but are not necessary to achieve the 50% energy savings goal. These recommendations are provided for additional HVAC strategies and renewable energy systems.

The AEDG-MBBR shows that the 50% target is not only possible, but easily achievable. Case studies show stores around the country that have achieved and surpassed this target. Best practices and cautions are also provided to demonstrate how to implement the recommendations. The recommendation tables in the AEDG-MBBR do not include all the components listed in Standard 90.1-2004, and instead focus only on the primary energy systems (lighting, HVAC, etc.). The underlying energy analysis presumes that all other components comply with the criteria in Standard 90.1-2004.

By specifying a goal and identifying paths to achieve it in each climate zone, the AEDG-MBBR provides design direction to build energy-efficient retail stores that use 50% less energy than those built to the minimum requirements of Standard 90.1-2004. There may be other means of achieving the target goal, and this guide strives to help generate ideas for continued innovation.

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

The AEDG-MBBR is part of a series of AEDGs targeting 50% energy savings over levels achieved by following *ANSI/ASHRAE/IESNA Standard 90.1-2004*. The other guides in the 50% energy savings series include:

- The *Advanced Energy Design Guide for Small to Medium Office Buildings: Achieving 50% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2011c)
- The *Advanced Energy Design Guide for K-12 School Buildings: Achieving 50% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2011a)
- The *Advanced Energy Design Guide for Large Hospitals: Achieving 50% Energy Savings Toward a Net Zero Energy Building* (ASHRAE et al. 2012)

1.1 Objectives

One of the National Renewable Energy Laboratory's (NREL) tasks in developing the AEDG-MBBR was to provide the analysis and modeling support to:

- Verify energy savings: the specific prescriptive recommendations that, in aggregate, yield at least 50% savings beyond a baseline building built to Standard 90.1-2004 for each climate region. The 50% savings value is measured based on the total energy consumption, not just regulated loads. It is not an average of the national energy savings; 50% savings were verified for each U.S. climate zones and corresponding subzone.
- Develop recommendations that meet a numeric goal value: the energy savings goal is a hard value as opposed to an approximate target. As in past AEDGs, the AEDG-MBBR is intended for use as an option in obtaining Energy and Atmosphere credits under the USGBC Leadership in Energy and Environmental Design rating system.

Separate from the AEDG-MBBR, this Technical Support Document (TSD) was written to document the process used to develop the AEDG-MBBR and the analysis and modeling performed to support that development. Its specific objectives include:

- Document the process and schedule used to develop the AEDG-MBBR.
- Document prototypical medium and big box retail store characteristics.
- Document the EnergyPlus (DOE 2011) modeling assumptions used to establish 50% energy savings.
- Document the baseline and low-energy EnergyPlus retail store models.
- Present the recommendations for achieving at least 50% savings over Standard 90.1-2004.
- Demonstrate that the recommendations result in 50% or greater energy savings by climate zone.

1.2 Scope of the AEDG and TSD

Each guide in the AEDG series provides recommendations and user-friendly design assistance to designers, developers, and owners of commercial buildings to encourage setting and achieving energy-savings goals. The AEDGs provide prescriptive packages that enable energy savings targets for each climate zone to be reached.

The AEDG-MBBR applies primarily to box retail buildings with 20,000 ft² to 100,000 ft² of floor area with administrative and office areas; sales areas; hallways and restrooms; meeting and dining areas; storage spaces; and mechanical/electrical rooms. For this TSD, a box retail building is a large, free-standing, rectangular, single-floor structure built on a concrete slab. This guide does not consider commercial refrigeration, kitchens, or other atypical specialty spaces that generate extraordinary heat or pollution. Certain aspects of retail building design, including commercial refrigeration, domestic water well piping, and sewage disposal, are excluded, as they were too complex to include given the scope of the project. Significant energy efficiency opportunities may be available with these aspects, and AEDG-MBBR users are encouraged to take advantage of these opportunities.

The AEDG-MBBR is also not intended to substitute for rating systems or references that address the full range of sustainability issues in retail stores, such as acoustics, productivity, indoor air quality, water efficiency, landscaping, and transportation, except as they relate to operational energy consumption (ASHRAE et al. 2011b). The AEDG-MBBR contains recommendations only and is not a code or standard.

The guides in the AEDG series also do not provide detailed documentation for developing the recommendations or the energy savings details. This TSD describes the methodology for

developing the AEDG-MBBR and provides the technical details that were used to determine energy savings, including model inputs and assumptions.

1.3 AEDG-MBBR Layout and Content

1.3.1 Chapter 1 Introduction

This chapter contains information about the project goal and scope, as well as instructions for use.

1.3.2 Chapter 2 Integrated Design Process

This chapter provides resources for those who want to understand and adopt an overall, integrated process for designing, constructing, and operating energy-efficient retail stores. The guide presents an integrated process for achieving energy savings in these facilities and is valuable for designers who want to augment and improve their practices to ensure energy efficiency is deliberately considered at each stage of the development process, from project conception through building operation. Figures and checklists are included to aid in addressing energy goals in each phase of the design process. This chapter addresses the details and best practices of an integrated design process, and discusses the benefits and features of integrated design, specifics about the process, and step-by-step details about its phases. It also discusses store prototype development as it relates to continuous improvement for retailers who build across the country, as well as key design strategies for controlling capital costs to help the users overcome the notion that more efficient buildings must cost more than conventional ones.

1.3.3 Chapter 3 Applying Energy Modeling and Benchmarking Strategies

This chapter discusses the application of energy modeling to retail store design and presents performance targets to better define the 50% energy savings goal. These targets are presented as annual absolute whole-building energy use intensity (EUI) values, and owners are encouraged to set their own EUI targets to provide focused and measurable 50% savings goals.

Throughout the first three chapters, five detailed case studies illustrate techniques discussed in the guide. EUIs are provided to benchmark future buildings against these buildings. All the case studies use some of the recommendations in the tables, but predate the publication of the AEDG-MBBR and were not developed explicitly using those tables. They provide motivation and examples for others to follow and validate the guide's recommendations.

1.3.4 Chapter 4 Design Strategies and Recommendations by Climate Zone

This chapter contains the climate-specific recommendation tables, a unique set of energy efficiency recommendations for each of the U.S. climate zones and corresponding subzones in the United States. Recommendations are organized by several categories: envelope, electric lighting, daylighting, plug loads, SWH, HVAC, and quality assurance (QA). The recommendations are simply one path to reach the 50% energy savings target over Standard 90.1-2004. Other approaches may also save energy; however, identifying all possible solutions is not in the scope of this guide; assurance of the savings from other approaches is left to the user. To achieve 50% energy savings, this guide assumes compliance with the more stringent of either the applicable edition of Standard 90.1 or the local code requirements in all areas not addressed in the climate-specific recommendation tables. Future editions of energy codes may have more stringent values.

1.3.5 Chapter 5 How to Implement Recommendations

The final chapter provides guidance about good practices for implementing the recommendations, as well as tips to avoid known problems in energy-efficient construction. It includes sections that discuss the building envelope, daylighting, electric lighting, plug loads, SWH, HVAC, QA and commissioning, and additional bonus savings opportunities. The bonus savings section includes areas for additional good practice items that, if implemented properly, should achieve savings beyond the 50% level. Throughout the section, technology case studies giving in-depth review of various building component specific items are presented. This chapter includes the following how-to sections:

- The envelope how-to section contains climate zone-specific information about explicit types of walls, roofs, floors, doors (including vehicular dock doors), vestibules, insulation, infiltration, and vertical fenestration.
- The daylighting how-to section provides tips on general principles; analysis tool information; daylighting space types and layouts, including space type strategies; skylight information; controls; photosensor specification and placement; and system commissioning.
- The lighting how-to section details proper space planning, lighting by space type, best practices for interior finishes, specific lamp and ballast types, advanced controls, space type specific lighting layouts, control strategies, and exterior lighting (including parking lot lighting) power and control.
- The plug load how-to section provides methods to reduce the connected load, best practices for sales floors, offices, and security systems, ways to reduce the energy used by illuminated signs and graphics, methods to reduce parasitic loads, and plug load control strategies.
- The SWH how-to section discusses the types of systems that are well suited for the retail environment, proper sizing of the systems, choosing energy-efficient systems, and the best locations for the system components.
- The HVAC section includes best practices for four HVAC systems types:
 - Packaged variable air volume (VAV) direct expansion (DX) air conditioner with a gas furnace (VAV)
 - Packaged constant air volume (CAV) DX air conditioner with a gas furnace and a dedicated outdoor air system (DOAS) (CAV DOAS)
 - Air source heat pump (ASHP) with electric resistance supplemental heat and a DOAS (ASHP DOAS)
 - Water source heat pump (WSHP) with a DOAS (WSHP DOAS).

The HVAC section also contains recommendations for DOASs; evaporative condensers; exhaust air energy recovery; indirect evaporative cooling; hydronic heating systems; ventilation air and demand-controlled ventilation (DCV); economizers; system-level control strategies; thermal zoning; ductwork design and duct insulation/sealing; exhaust air systems; testing, adjusting, and balancing; air cleaning; relief versus return fans; zone controls; heating sources; noise control; and proper maintenance.

- The QA and commissioning section contains specific details about commissioning and its importance in every step of the design process, as well as information on measurement and verification (M&V).

- The bonus savings section includes best practices for ground-source heat pump systems, photovoltaic systems, wind turbine power, transpired solar collectors, and power purchase agreements.

1.4 Technical Support Document Organization

This report is presented in five sections: Section 1 introduces the AEDG-MBBR and the supporting background information; Section 2 outlines the development process of the AEDG-MBBR; Section 3 provides the evaluation approach, including baseline and low-energy modeling methods and assumptions; Section 4 discusses the energy target section of the AEDG-MBBR; and Section 5 documents the final recommendations and energy savings.

The AEDG-MBBR scoping document can be found in Appendix A. Additional information on the PC development process is included in Appendix B. Appendix C contains tabular data about the schedules used in the energy models. Appendix D contains code used to control the HVAC systems in EnergyPlus.

2. AEDG-MBBR Development Process

The AEDG-MBBR was developed by a PC representing a diverse group of professionals. Guidance and support were provided through collaboration between ASHRAE, AIA, IES, USGBC, and DOE. PC members were provided by these partner organizations, and the ASHRAE Project Committee 90.1 (SSPC 90.1). A steering committee (SC) was assembled to oversee the development process, composed of representatives of ASHRAE, AIA, IES, USGBC, and DOE. The SC issued a scoping document to the PC, including the timeline for the task, energy savings goal, intended target audience, space types to include, and desired design assistance characteristics.

The PC followed SC guidance to develop a plan for completing the AEDG-MBBR. Key milestones were determined based on a final publication date and used a schedule similar to those developed for previous guides, including two peer review periods corresponding with a 60% completion draft (technical refinement) and a 90% completion draft (final review). Four PC meetings were held at ASHRAE headquarters, Target Corporation headquarters, and NREL. Many conference calls with the full PC were also held to provide updates on the AEDG-MBBR's progress toward the peer review and publication milestones.

2.1 Steering Committee

The SC comprised representatives of the partner organizations and guided the PC in developing the AEDG-MBBR. The SC had a chair, one representative from each partner organization (AIA, IES, USGBC, ASHRAE, and DOE), a liaison from ASHRAE SSPC 90.1, and one ASHRAE staff member; for a total of eight people. The guidance included a timeline for the task, an energy savings goal, an intended target audience, and desired design assistance characteristics. The SC guidance points were to:

- Develop and document a process to achieve 50% savings over Standard 90.1-2004 in medium to big box retail buildings.
- Produce recommendations in a technically sound AEDG for medium to big box retail buildings.
- Constrain the scope and duration of the analysis to maintain the project schedule.
- Rely on current knowledge of energy-efficient building design, supplemented with energy design analysis.

Additional priorities identified by the SC were provided in a scoping document, which included:

- The baseline for energy use evaluation is annual site energy consumption.
- Address the practical how-to, user-friendly information needs of the AEDG-MBBR's intended users, who are designers in medium to large firms, design/build contractors, and construction firms.
- The interaction of building components and systems will need to be considered rather than having all the savings come from individual parts (savings from systems integration is encouraged). Accommodate, to the extent practical, design flexibility through use of efficiency measure packages that users may choose from.
- Adopt a prescriptive recommendation approach with measure packages. This will include envelope, mechanical, lighting, and water heating measures. The document will be formatted for easy use, provide specific procedures, convey best practices, and avoid

the mandatory language that is typical of codes and standards to increase usability for the target audience.

- In addition to prescriptive energy efficiency measures, the AEDG-MBBR should contain “how to” guidance to help the designer/builder construct an energy-efficient retail building. The document should be presented in a very user-friendly manner to reduce design time. By focusing on user-friendly layouts and presentation, as well as prescriptive design recommendations, the AEDG-MBBR should ease the burden for the designers and give corporate decision-makers an overview of specific, easy-to-follow recommendations.
- The prescriptive recommendations presented should be sufficient to allow innovative firms to extend the information when designing facilities that might be evaluated using performance-based criteria. That is, some additional allowance or flexibility should be provided for people who are accustomed to performance-based documents.
- Several case studies should be included to illustrate the energy efficiency components identified. These case studies can focus on the geographic regions or illustrate particular items or recommended techniques.

The full scoping document can be found in Appendix A.

2.1.1 Inclusion of Economics and Cost

The purpose of the AEDG-MBBR is to assist designers in the design of energy-efficient retail buildings. The guide focuses on the goal of 50% energy savings, rather than on installations that have a payback threshold.

The AEDG-MBBR does include numerous cost control strategies and best practices, and the case studies help to reinforce the claim that high-performance stores can be built within typical budgets.

2.2 Approval Authority

The final approval for the AEDG-MBBR was the responsibility of the SC. Committee members were responsible for reflecting the opinions of the partner organization they represented. This included consulting with their organizations and getting buy-in during the process, as well as providing peer reviews. Efforts were made to agree on the content, as is done during the development of the ASHRAE Fundamentals Handbook (ASHRAE 2009); however, the AEDG-MBBR is not a consensus document.

2.3 Project Committee Organization and Membership

The AEDG-MBBR was developed by a PC administered under ASHRAE’s Special Project procedures. The AEDG-MBBR PC was designated as ASHRAE Special Project 135 (SP-135), and included membership from each partner organization. Table 2–1 lists the PC members and the organizations they represented. Some members were not affiliated with a partner organization. In these cases, the function of that member was listed instead.

Table 2–1 AEDG-MBBR PC Organization Chart

Member	Organization/Function
Shanti Pless	Chair
Merle McBride	Vice chair
Dan Nall	AIA/USGBC representative
Scott Williams	AIA/USGBC representative
Michael Lane	IES representative
Bernie Bauer	IES representative
Carol Marriott	ASHRAE representative
Don Colliver	Steering committee ex officio
Lilas Pratt	ASHRAE staff liaison
Matt Leach	Analysis support
Eric Bonnema	Analysis support

The SC helped to select PC members with energy efficiency experience in retail. Each represented SC organization was given the chance to provide peer review input on the various review drafts produced by the PC. In effect, these representatives were intended to be the interfaces to their respective organizations to ensure a large body of input into the AEDG-MBBR development.

Because the AEDG-MBBR was developed under the ASHRAE special project procedures, and not the standards development procedures, the peer reviews were not considered public reviews. However, review copies were made available to all partner organizations, and to the various ASHRAE bodies (SPCC 90.1) represented by the PC membership. Interested parties could also download review copies from the ASHRAE website during the advertised review period.

2.4 Development Schedule and Process

Following SC guidance, the PC developed a one-year plan for completing the AEDG-MBBR. Key milestones in the development schedule were determined based on the final publication date and time needed for the publication process. The PC planned for two peer review periods that corresponded with a 60% completion draft (technical refinement) and a 90% completion draft (final review). Four PC meetings were held in addition to eight interim conference calls.

Further information about each meeting is included in the agendas, which are provided in Appendix B. These agendas were updated after each meeting to reflect the actual discussions and length of time spent on each item. After each meeting, the meeting notes, agenda, action items, future schedules, and other related documents were compiled into a meeting report. These reports were very useful for reference and organizational purposes during the AEDG-MBBR development.

The iterative development of the prototype, baseline, and low-energy models included discussion of the model inputs and the current model results at every meeting and conference call. Results from the modeling, combined with input from the PC, led to the final AEDG-MBBR recommendations. The following steps show the modeling process used, from the initial prototype development to the final recommendations:

1. Use the expertise of the PC to help define inputs not governed by applicable standards.
2. Present preliminary results for the prototype models to the PC.
3. Develop a consensus from the PC on the prototype model inputs.

4. Generate baseline models by applying the climate-specific criteria in Standard 90.1-2004.
5. Investigate initial strategies by applying preliminary HVAC and envelope recommendations to the prototype models.
6. Present the low-energy modeling results to the PC and identify recommendations that do not meaningfully contribute to the 50% energy savings goal.
7. Fine-tune the recommendations to achieve at least 50% whole-building energy savings in all climate zones for each store type.
8. Document final recommendations for the AEDG-MBBR that achieve at least 50% savings.

The following sections of this TSD present the prototype development results from Step 3, the baseline model results from Step 4, and the final recommendations and energy savings results as documented in Step 8.

3. Evaluation Approach

This chapter describes the analysis methods used to support development of the AEDG-MBBR. It explains how the prototype, baseline, and low-energy models were developed, and how the resultant energy savings were quantified.

3.1 Determining Energy Savings

The purpose of the building energy simulation analysis is to assess and quantify the energy savings potential of the final AEDG-MBBR recommendations. All AEDGs contain a set of energy efficiency recommendations for all U.S. climate zones and their corresponding subzones. To provide the prescriptive recommendations necessary to achieve 50% energy savings, a specific, quantitative energy savings goal must be measured against Standard 90.1-2004.

The following steps were used to determine whether the 50% savings goal was met or exceeded:

1. Develop “typical” retail store prototype characteristics.
2. Create baseline models from the prototypes that are minimally compliant with Standard 90.1-2004.
3. Use energy modeling iteratively to help inform AEDG-MBBR recommendations and ultimately create complete low-energy models based on the final recommended energy efficiency technologies in the AEDG-MBBR.
4. Verify 50% energy savings were achieved for each of the four investigated HVAC system types in the AEDG-MBBR across the U.S. climate zones and corresponding subzones.

These steps are presented in a linear fashion, but there was some iteration among the steps. The flowchart in Figure 3–1 presents a visual representation of the evaluation approach.

3.1.1 Site Energy Use

The 50% energy savings goal of the AEDG series is based on site energy savings between a minimally code compliant building and a low-energy building that uses the AEDG recommendations. Other metrics, such as energy cost savings, source energy savings, and carbon savings could be used to determine energy savings. Each metric has advantages and disadvantages from an implementation and a calculation perspective, and each can favor different technologies and fuel types. The AEDG-MBBR uses site energy savings, as directed by the SC, to retain consistency with previous AEDGs.

3.1.2 Whole-Building Energy Savings

Historically, energy savings have been expressed in two ways: those associated with regulated loads and those associated with the whole building. The “regulated loads” energy savings indicate the savings when only the code-regulated loads are included in the total energy use. Unregulated loads typically include plug and some process loads. The “whole-building” energy savings indicate the savings when all the loads (regulated and unregulated) are included in the energy savings calculations. In general, for the same level of percent savings, whole-building savings are more challenging to attain than regulated loads savings. The AEDG-MBBR uses the “whole-building” energy savings method for determining energy savings and contains recommendations for both regulated and unregulated loads.

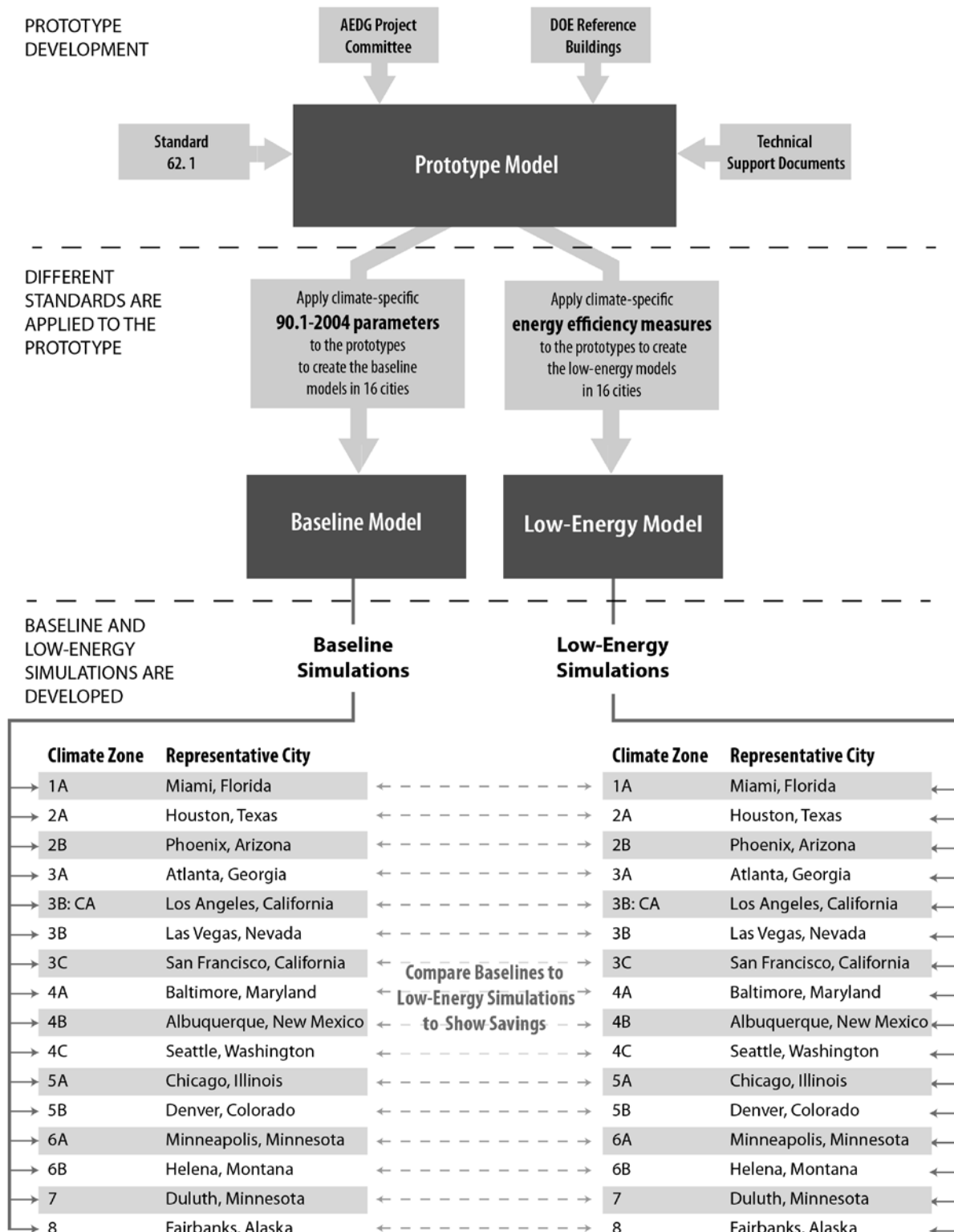


Figure 3–1 Flow diagram of modeling process
(Credit: Marjorie Schott/NREL)

3.1.3 Modeling Methods

EnergyPlus version 6.0 (DOE 2011) was used to complete the energy simulations in the AEDG-MBBR. This software was selected because it is the contemporary DOE tool, and accounts for the complicated interactions between climate, internal gains, building form and fabric, HVAC systems, and renewable energy systems. EnergyPlus is a heavily tested program with formal validation efforts repeated for every release (Judkoff et al. 1995). All simulations were completed with an NREL analysis platform called Opt-E-Plus (NREL 2010) that manages inputs and outputs of the EnergyPlus simulations. Opt-E-Plus' core functionality is the user's ability to pass high-level parameters (building area, internal gains per zone, HVAC system configuration, etc.) to generate a fully parameterized EnergyPlus input file. Such files are generated rapidly and can be easily changed to incorporate changes during the evolution of the model. The high-level parameter file is a structured text file written in Extensible Markup Language. Modifying the high-level parameters is preferred over modifying the EnergyPlus input file, because it greatly simplifies the modeling input development process. Modifying EnergyPlus input files can be time intensive when the high-level parameters have a one-to-many relationship with the corresponding objects in the low-level input file.

The AEDG-MBBR simulations were used to evaluate and vet suggested guide recommendations and to verify that the final set met the savings goal. There were one baseline (baseline HVAC system) and four low-energy (four low-energy HVAC system types) models for each prototype (medium box low plug, medium box high plug, and big box) for a total of 15 separate seed (starting point) energy models. The Opt-E-Plus software then took these 15 seed models and "swept" them across the 16 cities representing the U.S. climate zones and corresponding subzones. The Opt-E-Plus "sweep" took each seed energy model file, created 16 separate energy models, and applied climate zone-specific details such as weather data, economizer requirements, and building envelope specifications from Standard 90.1-2004 (for the baseline model) or the AEDG-MBBR recommendations (for the low-energy models). This resulted in 240 (48 baseline and 192 low-energy) energy models.

3.1.3.1 Climate Zones

The AEDGs contain a unique set of energy efficiency recommendations for each of the climate zones and corresponding three subzones in the United States (see Figure 3–2). The zones are defined primarily by heating degree days and cooling degree days (Briggs et al. 2003), and range from very hot (Zone 1A) to 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. These climate zones may be mapped to other climate locations for international use.

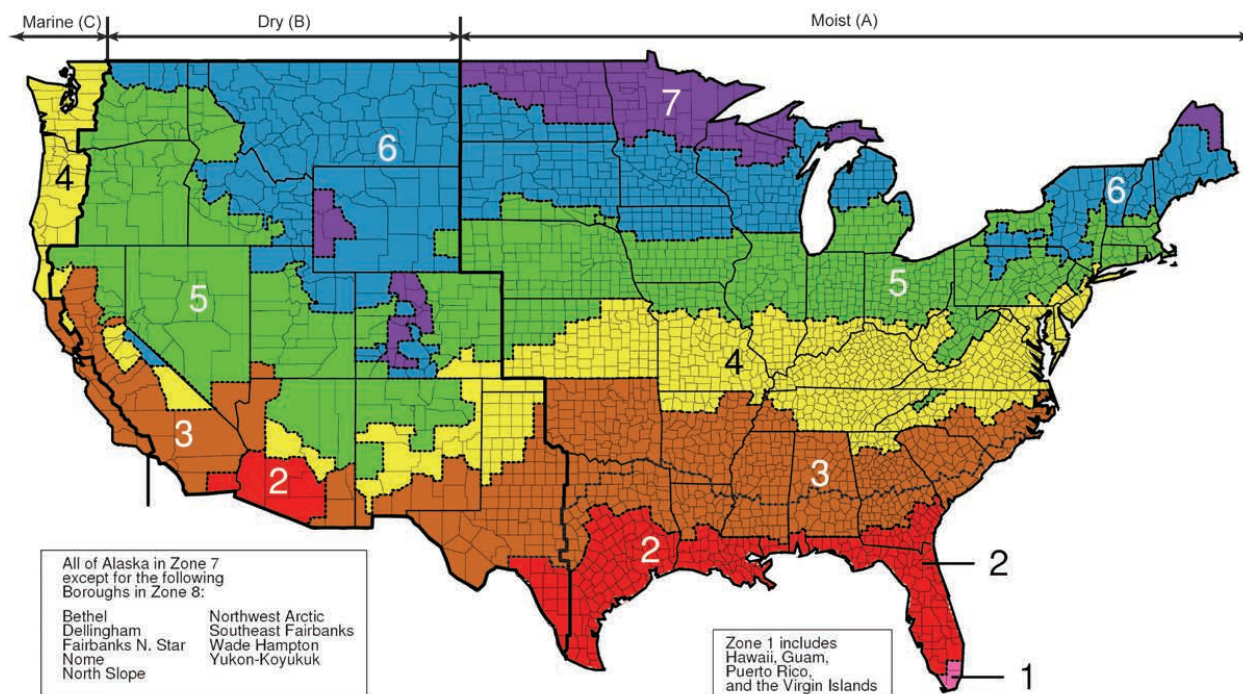


Figure 3–2 U.S. climate zones
(Credit: DOE (2003))

The 16 specific locations for which analyses were performed are listed here and are designated as being representative of their climate zones. Large cities were chosen, as their weather data directly apply to a large fraction of the total U.S. building floor area. Energy savings were determined by running baseline and low-energy model simulations with the same typical meteorological weather file, TMY2 data (one set of simulations for each city).

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

There are two representative cities for climate zone 3B. Throughout this report, 3B will represent Las Vegas, Nevada and 3B:CA will be used to denote Los Angeles, California. See Deru et al. (2011) for more discussion on the location determination process.

3.2 Prototype Model Overview

For the AEDG-MBBR, the models from Hale et al. (2009) were used as a starting point to help define certain building characteristics that were not code-regulated. Three prototype models were developed; two medium box and one big box. The two medium box stores were identical except for the plug loads; the low plug prototype was meant to represent a store that sells items such as clothing or books that have little plug-in merchandise; the high plug prototype was meant to represent an electronics retailer with a larger amount of plug-in merchandise. A larger big box prototype was developed to represent larger general merchandise stores. The prototype model characteristics remained consistent between the baseline and low-energy models. Table 3–1 presents a summary of the prototype models.

Table 3–1 Prototype Model Summary

Building Characteristic	Medium Box Low Plug	Medium Box High Plug	Big Box
Size	40,500 ft ²	40,500 ft ²	99,225 ft ²
Aspect ratio	1.25	1.25	1.00
Sales floor area	32,400 ft ²	32,400 ft ²	79,380 ft ²
Back-of-house area	8,100 ft ²	8,100 ft ²	19,845 ft ²
Floor-to-ceiling height	20 ft	20 ft	20 ft
Space types	Sales floor, vestibule, stock room, office, meeting room, break room, restroom, corridor, mechanical room		
Wall constructions	Steel framed	Steel framed	Mass
Roof construction	Insulation entirely above deck	Insulation entirely above deck	Insulation entirely above deck
Window area	22% (south façade only)	22% (south façade only)	22% (south façade only)
Window sill height	3.6 ft	3.6 ft	3.6 ft
Window height	4.4 ft	4.4 ft	4.4 ft
Peak plug loads	0.35 W/ft ²	0.54 W/ft ²	0.36 W/ft ²
Percent conditioned	Fully heated and cooled	Fully heated and cooled	Fully heated and cooled

3.2.1 Geometry

Table 3–2 shows a tabular breakdown of zone area for the medium box prototypes and Figure 3–3 shows the zone layout for the models. Table 3–3 and Figure 3–4 and show the same information for the big box prototype model.

Table 3–2 and Table 3–3 also show a mapping of each zone to a space type. These space types are referenced throughout the rest of the TSD when describing other model inputs (lighting, plug loads, etc.).

Table 3–2 Medium Box Zone Area Breakdown

Zone Name	Zone Type	Quantity	Dimensions (ft × ft)	Zone Area (ft ²)	Total Area (ft ²)
Main sales	Sales floor	1	225.0 × 129.0	29,025.0	29,025
Vestibule	Vestibule	1	20.0 × 15.0	300.0	300
Corridor	Corridor	1	100.0 × 6.0	600.0	600
Restrooms	Restroom	1	25.0 × 30.0	750.0	750
Stock room	Stock room	1	125.0 × 36.0	4,500.0	4,500
Office	Office	1	15.0 × 30.0	450.0	450
Meeting room	Meeting room	1	25.0 × 30.0	750.0	750
Break room	Break room	1	25.0 × 30.0	750.0	750
Mechanical room	Mechanical room	1	10.0 × 30.0	300.0	300
Perimeter sales	Sales floor	2	102.5 × 15.0	1,537.5	3,075

Table 3–3 Big Box Zone Area Breakdown

Zone Name	Zone Type	Quantity	Dimensions (ft × ft)	Zone Area (ft ²)	Total Area (ft ²)
Main sales	Sales floor	1	315.0 × 237.0	74,655.0	74,655
Vestibule	Vestibule	1	20.0 × 15.0	300.0	300
Corridor	Corridor	1	140.0 × 8.0	1,120.0	1,120
Restrooms	Restroom	1	35.0 × 55.0	1,925.0	1,925
Stock room	Stock room	1	175.0 × 63.0	11,025.0	11,025
Office	Office	1	21.0 × 55.0	1,155.0	1,155
Meeting room	Meeting room	1	35.0 × 55.0	1,925.0	1,925
Break room	Break room	1	35.0 × 55.0	1,925.0	1,925
Mechanical room	Mechanical room	1	14.0 × 55.0	770.0	770
Perimeter sales	Sales floor	2	147.5 × 15.0	2,212.5	4,425

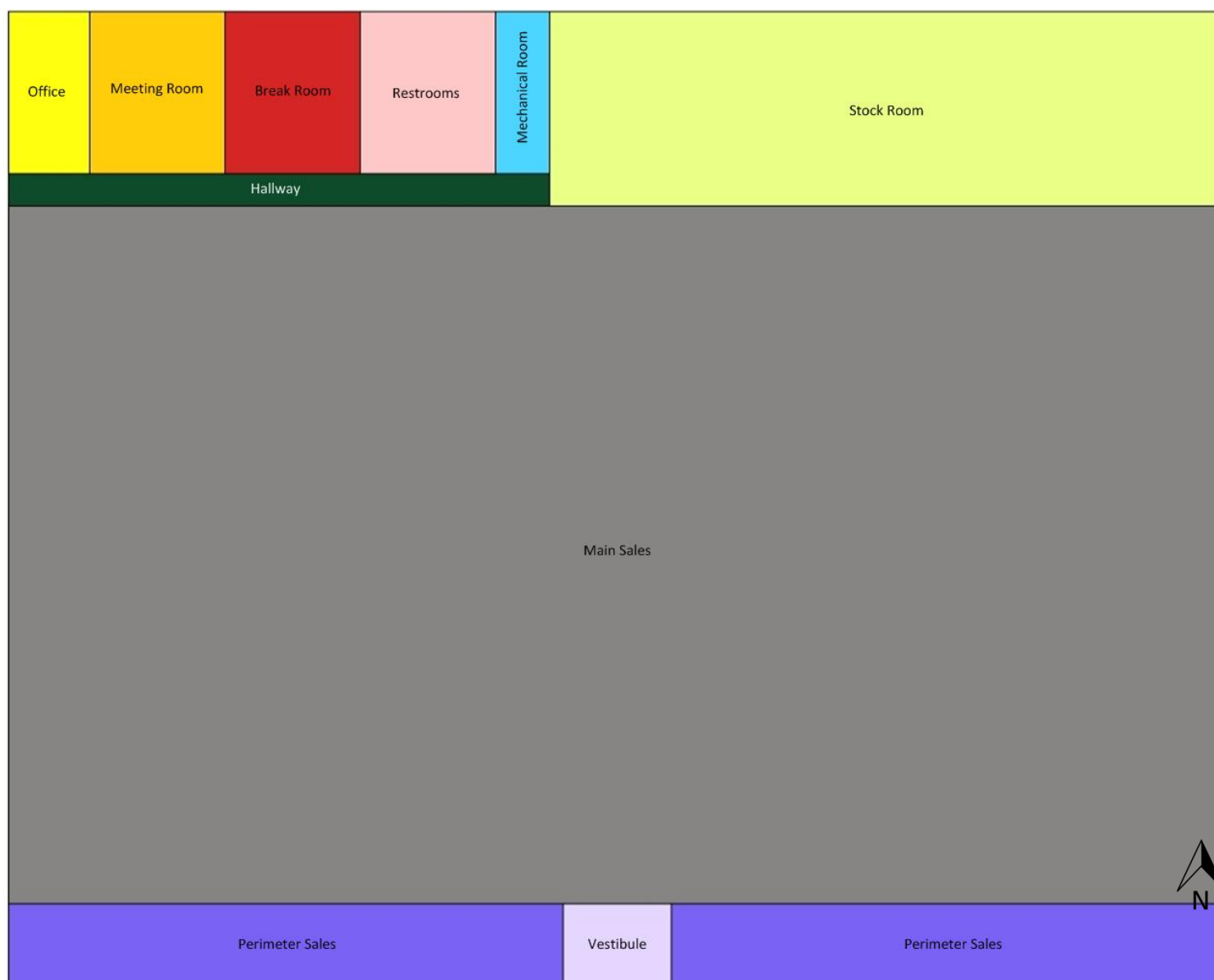


Figure 3–3 Medium box zone layout

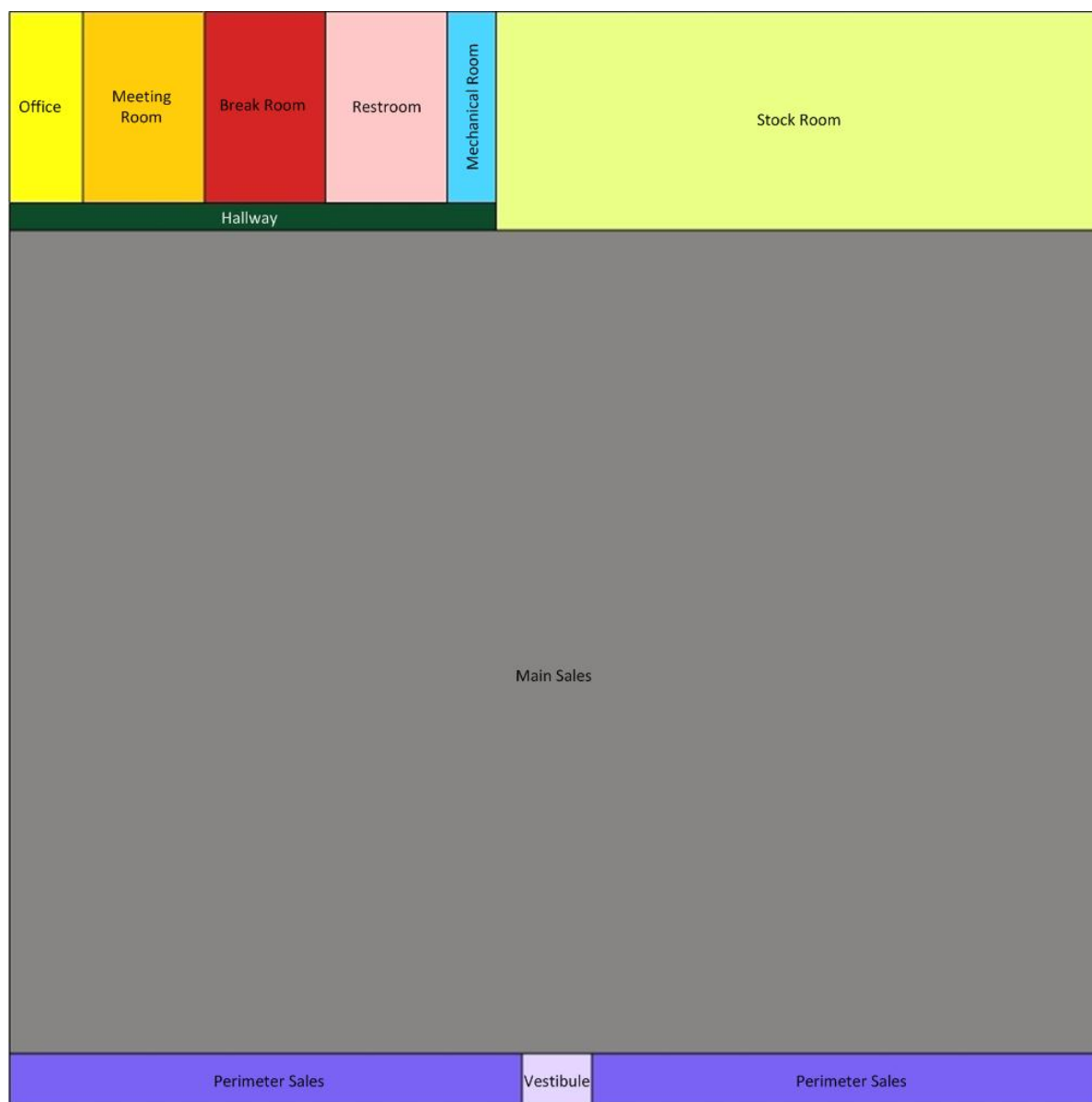


Figure 3–4 Big box zone layout



Table 3–4 provides a breakdown of the prototype models by space type.

Table 3–4 Prototype Space Type Breakdown

Zone Type	Medium Box		Big Box	
	Area (ft ²)	Percent of Total	Area (ft ²)	Percent of Total
Sales floor	32,100	79.3%	79,090	79.7%
Vestibule	300	0.7%	300	0.3%
Corridor	600	1.5%	1,120	1.1%
Restroom	750	1.9%	1,925	1.9%
Stock room	4,500	11.1%	11,025	11.1%
Office	450	1.1%	1,155	1.2%
Meeting room	750	1.9%	1,925	1.9%
Break room	750	1.9%	1,925	1.9%
Mechanical room	300	0.7%	770	0.8%
Total	40,500	100%	99,235	100%

3.2.2 Ventilation and Occupancy

Table 6-1 in Standard 62.1-2004 (ASHRAE 2004a) was used to determine the models' ventilation requirements. Table 3–5 shows space types, their mapping to the “Occupancy Category” column in Standard 62.1-2004 Table 6-1, and the ventilation rates used in all models. The OA rate values and the peak occupant densities are from Standard 62.1-2004 Table 6-1. The double colon in Table 3–5 is a means for indicating the row headings and occupancy categories in Table 6-1 in Standard 62.1-2004 (ASHRAE 2004a). As a simplification, the restroom ventilation rate was set to the same as the sales floor.

Table 3–5 Ventilation Rates by Space Type

Zone Type	Occupancy Category (From Table 6-1 in 62.1-2004)	People OA Rate (cfm/person)	Area OA Rate (cfm/ft ²)	Peak Occupant Density (#/1000 ft ²)
Sales floor	Retail::Sales	7.5	0.12	15
Vestibule	Retail::Sales	7.5	0.12	15
Corridor	General::Corridors	0.0	0.06	0
Restroom	Retail::Sales	7.5	0.12	15
Stock room	General::Corridors	0.0	0.12	3.33*
Office	Office Buildings::Office space	5.0	0.06	5
Meeting room	General::Conference/meeting	5.0	0.06	50
Break room	Food and Beverage Service::Cafeteria/fast food dining	7.5	0.18	70
Mechanical room	General::Corridors	0.0	0.06	0

* Value from (Deru et al. 2011) for back-of-house space in stand-alone retail model

The peak occupant densities in Table 3–5 are modified by schedules within EnergyPlus, which were adapted by the PC from those in Hale et al. (2009). The PC modified the schedules using their experience along with data collected from retail stores. The main modification was to add extended occupancy for the holiday season (the month of December). The occupancy schedules can be seen in Figure 3–5 and Figure 3–6.

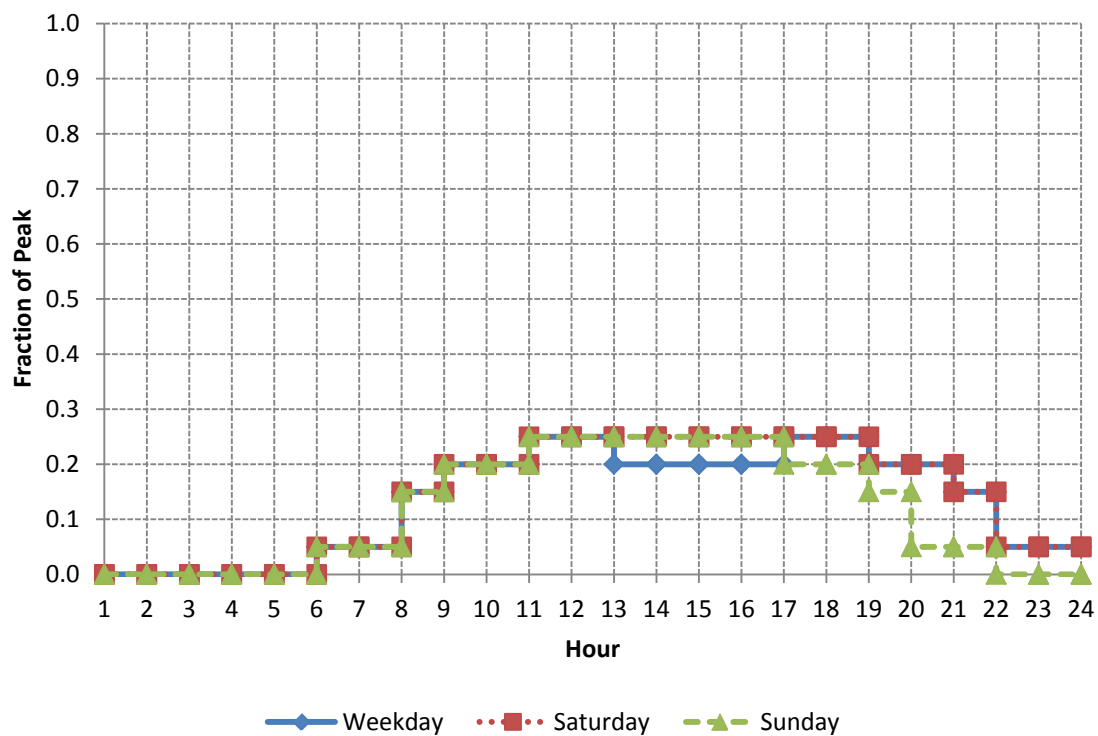


Figure 3–5 Building occupancy schedule, January–November

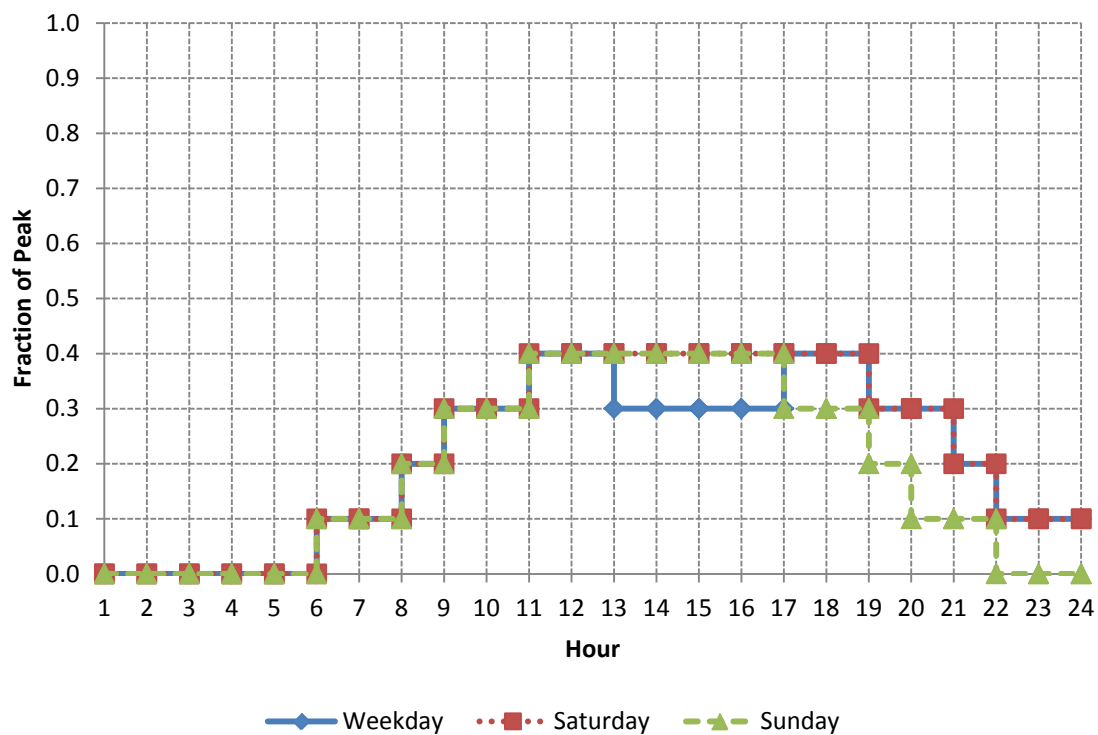


Figure 3–6 Building occupancy schedule, December

3.2.3 Infiltration

Infiltration is the flow of OA into a building through cracks and other unintentional openings and through the normal use of exterior doors for ingress and egress. Infiltration is also known as air leakage into a building (ASHRAE 2009).

Infiltration rates were calculated using an infiltration rate factor and total exterior wall areas for each zone. The calculated infiltration rate factor was assumed to be constant throughout the year. This is a good assumption for annual energy performance, but caution should be used in evaluating hour-by-hour loads with this method.

To determine the infiltration rate factor, the building was assumed to be constructed in such a manner that at a pressure differential of 75 Pa, the infiltration rate was equivalent to 0.4 cfm/ft² of external wall area. Using a flow coefficient of 0.65 and an assumed pressure differential across the envelope of 4 Pa (a pressure likely to be encountered during normal building operation), the final infiltration rate factor was calculated to be 0.06 cfm/ft². This methodology is consistent with that used by Deru et al. (2011).

Because a large amount of OA was brought into the building by the HVAC system, the calculated zone infiltration rates were modified via an infiltration schedule that was set to 0.5 during HVAC system operation. This schedule was a simple multiplier that in this case reduced the total infiltration by half. This schedule changed to 1.0 when the HVAC system was shut off for the night, to simulate the greater infiltration rate that would result from the building no longer being pressurized. The infiltration schedule can be seen in Figure 3–7.

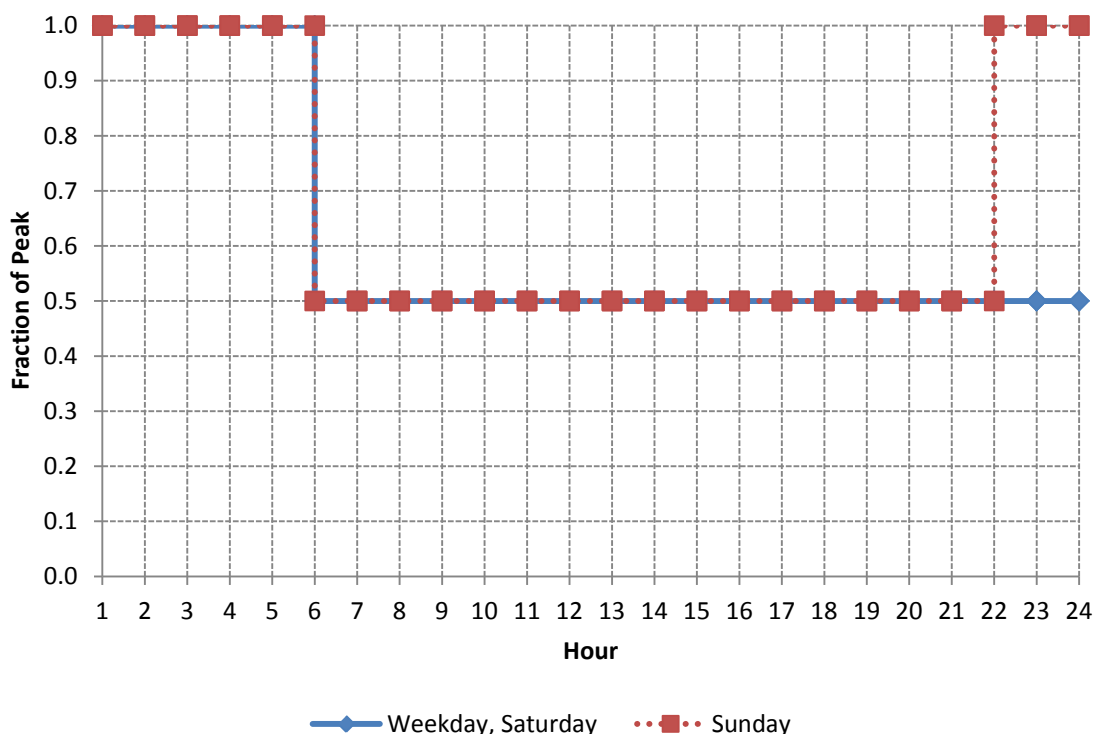


Figure 3–7 Infiltration schedule

3.2.4 Thermostat Set Points

The thermostat set points in the models were derived from those in Hale et al. (2009) and modified by the PC based on their experience. The occupied heating set point is 70°F and the unoccupied set point is 60°F. The occupied cooling set point is 75°F and the unoccupied set point is 86°F. The heating and cooling set point schedule is shown in Figure 3–8. This schedule remained consistent between the baseline and low-energy models.

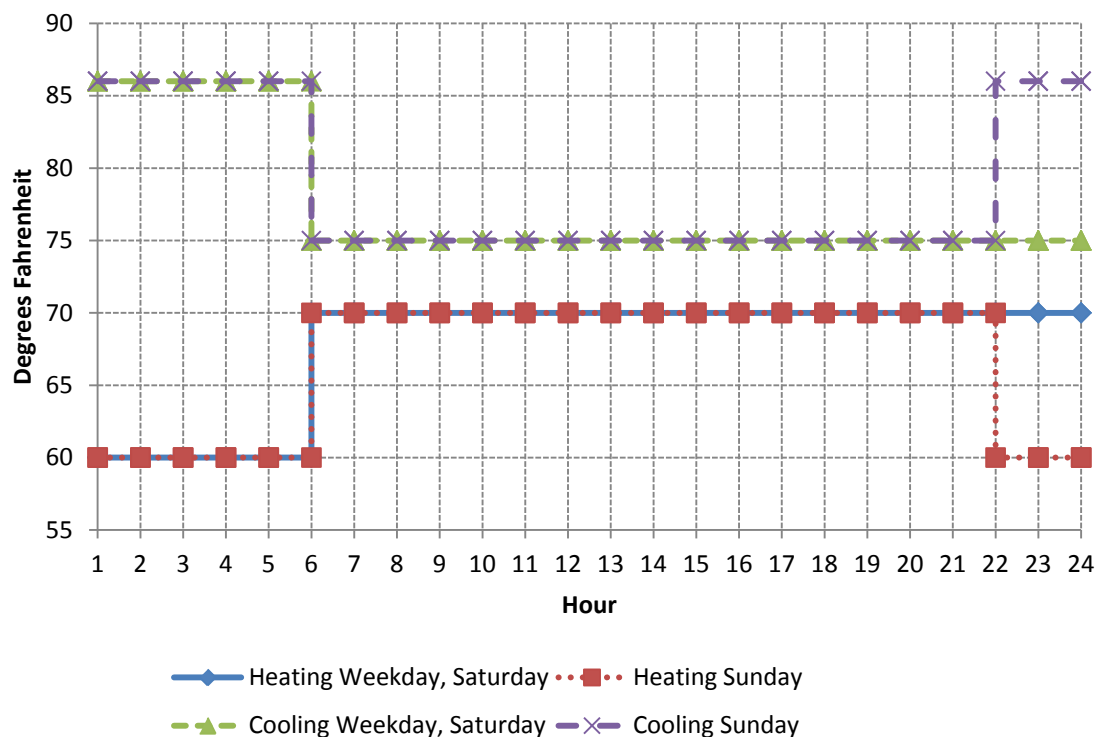


Figure 3–8 Heating and cooling set point schedule

3.3 Baseline Model Development and Assumptions

The baseline models were derived from the prototype models by applying the applicable criteria in Standard 90.1-2004. The PC used their expertise to help define items (such as lighting schedules) not specified by Standard 90.1-2004. Figure 3–9 shows a rendering of the medium box baseline models, and Figure 3–10 shows a rendering of the big box baseline model.

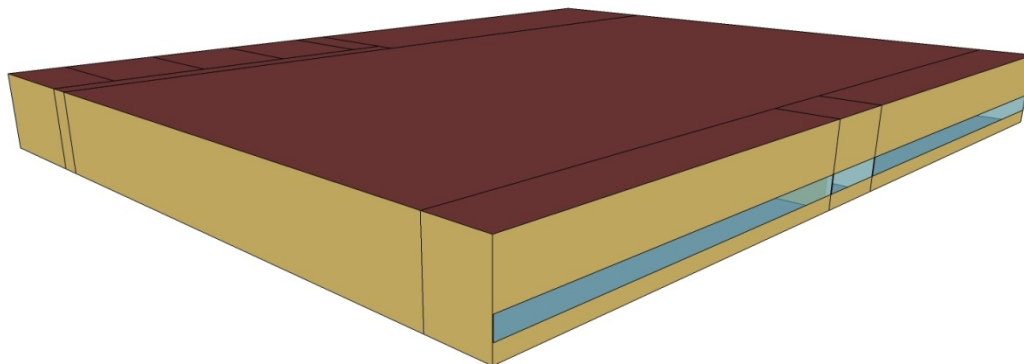


Figure 3-9 Medium box baseline models rendering

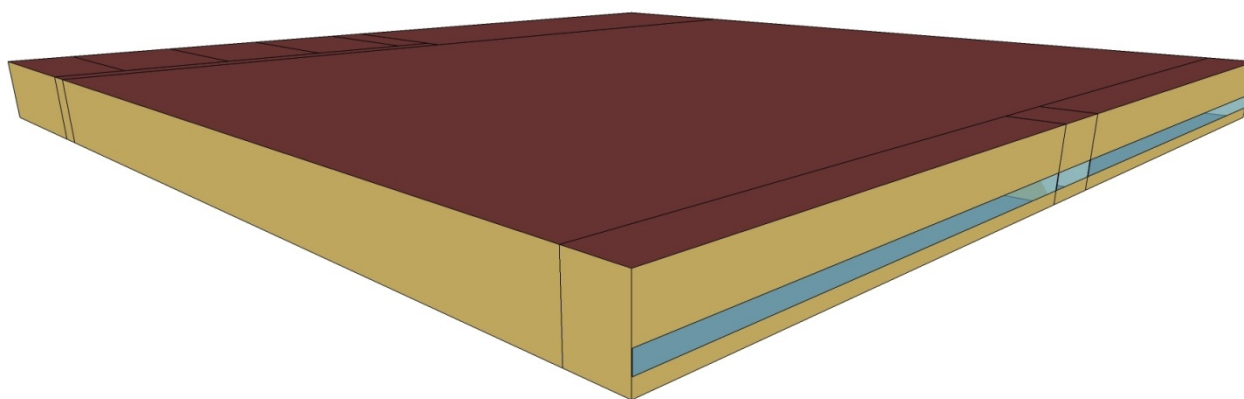


Figure 3-10 Big box baseline model rendering

3.3.1 Envelope

The PC assumed, based on the experience of those in the retail construction industry, that facilities were typically constructed with steel-framed (for the medium box store) or mass (for the big box store) exterior walls, built-up roofs, and slab-on-grade floors. These constructions represent common practices. There are some regional variations, but the PC felt that steel-framed walls for the medium box store, mass walls for the big box store, built-up roofs, and slab-on-grade floors were the most common techniques.

The baseline retail store envelope characteristics were developed to meet the prescriptive design option requirements in accordance with Standard 90.1-2004 Section 5.2. For the Standard 90.1-2004 baselines, the prescriptive building envelope option in Section 5.5 was used. Layer-by-layer descriptions of the constructions were used to model the building thermal envelope in EnergyPlus.

3.3.1.1 Exterior Walls

The baseline medium box stores were modeled with steel-framed wall constructions; the layers consisted of exterior sheathing, batt insulation between steel studs, and interior gypsum board. The baseline big box store was modeled with mass wall constructions; the layers consisted of stucco, concrete block, rigid insulation, and gypsum board. Insulation R-values were selected to meet the minimum wall insulation requirements in Tables 5.5-1 through 5.5-8 (Building

Envelope Requirements) of Standard 90.1-2004, as defined by climate zone. The baseline exterior wall R- and U-values are listed in Table 3–6.

Table 3–6 Baseline Exterior Wall Constructions

Climate Zone	Steel-Framed Exterior Walls (Medium Box Store)		Mass Exterior Walls (Big Box Store)	
	Assembly U-Factor (Btu/h·ft ² ·°F)	Insulation R-Value, Nominal (h·ft ² ·°F/Btu)	Assembly U-Factor (Btu/h·ft ² ·°F)	Insulation R-Value, Nominal (h·ft ² ·°F/Btu)
1 (A)	U-0.124	R-13.0	U-0.580	NR*
2 (A,B)	U-0.124	R-13.0	U-0.580	NR*
3 (A,B,C)	U-0.124	R-13.0	U-0.151	R-5.7 c.i.
4 (A,B,C)	U-0.124	R-13.0	U-0.151	R-5.7 c.i.
5 (A,B)	U-0.084	R-13.0 + R-3.8 c.i.	U-0.123	R-7.6 c.i.
6 (A,B)	U-0.084	R-13.0 + R-3.8 c.i.	U-0.104	R-9.5 c.i.
7	U-0.064	R-13.0 + R-7.5 c.i.	U-0.090	R-11.4 c.i.
8	U-0.064	R-13.0 + R-7.5 c.i.	U-0.080	R-13.3 c.i.

* No insulation requirement

The mass wall was assembled assuming 8-in. medium weight concrete blocks with a density of 140 lb/ft³ and solid grouted cores. The mass wall includes the following layers:

- Exterior air film (calculated by EnergyPlus)
- 1-in exterior stucco
- 8-in. concrete block, 140 lb/ft³
- 1-in. metal clips with rigid insulation (R-value varies by climate)
- 0.5-in. thick gypsum board
- Interior air film (calculated by EnergyPlus).

The steel-framed wall layer details are as follows:

- Exterior air film (calculated by EnergyPlus)
- Nominally R-2 exterior sheathing
- Batt wall insulation (R-value varies by climate)
- 0.5-in. thick gypsum board
- Interior air film (calculated by EnergyPlus).

To calculate the thermal performance of the interior air films, the “TARP” algorithm in EnergyPlus for surface heat transfer film coefficients was used. To calculate the thermal performance of the exterior air films, the “DOE-2” algorithm in EnergyPlus for surface heat transfer film coefficients was used. These algorithms are based on linearized radiation coefficients that are separate from the convection coefficients, as determined by surface roughness, wind speed, and terrain. However, standardized combined film coefficients were used to target assembly U-factors; these coefficients can be seen in Table 3–7 (DOE 2011).

Table 3–7 Standard Air Film Coefficients

Surface Class	Interior Air Film Coefficient (h·ft ² ·°F/Btu)	Exterior Air Film Coefficient (h·ft ² ·°F/Btu)
Wall	0.68	0.17
Floor	0.92	0.46
Ceiling/roof	0.61	0.46

3.3.1.2 Roofs

Built-up, rigid insulation above a structural metal deck roof was used in the baseline models. The layers consisted of the roof membrane, roof insulation, and metal decking. The U-factors varied based on the applicable climate zone. Added insulation was continuous and uninterrupted by framing. Roof insulation R-values were set to match the minimum roof insulation requirements in Tables 5.5-1 through 5.5-8 of Standard 90.1-2004, by climate. The baseline roof U-factors are summarized in Table 3–8.

Table 3–8 Baseline Roof Constructions

Climate Zone	Assembly U-Factor (Btu/h·ft ² ·°F)	Insulation R-Value, Nominal (h·ft ² ·°F/Btu)
1 (A)	U-0.063	R-15.0 c.i.
2 (A,B)	U-0.063	R-15.0 c.i.
3 (A,B,C)	U-0.063	R-15.0 c.i.
4 (A,B,C)	U-0.063	R-15.0 c.i.
5 (A,B)	U-0.063	R-15.0 c.i.
6 (A,B)	U-0.063	R-15.0 c.i.
7	U-0.063	R-15.0 c.i.
8	U-0.048	R-20.0 c.i.

Standard 90.1-2004 does not specify absorptance or other surface assumptions. The roof exterior finish was assumed to be a single-ply roof membrane with gray ethylene propylene polymer membrane in the baseline models. Therefore, a solar reflectance of 0.3, a thermal absorption of 0.9, and a visible absorption of 0.7 were assumed.

3.3.1.3 Slab-on-Grade Floors

The baseline buildings were modeled with slab-on-grade floors, which were composed of a carpet pad layer over an 8-in. thick heavyweight concrete layer.

A slab program that is packaged with EnergyPlus, which determines the temperature of the ground under the slab based on the area of the slab, the location of the building, and the type of insulation under or around the slab, was used to model the ground coupling. For the baseline models, the program was used to run a simple building in each location with the slab insulation requirements in Standard 90.1-2004. The program reports the perimeter ground monthly temperatures, the core ground monthly temperatures, and monthly averages of these temperatures. For this analysis, the average monthly temperatures were used as the input for the ground temperatures under the floor slab in the EnergyPlus input files, and can be found in Table 3–9 and Table 3–10.

Table 3–9 Simulated Monthly Ground Temperatures (°F), 1A–4A

Month	1A	2A	2B	3A	3B:CA	3B	3C	4A
Jan	72.5	69.0	66.7	67.9	68.2	66.0	67.8	67.5
Feb	72.8	68.6	66.6	67.8	68.2	66.0	67.9	67.4
Mar	73.0	69.4	68.7	67.9	68.2	66.0	67.8	67.5
Apr	73.3	71.8	70.5	68.8	68.4	68.6	67.9	67.5
May	73.5	73.0	70.7	71.7	69.0	69.6	67.9	68.9
Jun	73.5	73.2	70.1	72.6	69.7	69.7	68.1	71.8
Jul	73.6	73.3	69.9	72.8	72.3	69.4	68.6	72.4
Aug	73.6	73.3	70.3	73.0	72.9	69.5	68.1	72.6
Sep	73.6	73.4	70.6	73.1	73.0	69.8	68.8	71.9
Oct	73.7	73.1	70.9	70.1	71.5	69.6	68.2	69.1
Nov	73.5	70.9	68.6	68.5	69.1	66.6	68.0	68.1
Dec	73.2	69.2	66.9	68.1	68.4	66.1	67.9	67.6

Table 3–10 Simulated Monthly Ground Temperatures (°F), 4B–8

Month	4B	4C	5A	5B	6A	6B	7	8
Jan	66.6	67.5	67.1	66.6	66.8	66.4	66.5	65.2
Feb	66.6	67.5	67.1	66.5	66.8	66.5	66.5	65.1
Mar	66.5	67.5	67.2	66.6	66.9	66.5	66.6	65.4
Apr	66.6	67.6	67.3	66.7	67.1	66.6	66.8	65.7
May	68.8	67.7	68.0	66.9	68.3	66.7	66.9	66.0
Jun	70.5	68.1	71.0	68.8	70.8	68.1	67.6	66.4
Jul	70.8	69.3	72.0	70.7	71.8	70.4	69.7	67.3
Aug	71.1	70.0	72.3	71.2	72.1	69.8	68.8	66.6
Sep	71.3	68.8	70.6	68.8	69.2	67.7	67.6	66.4
Oct	67.7	68.0	68.2	67.2	67.8	66.9	67.2	66.1
Nov	66.9	67.7	67.6	66.8	67.4	66.7	67.0	65.7
Dec	66.7	67.6	67.3	66.6	67.1	66.5	66.7	65.4

3.3.1.4 Fenestration

Building fenestration includes all envelope penetrations used for ingress and egress or lighting, such as windows, doors, and skylights.

Standard 90.1-2004 (ASHRAE 2004b) specifies window properties as window systems and not as window frame and glass separately; thus, window frames were not explicitly modeled and only one window was modeled per exterior surface. This reduced the complexity and increased the speed of the EnergyPlus simulations. Only the south façade of the building was glazed, and had an overall fraction of fenestration to gross wall area of 22%, with individual fenestration objects distributed evenly on applicable exterior surfaces. Box retail stores usually do not have much glazing. For this model, only the front of the store (the south façade) was glazed.

The U-factors and solar heat gain coefficients (SHGCs) that were applied to the fenestration objects were whole-assembly values and included framing effects. The performance criteria listed in Table 3–11 were set to match the requirements of Table 5.5-1 through Table 5.5-8 in Standard 90.1-2004 (ASHRAE 2004b). The multipliers from the visible light transmittance (VLT) table, Table C3.5 in Standard 90.1-2004 Appendix C (ASHRAE 2004b), were used to calculate VLT values for the baseline windows.

Table 3–11 Baseline Window Constructions

Climate Zone	U-Factor (Btu/h·ft ² ·°F)	SHGC	VLT
1 (A)	1.22	0.25	0.250
2 (A,B)	1.22	0.25	0.250
3 (A,B)	0.57	0.25	0.318
3 (C)	1.22	0.34	0.340
4 (A,B,C)	0.57	0.39	0.495
5 (A,B)	0.57	0.39	0.495
6 (A,B)	0.57	0.39	0.495
7	0.57	0.49	0.490
8	0.46	NR, 0.49 used	NR, 0.490 used

3.3.2 Electric Lighting

3.3.2.1 Interior Lighting

The lighting power densities (LPDs) used in the baseline models are listed in Table 3–12. These values were determined by using the space-by-space method in Standard 90.1-2004, Table 9.6.1 (ASHRAE 2004b). The double colon in Table 3–12 is a means for indicating the common space types and subspace types in Table 9.6.1 in Standard 90.1-2004 (ASHRAE 2004b).

Table 3–12 LPD by Space Type

Model Space Type	90.1-2004 Table 9.6.1 Space Type	LPD (W/ft ²)
Sales floor	Retail::sales area	3.35*
Vestibule	Corridor/transition	0.50
Corridor	Corridor/transition	0.50
Restroom	Restrooms	0.90
Stock room	Active storage	0.80
Office	Office – enclosed	1.10
Meeting room	Conference/meeting/multipurpose	1.17** (1.30)
Break room	Dining area	0.81** (0.90)
Mechanical room	Electrical/mechanical	1.50

* Includes 1.65 W/ft² of accent lighting

** 10% reduction applied in the models to account for occupancy sensors, the 90.1 value is in parenthesis

The peak values in Table 3–12 were modified with hour-by-hour multiplier schedules in EnergyPlus. Both the medium box and big box models used the schedules in Figure 3–11. The lighting schedules were adapted by the PC from those in Hale et al. (2009) based on their experience with retail stores.

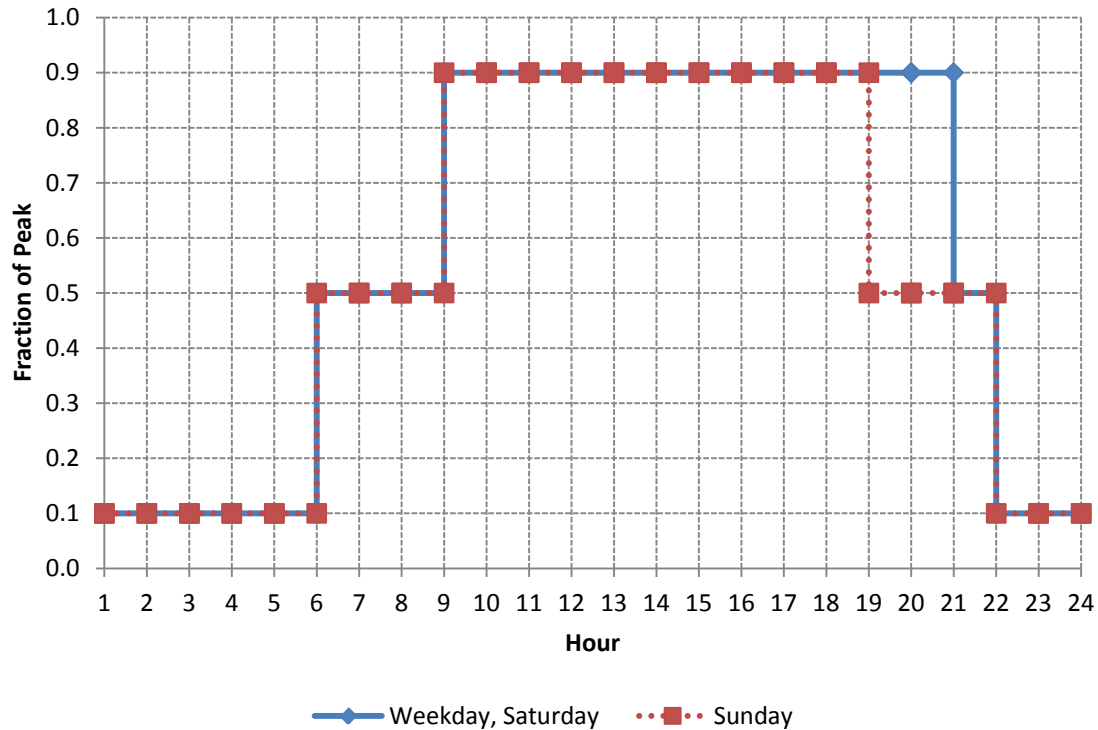


Figure 3-11 Baseline lighting schedule

3.3.2.2 Exterior Lighting

The exterior lighting in the models was meant to represent parking lot lighting. The parking lot area was assumed to be 2.5 times the building area (101,250 ft² for the medium box store, 248,088 ft² for the big box store). The LPD was 0.15 W/ft² of parking lot area (Standard 90.1-2004 Table 9.4.5), resulting in 15,188 W for the medium box store and 37,213 W for the big box store. In both models, the lights were controlled by an astronomical clock that turned the lights on when the sun set and off when the sun rose.

3.3.3 Plug and Process Loads

The plug and process loads were adapted from Hale et al. (2009) based on PC input. Table 3-13 shows a summary of the plug and process loads used in the models.

Table 3–13 Baseline Model Plug and Process Loads

Space Type	Medium Box		Big Box (W/ft ²)
	Low Plug (W/ft ²)	High Plug (W/ft ²)	
Sales floor	0.40	0.70	0.40
Vestibule	0.00	0.00	0.00
Corridor	0.00	0.00	0.00
Restroom	0.10	0.10	0.10
Stock room	0.75	0.75	0.75
Office	0.75	1.10	0.75
Meeting room	0.75	1.10	0.75
Break room	2.60	2.60	2.60
Mechanical room	0.00	0.00	0.00

The peak values in Table 3–13 were modified with hour-by-hour multiplier schedules in EnergyPlus. The electrical schedules in the model were adapted by the PC from those in Hale et al. (2009) based on their experience with retail stores.

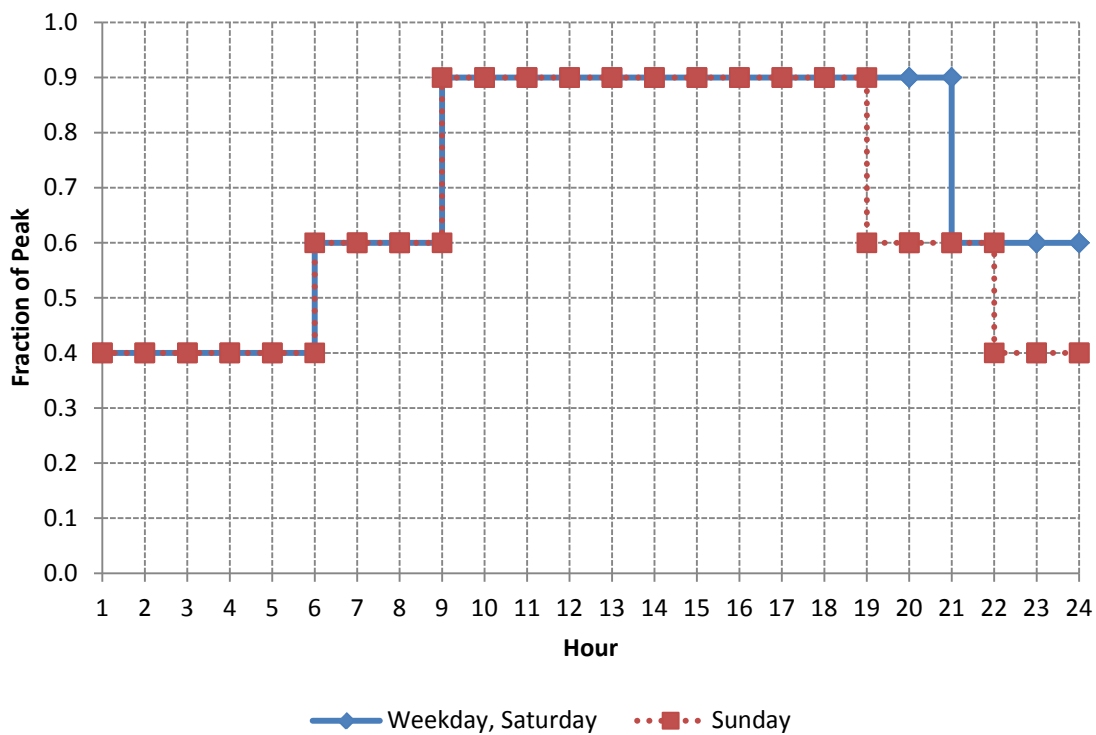


Figure 3–12 Baseline plug and process load schedule

3.3.4 Heating, Ventilation, and Air-Conditioning

The three baseline models were similarly zoned; that is, each EnergyPlus thermal zone (the disjoint rectangles in Figure 3–3 [medium box] and Figure 3–4 [big box]) contained packaged unitary heating and cooling equipment. These systems were modeled by assigning an autosized packaged single-zone system with a 36% efficient constant volume fan with a 2.7 in. w.c.

pressure drop, a 3.69 coefficient of performance (COP) DX cooling coil, and an 80% efficient natural gas-fired furnace to each thermal zone. The units contained desuperheat coils to help control humidity. Not all retailers can control humidity in their stores, but a conservative approach from an energy consumption standpoint was taken to model humidity control. Hot gas reheat coils are passive and proper humidity levels may be achieved at the expense of overcooling of the space. To overcome this problem, active electric heating coils were modeled in EnergyPlus to maintain comfort by adding electric baseboard heat to each zone. We assumed that the larger zones would be served by multiple such units, even though EnergyPlus assigned only one HVAC system, which was meant to represent multiple, identical smaller packaged units that operated in tandem to condition the space. This is acceptable because normalized performance curves for the smaller unit were used. For purposes of specifying efficiency, we assumed 10-ton units in all cases, with multiple 10-ton units serving larger spaces.

3.3.5 Service Water Heating

The baseline SWH system remained unchanged from Hale et al. (2009). The system included an electric storage water heater with a thermal efficiency (E_t) of 86.4%. The consumption rates of hot water were determined using ASHRAE (2003), specifically Chapter 49, Table 8. That table does not have an entry for retail, so we assumed that the retail hot water use was similar to that in an office building. The peak hot water consumption rate for all baseline models was 18 gal/h, based on 40 gal/h for sinks and 20 gal/h for public lavatories, multiplied by a demand factor of 0.3. The water heater storage tank had a volume of 50 gal based on a storage capacity factor of 2.0 and 71.4% usable volume percentage. The consumption schedule as a fraction of peak load was the same as the occupancy schedule (see Figure 3–5 and Figure 3–6). The delivered hot water outlet temperature at the fixture was assumed to be 104°F and the water heater set point was 140°F.

3.3.6 Baseline Simulation Results

Table 3–14 and Table 3–15 present the simulation results for the medium box low plug load baseline model. These results are presented graphically in Figure 3–13. Table 3–16, Table 3–17, and Figure 3–14 present the same for the medium box high plug load baseline model, while Table 3–18, Table 3–19, and Figure 3–15 present the same for the big box baseline model.

Table 3–14 Medium Box Low Plug Baseline Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Interior lighting (electric)	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Heating (gas)	0.0	1.2	0.8	2.6	0.3	1.5	1.4	6.0
Heating (electric)	0.1	0.4	0.0	0.2	0.1	0.0	0.1	0.2
Cooling (electric)	32.5	25.2	18.9	14.1	7.9	14.0	2.5	11.2
Fans (electric)	19.0	19.9	20.7	19.9	18.1	20.5	16.2	19.3
SWH (electric)	0.5	0.6	0.5	0.7	0.6	0.6	0.7	0.7
Total	115.7	111.0	104.6	101.3	90.7	100.3	84.6	101.2

Table 3–15 Medium Box Low Plug Baseline Simulation Results, 4B–8

End Use (kBtu/ft²yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Interior lighting (electric)	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.5
Heating (gas)	3.5	3.7	8.9	5.7	15.3	10.6	19.2	40.8
Heating (electric)	0.0	0.1	0.2	0.1	0.2	0.1	0.2	0.2
Cooling (electric)	8.9	2.7	7.9	6.4	6.7	3.9	2.7	1.2
Fans (electric)	22.3	17.5	18.5	20.9	18.5	19.9	17.4	15.8
SWH (electric)	0.7	0.8	0.8	0.8	0.8	0.9	0.9	1.0
Total	99.1	88.6	100.0	97.5	105.1	99.1	104.2	122.8

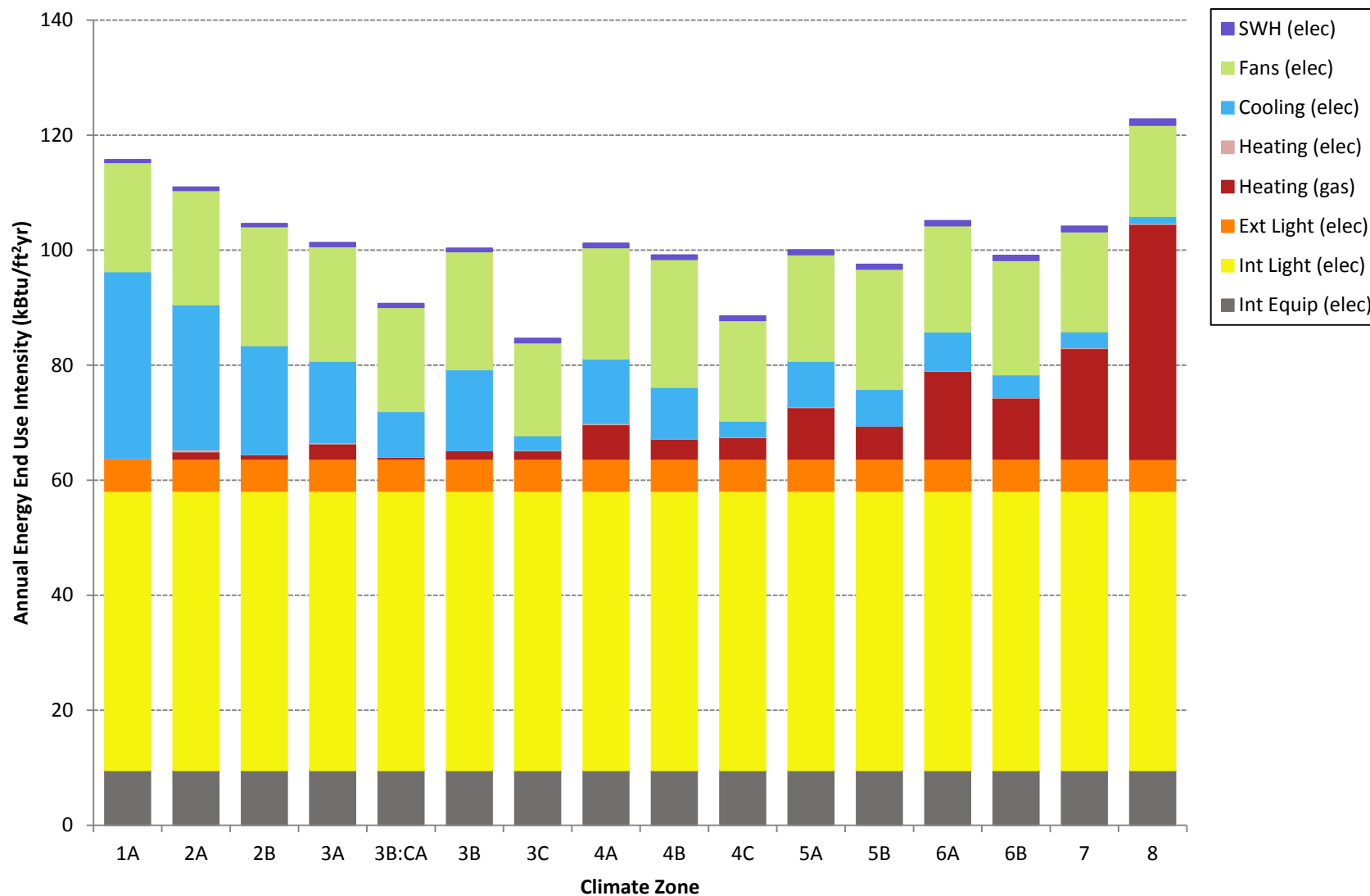


Figure 3–13 Medium box low plug baseline simulation results

Table 3–16 Medium Box High Plug Baseline Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
Interior lighting (electric)	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Heating (gas)	0.0	1.1	0.7	2.3	0.3	1.3	1.3	5.3
Heating (electric)	0.1	0.3	0.0	0.2	0.1	0.0	0.1	0.2
Cooling (electric)	33.4	25.8	20.0	14.7	8.4	14.9	2.8	11.6
Fans (electric)	19.9	20.8	21.6	20.8	19.0	21.5	17.0	20.2
SWH (electric)	0.5	0.6	0.5	0.7	0.6	0.6	0.7	0.7
Total	122.5	117.3	111.5	107.4	97.1	107.0	90.6	106.8

Table 3–17 Medium Box High Plug Baseline Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
Interior lighting (electric)	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.5
Heating (gas)	3.0	3.2	7.9	5.0	13.7	9.5	17.3	37.9
Heating (electric)	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Cooling (electric)	9.6	3.0	8.3	6.9	7.1	4.3	2.9	1.3
Fans (electric)	23.3	18.4	19.4	22.0	19.4	20.9	18.3	16.7
SWH (electric)	0.7	0.8	0.8	0.8	0.8	0.9	0.9	1.0
Total	105.4	94.2	105.3	103.4	109.8	104.3	108.3	125.9

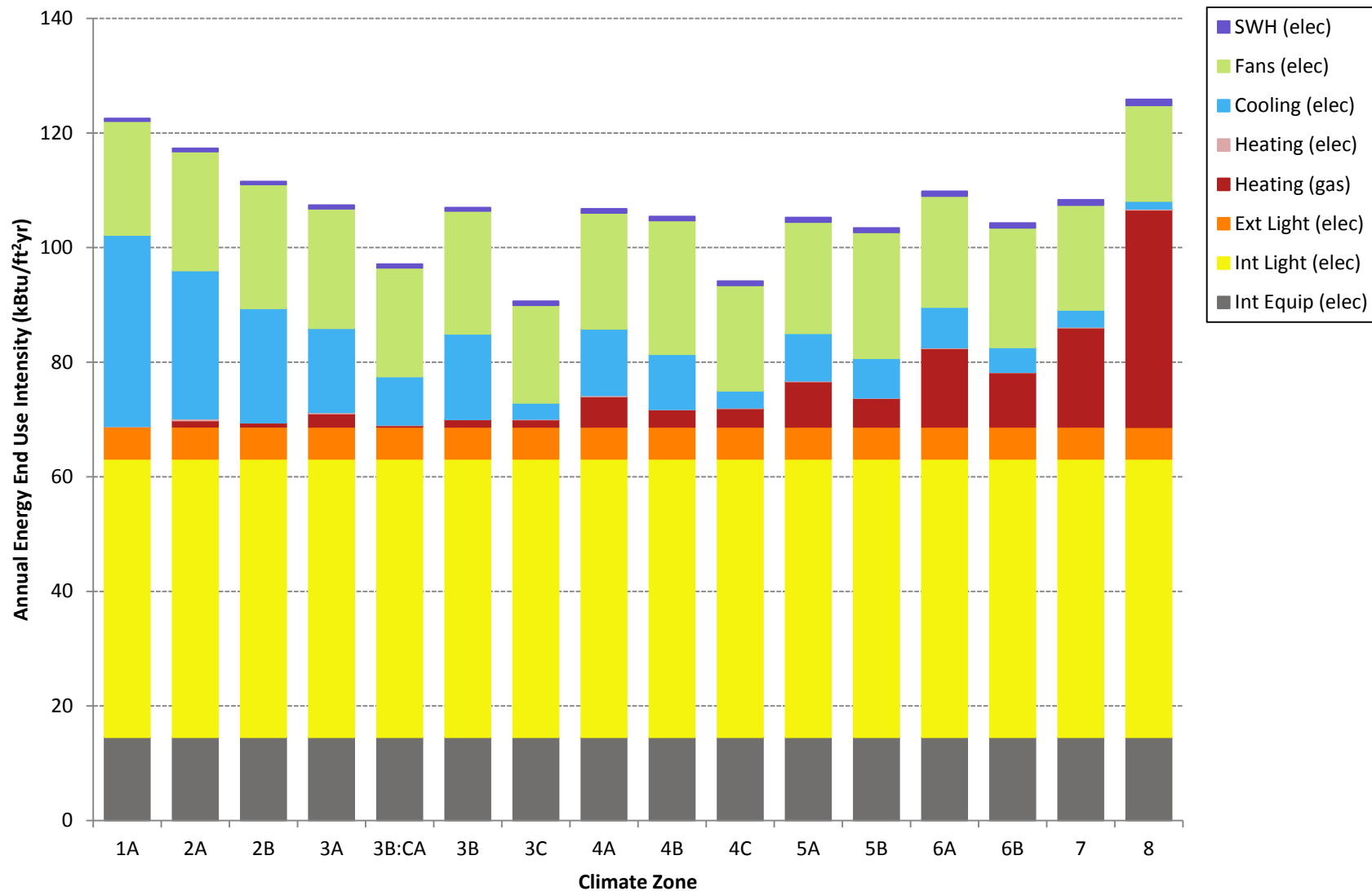


Figure 3–14 Medium box high plug baseline simulation results

Table 3–18 Big Box Baseline Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Interior lighting (electric)	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Heating (gas)	0.0	1.2	0.6	1.8	0.1	0.9	0.8	4.5
Heating (electric)	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.1
Cooling (electric)	32.2	24.6	20.0	13.2	7.4	13.4	2.4	10.4
Fans (electric)	19.5	20.2	21.5	18.4	16.8	18.6	14.5	17.7
SWH (electric)	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.3
Total	116.0	110.6	106.3	97.8	88.7	97.2	82.0	97.0

Table 3–19 Big Box Baseline Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Interior lighting (electric)	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.5
Heating (gas)	2.2	2.8	7.6	4.5	13.0	8.7	17.2	37.0
Heating (electric)	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1
Cooling (electric)	8.6	2.5	7.5	6.1	6.3	3.8	2.6	1.1
Fans (electric)	20.3	15.7	17.3	19.5	17.2	18.3	16.3	14.3
SWH (electric)	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4
Total	95.5	85.5	96.9	94.6	101.0	95.3	100.6	117.1

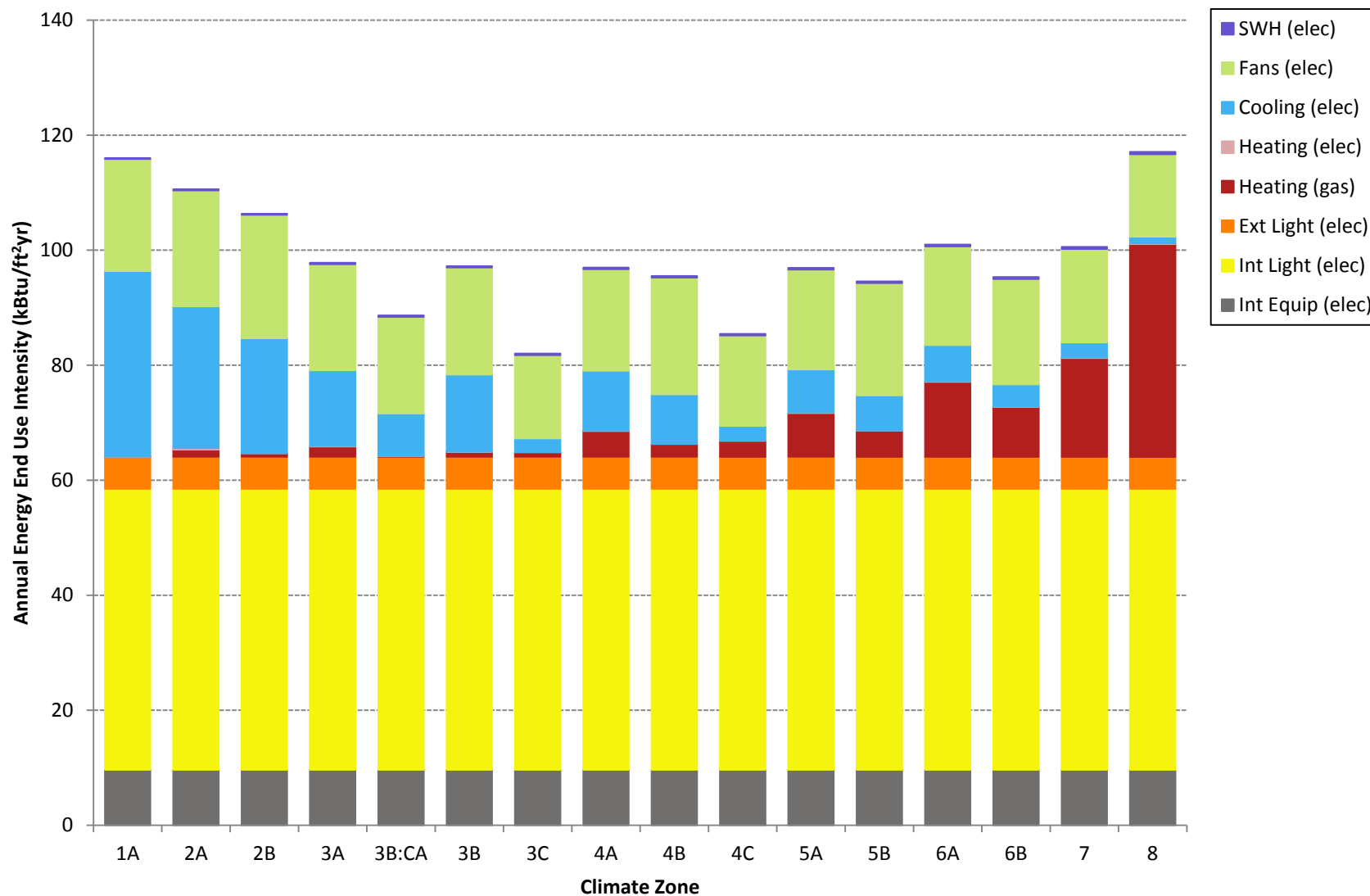


Figure 3–15 Big box baseline simulation results

3.3.7 All-Electric Baseline

The ASHP low-energy HVAC system (see Section 3.4.4.4) is all electric; that is, there is no on-site combustion for heating. To eliminate fuel switching and enable a fair comparison of energy use, an all-electric baseline was created for each prototype model. This model was used for comparison to the ASHP HVAC system. The only difference in the all-electric baseline models was that the natural gas-fired furnace in the HVAC units was replaced with an electric resistance coil. The results from these baselines formed the basis for comparison for the ASHP low-energy model variation.

Table 3–20 and Table 3–21 present the simulation results for the medium box low plug load electric baseline model. These results are presented graphically in Figure 3–16. Table 3–22, Table 3–23, and Figure 3–17 present the same for the medium box high plug load all-electric baseline model, while Table 3–24, Table 3–25, and Figure 3–18 present the same for the big box all-electric baseline model.

Table 3–20 Medium Box Low Plug All-Electric Baseline Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Interior lighting (electric)	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Heating (electric)	0.1	1.4	0.7	2.4	0.4	1.2	1.3	5.0
Cooling (electric)	32.5	25.2	18.9	14.1	7.9	14.0	2.5	11.2
Fans (electric)	19.0	19.9	20.7	19.9	18.1	20.5	16.2	19.3
SWH (electric)	0.5	0.6	0.5	0.7	0.6	0.6	0.7	0.7
Total	115.7	110.7	104.5	100.8	90.7	100.0	84.4	100.0

Table 3–21 Medium Box Low Plug All-Electric Baseline Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Interior lighting (electric)	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.5
Heating (electric)	2.8	3.1	7.3	4.6	12.4	8.6	15.6	32.9
Cooling (electric)	8.9	2.7	7.9	6.4	6.7	3.9	2.7	1.2
Fans (electric)	22.3	17.5	18.5	20.9	18.5	19.9	17.4	15.8
SWH (electric)	0.7	0.8	0.8	0.8	0.8	0.9	0.9	1.0
Total	98.4	87.8	98.2	96.4	102.1	97.0	100.3	114.6

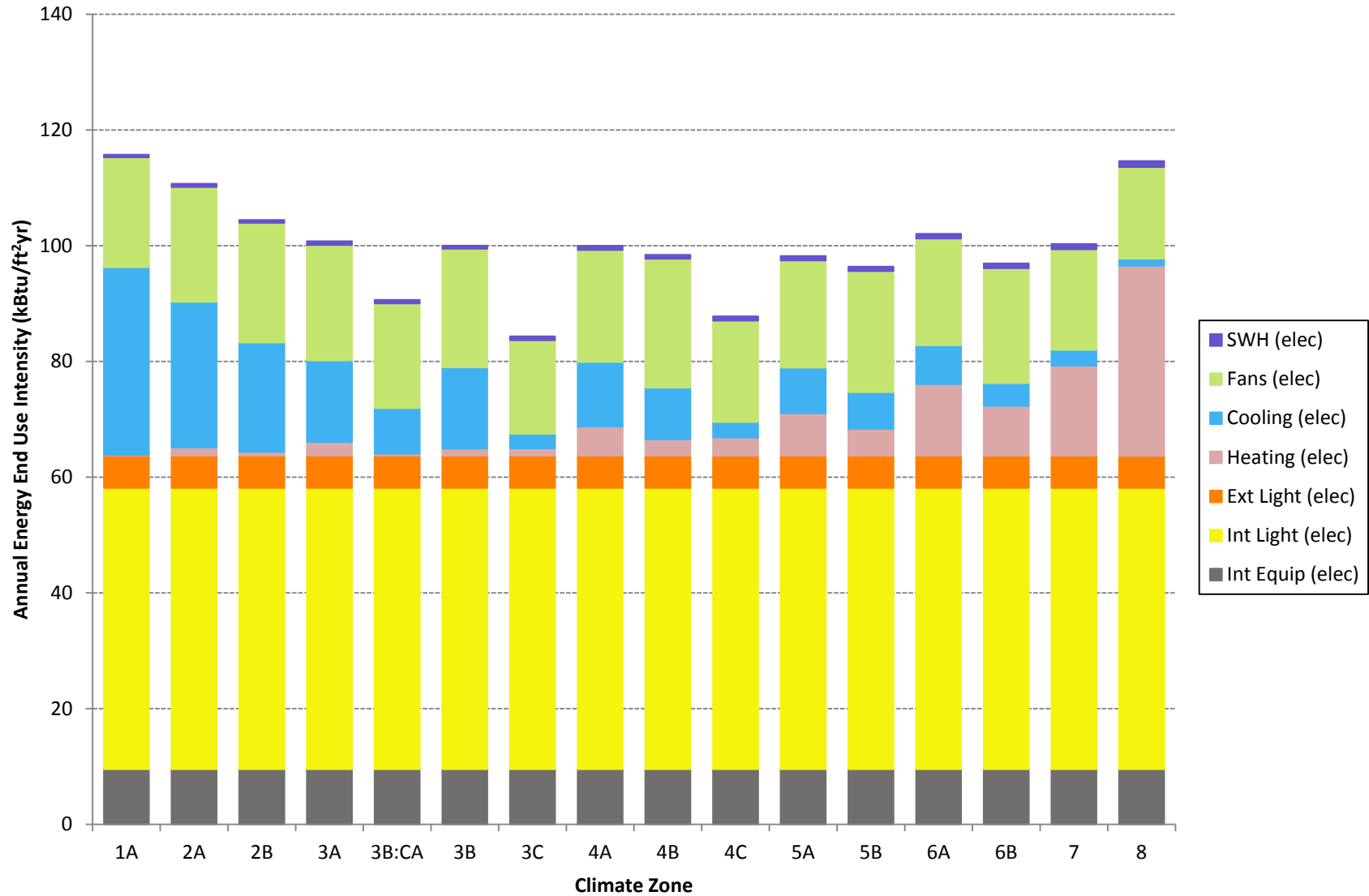


Figure 3–16 Medium box low plug all-electric baseline simulation results

Table 3–22 Medium Box High Plug All-Electric Baseline Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
Interior lighting (electric)	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Heating (electric)	0.1	1.2	0.6	2.1	0.3	1.1	1.1	4.4
Cooling (electric)	33.4	25.8	20.0	14.7	8.4	14.9	2.8	11.6
Fans (electric)	19.9	20.8	21.6	20.8	19.0	21.5	17.0	20.2
SWH (electric)	0.5	0.6	0.5	0.7	0.6	0.6	0.7	0.7
Total	122.5	117.1	111.4	107.0	97.1	106.7	90.4	105.7

Table 3–23 Medium Box High Plug All-Electric Baseline Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
Interior lighting (electric)	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.5
Heating (electric)	2.5	2.7	6.5	4.1	11.1	7.7	14.0	30.5
Cooling (electric)	9.6	3.0	8.3	6.9	7.1	4.3	2.9	1.3
Fans (electric)	23.3	18.4	19.4	22.0	19.4	20.9	18.3	16.7
SWH (electric)	0.7	0.8	0.8	0.8	0.8	0.9	0.9	1.0
Total	104.8	93.5	103.7	102.4	107.1	102.4	104.9	118.3

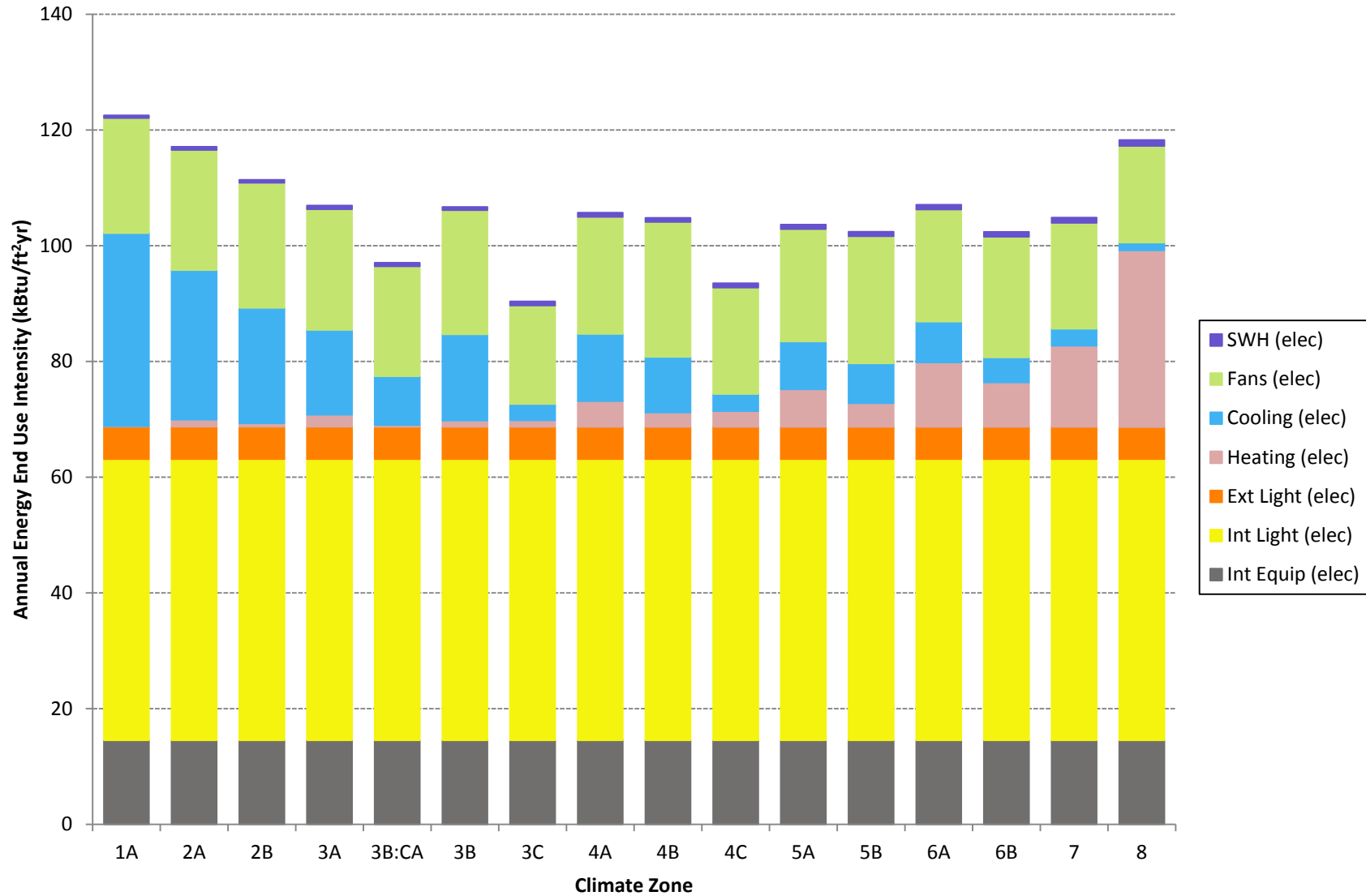


Figure 3–17 Medium box high plug all-electric baseline simulation results

Table 3–24 Big Box All-Electric Baseline Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Interior lighting (electric)	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Heating (electric)	0.1	1.3	0.5	1.5	0.1	0.7	0.7	3.7
Cooling (electric)	32.2	24.6	20.0	13.2	7.4	13.4	2.4	10.4
Fans (electric)	19.5	20.2	21.5	18.4	16.8	18.6	14.5	17.7
SWH (electric)	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.3
Total	116.0	110.4	106.2	97.5	88.6	97.0	81.9	96.1

Table 3–25 Big Box All-Electric Baseline Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Interior lighting (electric)	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8
Exterior lighting (electric)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.5
Heating (electric)	1.8	2.3	6.2	3.7	10.5	7.0	13.9	29.8
Cooling (electric)	8.6	2.5	7.5	6.1	6.3	3.8	2.6	1.1
Fans (electric)	20.3	15.7	17.3	19.5	17.2	18.3	16.3	14.3
SWH (electric)	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4
Total	95.1	84.9	95.4	93.7	98.4	93.6	97.1	109.7

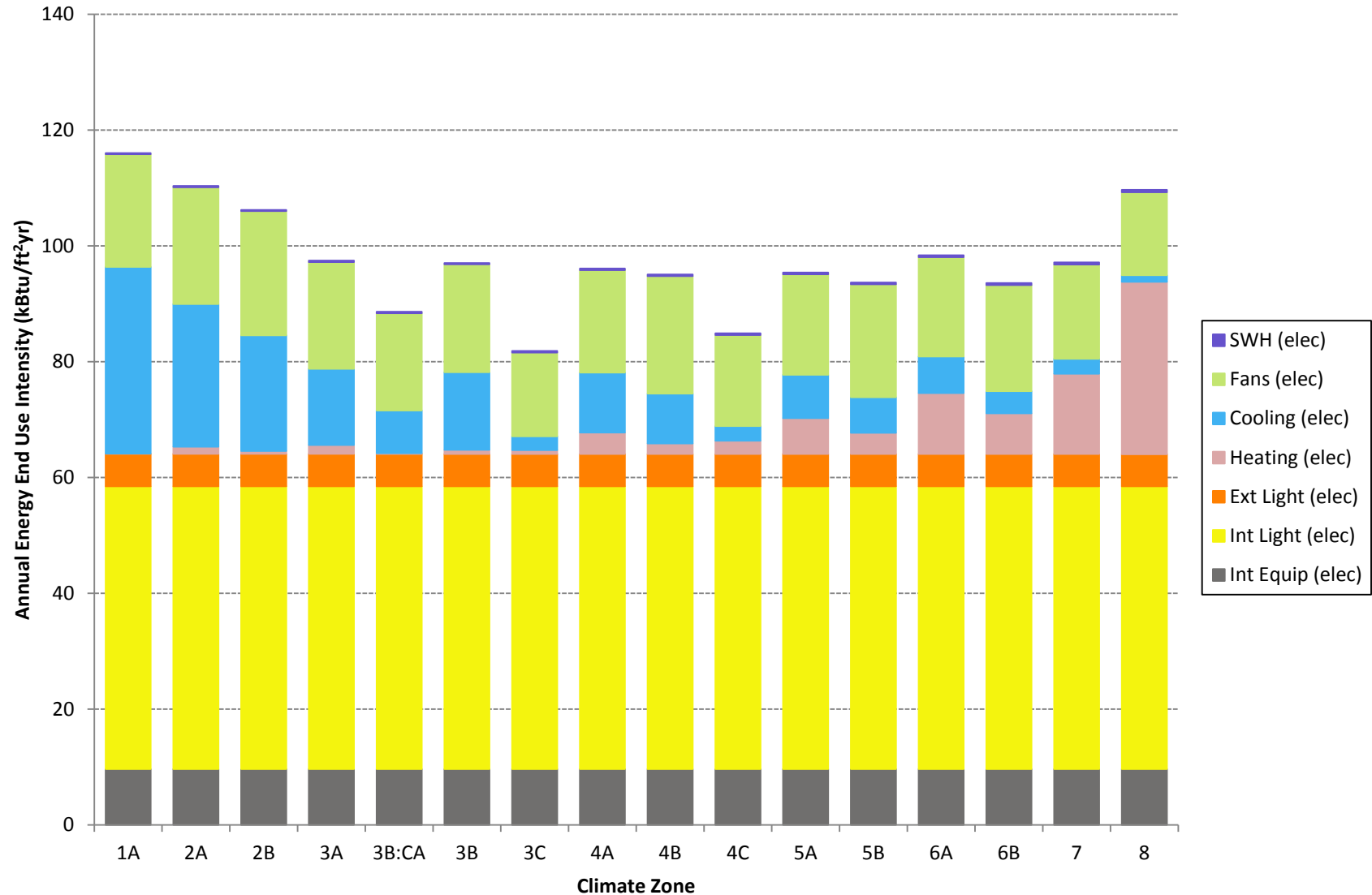


Figure 3–18 Big box all-electric baseline simulation results

3.4 Low-Energy Model Development and Assumptions

Extensive modeling was used to determine the effectiveness of all considered AEDG-MBBR recommendations. This section documents the energy models that incorporated the final set of AEDG-MBBR recommendations.

3.4.1 Envelope

3.4.1.1 Exterior Walls

The exterior walls in all three low-energy models were modeled exactly as in the baseline models, except for the insulation layer. The low-energy exterior wall R- and U-values are shown in Table 3–26 (steel-framed walls) and Table 3–27 (mass walls), with the baseline values included for easy comparison.

Table 3–26 Low-Energy Steel-Framed Exterior Wall Constructions

Climate Zone	Assembly U-Factor (Btu/h·ft ² ·°F)		Insulation R-Value, Nominal (h·ft ² ·°F/Btu)	
	Baseline Models	Low-Energy Models	Baseline Models	Low-Energy Models
1 (A)	U-0.124	U-0.064	R-13.0	R-13.0 + R-7.5 c.i.
2 (A,B)	U-0.124	U-0.064	R-13.0	R-13.0 + R-7.5 c.i.
3 (A,B,C)	U-0.124	U-0.064	R-13.0	R-13.0 + R-7.5 c.i.
4 (A,B,C)	U-0.124	U-0.057	R-13.0	R-13.0 + R-10.0 c.i.
5 (A,B)	U-0.084	U-0.049	R-13.0 + R-3.8 c.i.	R-13.0 + R-12.5 c.i.
6 (A,B)	U-0.084	U-0.043	R-13.0 + R-3.8 c.i.	R-13.0 + R-15.0 c.i.
7	U-0.064	U-0.037	R-13.0 + R-7.5 c.i.	R-13.0 + R-18.8 c.i.
8	U-0.064	U-0.037	R-13.0 + R-7.5 c.i.	R-13.0 + R-18.8 c.i.

Table 3–27 Low-Energy Mass Exterior Wall Constructions

Climate Zone	Assembly U-Factor (Btu/h·ft ² ·°F)		Insulation R-Value, Nominal (h·ft ² ·°F/Btu)	
	Baseline Models	Low-Energy Models	Baseline Models	Low-Energy Models
1 (A)	U-0.580	U-0.580	NR*	NR*
2 (A,B)	U-0.580	U-0.151	NR*	R-5.7 c.i.
3 (A,B,C)	U-0.151	U-0.123	R-5.7 c.i.	R-7.6 c.i.
4 (A,B,C)	U-0.151	U-0.104	R-5.7 c.i.	R-9.5 c.i.
5 (A,B)	U-0.123	U-0.090	R-7.6 c.i.	R-11.4 c.i.
6 (A,B)	U-0.104	U-0.071	R-9.5 c.i.	R-15.4 c.i.
7	U-0.090	U-0.067	R-11.4 c.i.	R-17.0 c.i.
8	U-0.080	U-0.063	R-13.3 c.i.	R-19.0 c.i.

* No insulation requirement

3.4.1.2 Roofs

The roofs in the low-energy models were modeled exactly as in the baseline models, except for the insulation layer. The low-energy roof R- and U-values used are provided in Table 3–28, with the baseline values included for easy comparison.

Table 3–28 Low-Energy Roof Constructions

Climate Zone	Assembly U-Factor (Btu/h·ft ² ·°F)		Insulation R-Value, Nominal (h·ft ² ·°F/Btu)	
	Baseline Models	Low-Energy Models	Baseline Models	Low-Energy Models
1 (A)	U-0.063	U-0.048	R-15.0 c.i.	R-20.0 c.i.
2 (A,B)	U-0.063	U-0.039	R-15.0 c.i.	R-25.0 c.i.
3 (A,B,C)	U-0.063	U-0.039	R-15.0 c.i.	R-25.0 c.i.
4 (A,B,C)	U-0.063	U-0.039	R-15.0 c.i.	R-25.0 c.i.
5 (A,B)	U-0.063	U-0.032	R-15.0 c.i.	R-30.0 c.i.
6 (A,B)	U-0.063	U-0.032	R-15.0 c.i.	R-30.0 c.i.
7	U-0.063	U-0.028	R-15.0 c.i.	R-35.0 c.i.
8	U-0.048	U-0.028	R-20.0 c.i.	R-35.0 c.i.

3.4.1.3 Slab-on-Grade Floors

The floors in the low-energy models were modeled exactly as those in the baseline models.

3.4.1.4 View Fenestration

The U-factors, SHGCs, and VLTs that were used in the low-energy models are shown in Table 3–29, with the baseline values included for easy comparison.

Table 3–29 Low-Energy View Window Constructions

Climate Zone	U-Factor (Btu/h·ft ² ·°F)		SHGC		VLT	
	Baseline Models	Low-Energy Models	Baseline Models	Low-Energy Models	Baseline Models	Low-Energy Models
1 (A)	1.22	1.20	0.25	0.25	0.250	0.250
2 (A,B)	1.22	0.70	0.25	0.25	0.250	0.250
3 (A,B)	0.57	0.60	0.25	0.25	0.318	0.320
3 (C)	1.22	0.60	0.34	0.25	0.340	0.320
4 (A,B,C)	0.57	0.50	0.39	0.40	0.495	0.510
5 (A,B)	0.57	0.45	0.39	0.40	0.495	0.510
6 (A,B)	0.57	0.45	0.39	0.40	0.495	0.510
7	0.57	0.40	0.49	0.45	0.490	0.450
8	0.46	0.40	0.49	0.45	0.490	0.450

3.4.2 Electric Lighting

3.4.2.1 Interior Lighting

The LPDs used in the low-energy models are listed in Table 3–30, with the baseline values included for easy comparison. The peak values in Table 3–30 were modified with hour-by-hour multiplier schedules in EnergyPlus. Both the medium box and big box stores used the schedules in Figure 3–19. The lighting schedule is similar to that used in the baseline models (Figure 3–11), except for after-hours control. In the low-energy models, the lights are completely shut off during unoccupied periods (versus 10% on in the baseline), and during staff stocking time the lights are at 16% on (versus 50% on in the baseline).

Table 3–30 Low-Energy LPD by Space Type

Space Type	Baseline LPD (W/ft ²)	Low-Energy LPD (W/ft ²)
Sales floor	3.35*	1.90***
Vestibule	0.50	0.45** (0.50)
Corridor	0.50	0.54** (0.60)
Restroom	0.90	0.86** (0.95)
Stock room	0.80	0.86** (0.95)
Office	1.10	0.81** (0.90)
Meeting room	1.17** (1.30)	0.81** (0.90)
Break room	0.81** (0.90)	0.45** (0.50)
Mechanical room	1.50	0.86** (0.95)

* Includes 1.65 W/ft² of accent lighting

** 10% reduction applied in the models to account for occupancy sensors; the value without occupancy sensors is in parenthesis

*** Includes 0.75 W/ft² of accent lighting

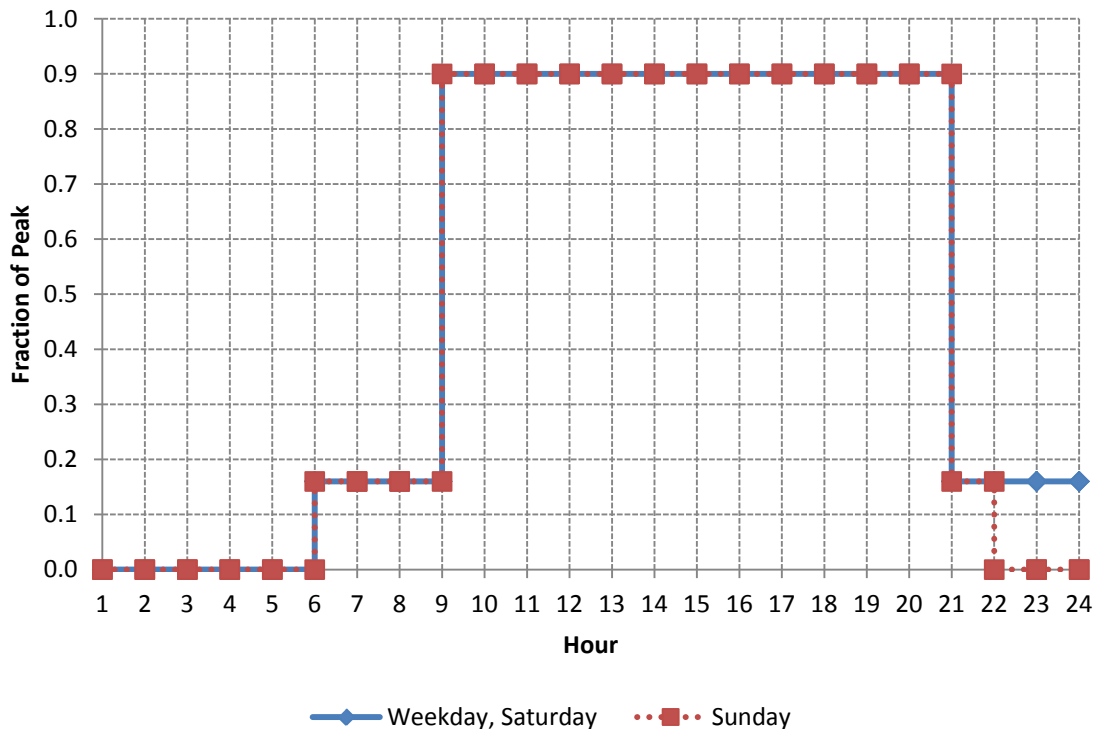


Figure 3–19 Low-energy lighting schedule

3.4.2.2 Exterior Lighting

As in the baseline models, the exterior lighting in the low-energy models is meant to represent parking lot lighting. The parking lot area assumption remained the same (2.5 times the building area [101,250 ft² for the medium box stores, 248,088 ft² for the big box store]). The LPD was 0.10 W/ft² of parking lot area (from the AEDG-MBBR recommendation tables, see Table 5–1 and Table 5–2), resulting in 10,125 W for the medium box stores and 24,809 W for the big box store. In both models, the lights were controlled by an astronomical clock that turned the lights

on when the sun set and off when the sun rose. The low-energy models also employed an energy-saving feature that turned the lights to quarter power from midnight to 6:00 a.m.

3.4.2.3 Daylighting

Daylighting in a box retail environment is highly situation and retailer specific. Often, retailers can successfully daylight only front entry and back-of-house spaces, which make up a small fraction of the store. Although there are many ways to successfully daylight a retail space, for this analysis, a conservative approach was taken to model no daylighting. The AEDG-MBBR contains many case studies and how-to tips. Daylighting is not discouraged in any way, but for this analysis we showed that daylighting is not always required to achieve the 50% energy savings goal.

3.4.3 Plug and Process Loads

The modeled low-energy model plug and process loads represented a 25% reduction over the baseline models. This reduction can be accomplished by installing ENERGY STAR® equipment, consolidating or removing equipment, etc.; more details can be found in the AEDG-MBBR. Table 3–31 shows a summary of the plug and process loads used in the low-energy models.

Table 3–31 Low-Energy Model Plug and Process Loads

Space Type	Medium Box		Big Box (W/ft ²)
	Low Plug (W/ft ²)	High Plug (W/ft ²)	
Sales floor	0.30	0.53	0.30
Vestibule	0.00	0.00	0.00
Corridor	0.00	0.00	0.00
Restroom	0.08	0.08	0.08
Stock room	0.56	0.56	0.56
Office	0.56	0.83	0.56
Meeting room	0.56	0.83	0.56
Break room	1.95	1.95	1.95
Mechanical room	0.00	0.00	0.00

The peak values in Table 3–31 were modified with hour-by-hour multiplier schedules in EnergyPlus. The electric equipment schedules in the low-energy models had the same values during operating hours as the baseline models; however, for the low-energy models, the schedule values during nonoperating hours were lowered from 0.4 to 0.1 to simulate the improved plug load control recommendations in the AEDG-MBBR. This schedule modification was meant to represent items such as computer power management and plug strip controls, and is in addition to the plug load reductions detailed in Table 3–31. (See the AEDG-MBBR for more details on plug load reduction strategies.)

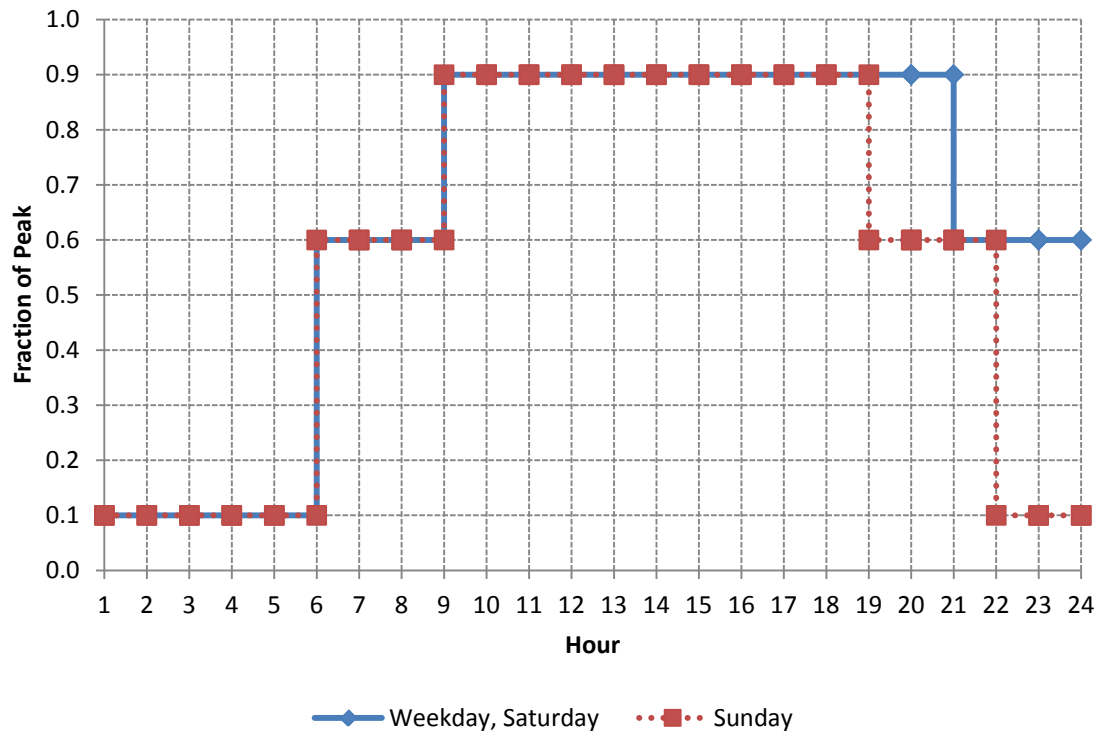


Figure 3-20 Low-energy plug and process load schedule

3.4.4 Heating, Ventilation, and Air-Conditioning

Although many types of HVAC systems could be used in retail stores, the AEDG-MBBR provides recommendations for each of the following four system types:

- Packaged VAV DX air conditioner with a gas furnace (VAV)
- Packaged CAV DX air conditioner with a gas furnace and a DOAS (CAV DOAS)
- ASHP with electric resistance supplemental heat and a DOAS (ASHP DOAS)
- WSHP with a DOAS (WSHP DOAS)

More than one HVAC system type is provided to give AEDG-MBBR users flexibility in designing high-performance retail buildings. The PC used their experience in designing retail stores to determine the HVAC system types to include in the AEDG-MBBR, and they felt these four types were widely applicable, readily available, and comparatively common. Energy modeling showed that all four system types (when coupled with the other recommendations) met or exceeded the 50% energy savings goals. The AEDG-MBBR discusses more variations among the modeled system types, but the PC members decided to model only the most common configurations.

The HVAC zoning for the low-energy models was the same as the baseline models; that is, each EnergyPlus thermal zone (the disjointed rectangles in Figure 3-3 [medium box] and Figure 3-4 [big box]) was served by the heating and cooling equipment described in detail in the following sections. For this analysis we assumed all units were 10 tons.

3.4.4.1 Packaged Variable Air Volume Direct Expansion System

In this low-energy model variation, each thermal zone was ventilated and conditioned via a packaged VAV system with electric reheat at the zone terminal boxes. The AEDG-MBBR specifies an energy efficiency ratio (EER) of 11.5 for a 10-ton unit. In EnergyPlus, the efficiency of DX cooling systems is specified by entering a COP. The COP input in EnergyPlus does not include the rated power consumption of the supply air fan, so the EER needs to be adjusted to remove the supply air fan energy. The procedure in Section 3.3.4.2.5 of Hale et al. (2009) was followed to determine the modeling inputs for EnergyPlus. The procedure is quickly outlined as follows; see Hale et al. (2009) for more details. The kW/ton of the unit can be determined by converting the 11.5 EER with an assumed COP of 4.0. This yields 0.1645 kW/ton, and assuming 400 cfm/ton this results in 0.551 hp/1000 cfm. Then assuming 1.5 in. w.c. for internal pressure drop and the ARI Standard 340/360 minimum external pressure drop of 0.3 in. w.c. for a 10-ton unit results in a total rated pressure drop of 1.8 in. w.c. This pressure drop is used only for the fan efficiency calculation. The ratio of 1.8 in. w.c. to 0.551 hp/1000 cfm (with proper unit conversions) results in a fan efficiency of 51.6%. The electrical efficiency of the motor was assumed to be 93% and the unit also had an 80% efficient natural gas fired furnace.

The VAV systems in the office, break room, corridor, stock room, meeting room, restroom, and mechanical room zones of Figure 3–3 (medium box) and Figure 3–4 (big box) had a pressure drop of 3.3 in. w.c. The systems in the main sales, perimeter sales, and vestibule zones of Figure 3–3 (medium box) and Figure 3–4 (big box) had a pressure drop of 2.2 in. w.c. The difference in pressure drop was to account for the more complex ductwork layout in the back-of-house areas. Each VAV system used a differential enthalpy controlled economizer. The supply air temperature of the systems was varied according to the EnergyPlus Energy Management System (EMS) code in Appendix D.1. The VAV systems also included DCV capability (in zones that had a per-person ventilation requirement), and energy recovery ventilators (ERVs) or indirect evaporative cooling (depending on climate zone).

The indirect evaporative coolers were modeled in climate zones 2B, 3B, 4B, and 5B and operated in the late spring through early fall (April 16 through September 30). In the later fall through early spring (October 1 through April 15) the coolers were used as sensible heat exchangers (with 65% heat exchanger effectiveness) for energy recovery. This scheme was modeled in EnergyPlus by alternating between an ERV and an evaporative cooler using the EMS code (see Appendix D.2). Each evaporative cooler had a wet bulb effectiveness of 58.5%, a dew point effectiveness of 90%, a blowdown ratio of 3, a wetted pressure drop of 1.18 in. w.c., and a dry pressure drop of 1.01 in. w.c.

The wetted pressure drop was calculated by summing the pressure drop of the components: 0.5 in. w.c. for the inlet path and 0.85 in. w.c. for the return path at 80% of the full flow rate (it was assumed that the restrooms exhausted 20% of the available exhaust air) ($0.5 \text{ in. w.c.} + 0.85 \text{ in. w.c.} \times 0.8 = 1.18 \text{ in. w.c.}$). The dry pressure drop was determined the same way, with 0.5 in. w.c. for the inlet path and 0.64 in. w.c. (at full flow) for the return path at 80% of the full flow rate (it was assumed that the restrooms exhausted 20% of the available exhaust air) ($0.5 \text{ in. w.c.} + 0.64 \text{ in. w.c.} \times 0.8 = 1.01 \text{ in. w.c.}$).

In climate zones 1A, 2A, 3A, 4A, 5A, and 6A the ERVs were modeled as sensible and latent rotary heat exchangers with an 82.6% sensible effectiveness, 76.1% latent effectiveness, and a 1.34 in. w.c. pressure drop. The pressure drop was calculated by combining the pressure drop of

the components: 0.7 in. w.c. for the inlet path and 0.8 in. w.c. for the return path at 80% of the full flow rate (it was assumed that the restrooms exhausted 20% of the available exhaust air) ($0.7 \text{ in. w.c.} + 0.8 \text{ in. w.c.} \times 0.8 = 1.34 \text{ in. w.c.}$).

In climate zones 4C, 6B, 7, and 8 the ERVs were modeled as sensible rotary heat exchangers with an 82.6% sensible effectiveness and a 1.01 in. w.c. pressure drop. The pressure drop was calculated by summing the pressure drop of the components: 0.5 in. w.c. for the inlet path and 0.64 in. w.c. (at full flow) for the return path at 80% of the full flow rate (it was assumed that the restrooms exhausted 20% of the available exhaust air) ($0.5 \text{ in. w.c.} + 0.64 \text{ in. w.c.} \times 0.8 = 1.01 \text{ in. w.c.}$).

All ERVs were equipped with exhaust-only frost control (with a threshold temperature of 10°F in climate zones with sensible-only ERVs and -10°F in climate zones with sensible and latent ERVs), an initial defrost time fraction of 0.167 min/min, and a defrost time increase rate of 0.024 (min/min)/°C. Climate zone 3C did not contain an ERV or evaporative cooler.

In EnergyPlus, DCV was modeled by varying the per-person ventilation requirement (see Table 3–5) based on the occupancy schedule for that zone (see Figure 3–5 and Figure 3–6). For example, the per-person ventilation requirement in the sales zone is 7.5 cfm/person and the peak occupant density is 15 people per 1000 ft². The sales zone is 32,100 ft², which results in a peak occupant value of about 480. The occupancy schedule value on January 1 at noon is 0.25, which means the occupant value is about 120. At 7.5 cfm/person, the ventilation rate would be approximately 900 cfm. This ventilation rate value fluctuates in this manner as the occupancy schedule changes. DCV was modeled in all spaces with a per-person ventilation requirement in Table 3–5, and there was no threshold of occupancy driving OA rates.

3.4.4.2 DOAS

The three other low-energy model variations used a DOAS to supply ventilation air to the space; space conditioning was handled through other means. Each model contained two multizone DOAS, one serving the sales area and another serving the back-of-house areas. The sales area DOAS served the vestibule, perimeter sales, and main sales areas; the back-of-house DOAS served the hallway, office, meeting room, break room, restroom, mechanical room, and stock room zones, illustrated in Figure 3–3 (medium box) and Figure 3–4 (big box).

The DOASs were modeled with an 80% efficient natural gas-fired furnace, a 4.0 COP DX cooling coil, and a VAV fan. The DOAS supplied air at 53°F year-round. The VAV fan had an efficiency of 51.6%; the fan motor had an efficiency of 93%; and the system pressure drop at full flow was 2.5 in. w.c. for the sales DOAS and 3.3 in. w.c. for the back-of-house DOAS. The difference in pressure drop was to account for the more complex ductwork layout that would exist in the back-of-house areas. The DOAS also included DCV capability (in zones that had a per-person ventilation requirement), and ERVs or indirect evaporative cooling (depending on climate zone).

The indirect evaporative coolers were modeled in climate zones 2B, 3B, 4B, and 5B and operated in the late spring through early fall (April 16 through September 30). In the later fall through early spring (October 1 through April 15) the coolers were used as sensible heat exchangers (with 65% heat exchanger effectiveness) for energy recovery. This scheme was modeled in EnergyPlus by alternating between an ERV and an evaporative cooler using EMS code (see Appendix D.2). Each evaporative cooler had a wet bulb effectiveness of 58.5%, a dew

point effectiveness of 90%, a blowdown ratio of 3, a wetted pressure drop of 1.18 in. w.c., and a dry pressure drop of 1.01 in. w.c.

The wetted pressure drop was calculated by summing the pressure drop of the components: 0.5 in. w.c. for the inlet path and 0.85 in. w.c. for the return path at 80% of the full flow rate (we assumed that the restrooms exhausted 20% of the available exhaust air) ($0.5 \text{ in. w.c.} + 0.85 \text{ in. w.c.} \times 0.8 = 1.18 \text{ in. w.c.}$). The dry pressure drop was determined the same way, with 0.5 in. w.c. for the inlet path and 0.64 in. w.c. (at full flow) for the return path at 80% of the full flow rate. We assumed that the restrooms exhausted 20% of the available exhaust air ($0.5 \text{ in. w.c.} + 0.64 \text{ in. w.c.} \times 0.8 = 1.01 \text{ in. w.c.}$).

In climate zones 1A, 2A, 3A, 4A, 5A, and 6A the ERVs were modeled as sensible and latent rotary heat exchangers with an 82.6% sensible effectiveness, 76.1% latent effectiveness, and a 1.34 in. w.c. pressure drop. The pressure drop was calculated by summing the pressure drop of the components: 0.7 in. w.c. for the inlet path and 0.8 in. w.c. for the return path at 80% of the full flow rate. We assumed that the restrooms exhausted 20% of the available exhaust air ($0.7 \text{ in. w.c.} + 0.8 \text{ in. w.c.} \times 0.8 = 1.34 \text{ in. w.c.}$).

In climate zones 3C, 4C, 6B, 7, and 8 the ERVs were modeled as sensible rotary heat exchangers with an 82.6% sensible effectiveness and a 1.01 in. w.c. pressure drop. The pressure drop was calculated by summing the pressure drop of the components: 0.5 in. w.c. for the inlet path and 0.64 in. w.c. (at full flow) for the return path at 80% of the full flow rate. We assumed that the restrooms exhausted 20% of the available exhaust air ($0.5 \text{ in. w.c.} + 0.64 \text{ in. w.c.} \times 0.8 = 1.01 \text{ in. w.c.}$).

All ERVs were equipped with exhaust-only frost control (with a threshold temperature of 10°F in climate zones with sensible-only ERVs and -10°F in climate zones with sensible and latent ERVs), an initial defrost time fraction of 0.167 min/min, and a defrost time increase rate of 0.024 (min/min)/°C. The ventilation air from the DOAS was delivered to the zone via a VAV terminal unit that was capable of varying the ventilation rate.

DCV in the DOAS was modeled exactly as in the packaged VAV DX system. (See Section 3.4.4.1 for more details on how DCV was modeled in the DOAS.)

3.4.4.3 Packaged Constant Air Volume Direct Exchange With a Dedicated Outdoor Air System

In this low-energy model variation, ventilation was handled by the DOAS described in Section 3.4.4.2 and each thermal zone contained unitary heating and cooling equipment to handle space conditioning. These systems were modeled by placing an autosized system with a 51.6% efficient constant volume fan, a 2.2 in. w.c. pressure drop, a 4.0 COP DX cooling coil, and an 80% efficient gas-fired furnace in each thermal zone. The same procedure as in Section 3.4.4.1 was followed to convert the 11.5 EER specified by the AEDG-MBBR into the proper EnergyPlus inputs. These systems cycled with the load in each zone. We assumed that the larger zones would be served by multiple such units, even though EnergyPlus assigned only one HVAC system; that system was meant to represent multiple, identical smaller packaged units that operated in tandem to condition the space. This is acceptable because normalized performance curves for the smaller unit were used.

3.4.4.4 Air Source Heat Pump With a Dedicated Outdoor Air System

In this low-energy model variation, ventilation was handled by the DOAS described in Section 3.4.4.2 and each thermal zone contained an ASHP to handle space conditioning. These systems were modeled by placing an autosized ASHP with a 51.6% efficient constant volume fan, a 2.2 in. w.c. pressure drop, 11.5 EER (3.4 cooling COP)/3.4 heating COP (at 47°F) DX coils, and an electric supplemental heating coil. These systems cycled with the load in each zone. We assumed that the larger zones would be served by multiple such units, even though EnergyPlus assigned only one HVAC system; that system was meant to represent multiple, identical smaller packaged units that operated in tandem to condition the space. This is acceptable because normalized performance curves for the smaller unit were used. This system was compared to the all-electric baseline (Section 3.3.7) when results were generated (Section 5.2.3).

3.4.4.5 Water-Source Heat Pump With a Dedicated Outdoor Air System

In this low-energy model variation, ventilation was handled by the DOAS described in Section 3.4.4.2 and each thermal zone contained a WSHP to handle space conditioning. These systems were modeled by placing an autosized WSHP with a 51.6% efficient constant volume fan, a 2.2 in. w.c. pressure drop, 5.0 cooling COP/15.0 EER heating COP DX coils (efficiency values from the AEDG-MBBR), and an electric supplemental heating coil. These systems cycled with the load in each zone. We assumed that the larger zones would be served by multiple such units, even though EnergyPlus assigned only one HVAC system; that system was meant to represent multiple, identical smaller packaged units that operated in tandem to condition the space. This is acceptable because normalized performance curves for the smaller unit were used.

The heat pumps drew or rejected energy from or to a single plant water loop that was served by an 80% efficient variable-speed pump with 60 ft of head. The plant water loop included a boiler to maintain loop temperature above 68°F and an evaporative fluid cooler to maintain loop temperature below 86°F. The fluid cooler was modeled as a single-speed unit that cycled the fan to control capacity. It had a 0.2 evaporation loss factor, a 0.008% drift loss, and a 3.0 blowdown concentration ratio. The boiler on the loop was a 90% efficient natural gas-fired condensing boiler.

3.4.5 Service Water Heating

The SWH in both the medium box and big box low-energy models was modeled exactly as in the baseline, except that the water heaters were modeled as 90% efficient instead of 86.4% efficient. The hot water consumption rates were determined using ASHRAE (2003), specifically Chapter 49, Table 8. That table does not have an entry for retail, so we assumed that the retail hot water use was similar to that in an office building. The peak hot water consumption rate for all baseline models was 18 gal/h, based on 40 gal/h for sinks and 20 gal/h for public lavatories, multiplied by a demand factor of 0.3. The water heater storage tank had a volume of 50 gal based on a storage capacity factor of 2.0 and 71.4% usable volume percentage. The consumption schedule as a fraction of peak load was the same as the occupancy schedule (see Figure 3–5 and Figure 3–6). The delivered hot water outlet temperature at the fixture was assumed to be 104°F and the water heater set point was 140°F.

4. Energy Targets

Careful goal setting is required to design and construct high-performance buildings. The goal of the AEDG-MBBR was to provide guidance to procure a building that consumed at least 50% less energy than a computer-modeled Standard 90.1-2004 (ASHRAE 2004b) compliant baseline. To better define this goal, an absolute whole-building energy target—a single number that defines the energy performance of a building—should be set as a best practice. The lower the number is, the more energy efficient the building is. The AEDG-MBBR provides these targets to help users set goals for their design. These targets can be used to select design teams as part of a procurement strategy, to set early design goals, to track design development progress, and to help designers and owners ensure that the desired level of performance for a project is achieved. In general, the energy targets in the AEDG-MBBR are applicable to most retail stores.

The AEDG-MBBR energy targets were designed to simplify the process of setting whole-building absolute energy use targets. The prescriptive path represents one way, but not the only way, to achieve industry best practice energy performance. Specification of whole-building absolute energy use targets gives freedom to reach the performance goal with an approach that best fits the overall goals and constraints (including those not related to energy performance) of the project. Specification of the AEDG-MBBR whole-building absolute energy targets can eliminate most analysis that may otherwise be required to specify energy performance goals, because the guide values embody the knowledge required to set practical, aggressive energy performance targets in the medium and big-box retail environment.

One can specify an absolute energy target based on the AEDG-MBBR energy target and then focus analysis efforts toward achieving industry best practice energy performance rather than trying to define a reference point against which to measure performance. For a more detailed discussion see Leach et al. (2012).

The whole-building absolute energy targets for the AEDG-MBBR were developed in accordance with the following approach:

1. Start with the models from Hale et al. (2009); these models were minimally compliant with Standard 90.1-2004 (ASHRAE 2004b). The models vary according to building size and plug load density.
2. Update the models according to the AEDG-MBBR PC's expert guidance. Give special care to aspects of the model that are not prescribed by Standard 90.1-2004, including schedules and unregulated plug and process loads. The goal was to develop Standard 90.1-2004 compliant models that accurately captured typical (common practice) whole-building energy use for retail stores. The final models used for the analyses are defined in Section 3.3 of this report.
3. Simulate the industry-vetted baseline models across a set of climate zones that fully represent the variations in the U.S. climate zones (Figure 3–2). Benchmark modeling results against available sector data and solicit input from the PC. Make any necessary corrections to the model inputs and resimulate. Iterations continue until results are in line with sector data and industry expectations for baseline energy performance by climate zone.
4. Set climate-specific absolute targets representing 50% savings beyond Standard 90.1-2004 by halving baseline whole-building energy performance results. Confirm through

whole-building energy simulation and a case study survey (including committee member projects) that the 50% savings targets are feasible and representative of industry best practice energy performance.

The outcomes of this process can be seen in Table 4–1 and Table 4–2. The values in these tables represent 50% savings over the baseline models, which were compliant with Standard 90.1-2004 (ASHRAE 2004b). The PC confirmed that these results were in line with their expectations for 50% savings.

Table 4–1 Medium Box Retail Energy Targets

Climate Zone	Low Plug			High Plug		
	Low Accent (kBtu/ft ² yr)	Med Accent (kBtu/ft ² yr)	High Accent (kBtu/ft ² yr)	Low Accent (kBtu/ft ² yr)	Med Accent (kBtu/ft ² yr)	High Accent (kBtu/ft ² yr)
1A	42	58	81	45	61	85
2A	41	56	77	44	59	80
2B	37	53	75	40	56	79
3A	38	51	70	40	53	73
3B:CA	31	46	67	34	49	69
3B	36	50	72	38	53	75
3C	29	43	61	32	45	64
4A	39	51	68	41	53	70
4B	36	50	70	39	53	72
4C	33	44	61	35	47	63
5A	40	50	65	42	52	67
5B	36	49	67	39	51	69
6A	43	53	66	45	54	68
6B	39	50	65	41	52	67
7	44	52	63	46	54	65
8	56	61	69	57	62	71

Table 4–2 Big Box Retail Energy Targets

Climate Zone	Low Plug			High Plug		
	Low Accent (kBtu/ft ² yr)	Med Accent (kBtu/ft ² yr)	High Accent (kBtu/ft ² yr)	Low Accent (kBtu/ft ² yr)	Med Accent (kBtu/ft ² yr)	High Accent (kBtu/ft ² yr)
1A	42	58	82	45	62	85
2A	41	56	77	44	58	80
2B	38	54	77	41	57	80
3A	35	49	69	38	52	72
3B:CA	30	45	66	33	48	69
3B	34	49	71	37	52	74
3C	28	41	61	30	44	63
4A	37	49	66	39	51	68
4B	34	48	68	37	51	71
4C	31	43	60	33	45	62
5A	38	49	64	40	51	66
5B	35	47	66	37	50	68
6A	41	51	64	43	52	66
6B	37	48	63	39	50	65
7	42	50	62	44	52	63
8	53	58	67	54	60	68

Programmatic requirements can vary greatly from one application to another. A high-end retailer may use high-wattage accent lighting to display merchandise with a particular style; a discount retailer may use little or no accent lighting. Similarly, an electronics retailer may have significantly higher installed plug loads than a clothing retailer. Because plug loads and accent lighting can vary significantly according to project-specific requirements, the AEDG-MBBR energy targets were determined for a range of plug load and accent lighting levels. Energy targets are provided for two levels of baseline plug load requirements: Low and High, representing whole-building average installed plug load densities of 0.5 W/ft² and 0.7 W/ft², respectively. A general merchandise store would be a typical low-plug load case, whereas a dedicated electronics store would be a typical high-plug load case. Within each category of installed plug loads, energy targets are provided for three levels of baseline accent lighting requirements: (1) little or no accent lighting (Low), with a value of 0.0 W/ft²; (2) a typical level of accent lighting (Med), 1.6 W/ft² for sales areas; and (3) a high level of accent lighting (High), representative of retail applications with specialty accent lighting requirements, such as jewelry sales, with a value of 3.9 W/ft² for sales areas, the maximum allowed for a sales area by Standard 90.1-2004.

5. Evaluation Results

This section contains the PC-approved energy efficiency recommendations for the AEDG-MBBR. The simulated energy savings that are achieved as a result of applying these recommendations are also presented. End-use comparison figures are provided; the end-use data are also presented in tabular format.

The guide recommendations represent a way to achieve 50% energy savings over Standard 90.1-2004 in a typical retail building. The PC recognizes that there are other ways of achieving the 50% energy savings, and offers these recommendations as one way, but not the only way, of meeting the energy savings target. When a recommendation contains the designation “Comply with 90.1,” the AEDG-MBBR provides no recommendation for this component or system. In these cases, the user must meet the more stringent of either the applicable version of Standard 90.1 or the local code requirements.

5.1 Recommendation Tables for 50% Energy Savings

This section provides the recommendation tables in the AEDG-MBBR. The opaque envelope recommendations are presented for different climate zones by roof type, wall type, floor type, slab type, and door type. Recommendations for the thermal and optical characteristics of the vertical fenestration are provided. Interior lighting recommendations, including LPD, lamp efficacy, ballast specification, and controls; as well as exterior LPDs and controls, are presented. Plug and process load recommendations are provided. SWH efficiency recommendations are provided for electric and gas storage water heaters, as well as instantaneous units. Many types of HVAC systems could be used in retail stores, but the AEDG-MBBR provides recommendations for each of the following four system types:

- Packaged VAV DX air conditioner with a gas furnace (VAV)
- Packaged CAV DX air conditioner with a gas furnace and a DOAS (CAV DOAS)
- ASHP with electric resistance supplemental heat and a DOAS (ASHP DOAS)
- WSHP with a DOAS (WSHP DOAS)

Unique recommendations for cooling, heating, and fan efficiencies are included for each HVAC system type in the climate-specific recommendations. Either DCV or ERVs are also recommended, along with economizers (where applicable) for each HVAC system type.

The recommendation tables for the AEDG-MBBR (ASHRAE et al. 2011b) are shown in Table 5–1 and Table 5–2.

Table 5–1 AEDG-MBBR Recommendations: Climate Zones 1–4

Item		Component	Climate Zone 1 Recommendation	Climate Zone 2 Recommendation	Climate Zone 3 Recommendation	Climate Zone 4 Recommendation
Envelope	Roofs	Insulation entirely above deck	R-20.0 c.i.	R-25.0 c.i.		
		Metal building	R-19.0 + R-10.0 filled cavity			R-19.0 + R-11.0 Linear System (Ls)
		Solar reflectance index	78			No recommendation
	Walls	Mass (heat capacity > 7 Btu/ft²)	No recommendation	R-5.7 c.i.	R-7.6 c.i.	R-9.5 c.i.
		Metal building	R-0.0 + R-9.8 c.i.		R-0.0 + R-13.0 c.i.	R-0.0 + R-15.8 c.i.
		Steel framed	R-13.0 + R-7.5 c.i.			R-13.0 + R-10.0 c.i.
	Floors	Mass	No recommendation	R-10.4 c.i.	R-12.5 c.i.	R-14.6 c.i.
		Steel framed	No recommendation	R-30.0		R-38.0
	Slabs	Unheated	No recommendation			R-15 for 24 in.
		Heated	R-7.5 for 12 in.	R-10.0 for 24 in.	R-15.0 for 24 in	R-20 for 24 in.
	Doors	Swinging	U-0.70			U-0.50
		Nonswinging	Roll-up = U-0.25; All other = U-0.07			
		Vehicular/dock infiltration—door closed	0.28 cfm/ft² of door area			
		Vehicular/dock infiltration—door open, truck in place	Weather seals for dock, levelers, trailer hinges			
	Vestibules	At building entrance	Yes			
	View fenestration— all orientations	Thermal transmittance	U-1.20	U-0.70	U-0.60	U-0.50
SHGC		0.25			0.40	
VLT		0.25		0.32	0.51	
Daylighting/ Lighting	Interior lighting	LPD—ambient lighting	Sales floor = 1.15 W/ft²			
			Stock room = 0.6 W/ft²			
			Average of all other = 0.9 W/ft²			
		LPD—additional specialty sales floor lighting	Sporting goods, small electronics = 0.6 W/ft²			
			Furniture, clothing, cosmetics, art = 0.95 W/ft²			
			Jewelry, crystal, china = 1.5 W/ft²			

Item		Component	Climate Zone 1 Recommendation	Climate Zone 2 Recommendation	Climate Zone 3 Recommendation	Climate Zone 4 Recommendation
			All other = 0.4 W/ft ²			
		Light source efficacy (mean lumens per Watt)	T8 and T5 lamps > 2 ft = 92; T8 and T5 lamps ≤ 2 ft = 85; All other > 50			
		T8 ballasts	Nondimming = National Electrical Manufacturers Association (NEMA) Premium Instant Start; Dimming = NEMA Premium Programmed Start			
		All T5/T5HO ballasts	Electronic programmed start			
		All compact fluorescent lamp and high-intensity discharge ballasts	Electronic			
		Lighting controls	Sale floor = Time switch—auto to 25% 3 h before and after store open hours; auto to 2% or less after hours			
			Additional specialty lighting = auto ON only during store open hours			
			Stock room, restrooms = auto ON/OFF occupancy sensors			
			All other = manual ON auto OFF occupancy sensors			
			After hours = maximum 2% of total building LPD			
	Exterior lighting	Façade and landscape lighting	LPD = 0.075 W/ft ² in lighting zone 3 (LZ3) and LZ4; 0.05 W/ft ² in LZ2 Controls = auto OFF between 12:00 a.m. and 6:00 a.m.			
		Parking lot and drives	LPD = 0.1 W/ft ² in LZ3 and LZ4; 0.06 W/ft ² in LZ2 Controls = auto reduce to 25% (12 a.m. to 6 a.m.)			
		Walkways, plazas, and special feature areas	LPD = 0.16 W/ft ² in LZ3 and LZ4; 0.14 W/ft ² in LZ2 Controls = auto reduce to 25% (12:00 a.m. to 6:00 a.m.)			
		All other exterior lighting	LPD = follow Standard 90.1-2010 Controls = auto reduce to 25% (12:00 a.m. to 6:00 a.m.)			
Plug Loads	Equipment choices	ENERGY STAR equipment	All illuminated signage, security monitors, computers, equipment, and appliances (where available)			
		Vending machines	Delamp in break rooms and specify best-in-class efficiency; specify plug load managing systems for refrigerated vending			
		Procurement	Incorporate control and efficiency options in negotiations for all third-party owned plug loads; consolidate equipment where possible			
		Computers	Specify laptops, tablets, or mini-desktops where feasible			
		Signage	Use light-emitting diodes internally illuminated where applicable; Consolidate/replace static media with dynamic			
	Controls	Sales floor plug control	Auto control all display outlets that can be turned off during nonbusiness hours and all other sales outlets that can be turned off during unoccupied hours; specify auto standby modes for third-party owned/supplied plug loads			

Item		Component	Climate Zone 1 Recommendation	Climate Zone 2 Recommendation	Climate Zone 3 Recommendation	Climate Zone 4 Recommendation
		Computer power control	Network control with power-saving modes and control during unoccupied hours			
		Occupancy sensors	Office/break/security room plug strip occupancy sensors; other equipment as applicable			
		Timer switches	Water coolers, coffee makers, other small appliances auto shut-off during unoccupied hours			
		Policies	Store policy on allowed equipment			
SWH	SWH	Gas water heater efficiency	Condensing water heaters = 95% efficiency			
		Electric storage energy factor (EF) (≤ 12 kW, ≤ 20 gal)	$EF > 0.99 - 0.0012 \times \text{volume (gal)}$			
		Point-of-use heater selection	0.81 EF or 81% E_t			
		Electric heat pump water heater	COP 3.0 (interior heat source)			
		Pipe insulation ($d < 1.5$ in./ $d \geq 1.5$ in.)	1 in./1.5 in.			
HVAC	Packaged variable-volume DX air conditioner	Heating efficiency	80%			
		Cooling efficiency	< 65 kBtu/h = 15.0 seasonal energy efficiency ratio (SEER) $65\text{--}135$ kBtu/h = 11.5 EER, 12.8 integrated energy efficiency ratio (IEER) $135\text{--}240$ kBtu/h = 11.5 EER, 12.3 IEER $240\text{--}760$ kBtu/h = 10.5 EER, 11.3 IEER ≥ 760 kBtu/h = 9.7 EER, 10.9 IEER			
		Maximum external static pressure	Single zone = 0.7 in. w.c. Multizone = 1.8 in. w.c.			
	Packaged constant-volume DX air conditioner with DOAS	Heating efficiency	80%			
		Cooling efficiency	< 65 kBtu/h = 15.0 SEER $65\text{--}135$ kBtu/h = 11.5 EER, 12.8 IEER $135\text{--}240$ kBtu/h = 11.5 EER, 12.3 IEER $240\text{--}760$ kBtu/h = 10.5 EER, 11.3 IEER; ≥ 760 kBtu/h = 9.7 EER, 10.9 IEER			
		Maximum external static pressure	0.7 in. w.c.			
	Packaged single-zone ASHP with DOAS	Heating efficiency	< 65 kBtu/h = 9.0 heating seasonal performance factor $65\text{--}135$ kBtu/h = 3.4 COP at 47°F; 2.4 COP at 17°F $135\text{--}240$ kBtu/h = 3.2 COP at 47°F; 2.1 COP at 17°F			

Item		Component	Climate Zone 1 Recommendation	Climate Zone 2 Recommendation	Climate Zone 3 Recommendation	Climate Zone 4 Recommendation
Ø ≤			≥ 240 kBtu/h = 3.2 COP at 47°F; 2.1 COP at 17°F			
		Cooling efficiency	< 65 kBtu/h = 15.0 SEER, 12.0 EER 65–135 kBtu/h = 11.5 EER, 12.8 IEER 135–240 kBtu/h = 11.5 EER, 12.3 IEER ≥ 240 kBtu/h = 10.5 EER, 11.3 IEER			
		Maximum external static pressure	0.7 in. w.c.			
		Maximum fan power	0.4 W/cfm			
	Packaged single-zone WSHP with DOAS	Heating efficiency	Full load =15.0 EER; part load= 17.6 EER			
		Cooling efficiency	Full load = 5.0 COP; part load = 5.7 COP			
		Maximum external static pressure	0.7 in. w.c.			
		Maximum fan power	0.4 W/cfm			
		Water circulation pumps	Variable frequency drive (VFD) and NEMA premium efficiency			
		Cooling tower/fluid cooler	VFD on fans			
		Boiler efficiency	90% combustion efficiency			
	DOAS	Heating efficiency	See Table 5-10 in AEDG-MBBR			
		Cooling efficiency	See Table 5-10 in AEDG-MBBR			
		Fan external static pressure	Constant volume = 1.0 in. w.c. Variable volume (DCV) = 1.8 in. w.c.			
		Fan and motor	65% mechanical/motor efficiency in absence of whole unit EER rating; motor efficiency as per Standard 90.1-2010 Table 10.8B			
	Ventilation/exhaust	Cooling capacity for which an economizer is required	No economizer	≥ 54,000 Btu/h		
		DCV/performance-based ventilation	Control ventilation air based on pollutant concentrations in space (carbon dioxide, VOCs, etc.)			
		Exhaust air energy recovery	A (humid) zones = 75% total effectiveness; B (dry) zones = 75% sensible effectiveness; Capture minimum 80% available exhaust air, including general and bathroom, for energy recovery			
		Exhaust airflow control	Control based on occupancy using time clock or occupancy sensor			
	Ducts and dampers	OA air damper	Motorized damper			
		Duct seal class	Seal class A			
		Insulation level	R-6			
	Ø ≤	M&V/Benchmarking	Electrical submeters	Design and circuit for separate submeters for lighting, HVAC, general 120V, SWH,		

Item		Component	Climate Zone 1 Recommendation	Climate Zone 2 Recommendation	Climate Zone 3 Recommendation	Climate Zone 4 Recommendation
			renewables, and whole building			
		Benchmarks	Benchmark monthly energy use			
		Training	Facility operator or continuous benchmarking			

Table 5–2 AEDG-MBBR Recommendations: Climate Zones 5–8

Item		Component	Climate Zone 5 Recommendation	Climate Zone 6 Recommendation	Climate Zone 7 Recommendation	Climate Zone 8 Recommendation
Envelope	Roofs	Insulation entirely above deck	R-30.0 c.i.		R-35.0 c.i.	
		Metal building	R-19.0 + R-11.0 Ls	R-25.0 + R-11.0 Ls	R-30.0 + R-11.0 Ls	R-25.0 + R-11.0 + R-11.0 Ls
		Solar reflectance index	No recommendation			
	Walls	Mass (heat capacity > 7 Btu/ft²)	R-11.4 c.i.	R-15.4 c.i.	R-17.0 c.i.	R-19.0 c.i.
		Metal building	R-0.0 + R-19.0 c.i.		R-0.0 + R-22.1 c.i.	R-0.0 + R-25.0 c.i.
		Steel framed	R-13.0 + R-12.5 c.i.	R-13.0 + R-15.0 c.i.	R-13.0 + R-18.8 c.i.	
	Floors	Mass	R-14.6 c.i.	R-16.7 c.i.	R-20.9 c.i.	R-23.0 c.i.
		Steel framed	R-38.0		R-49.0	R-60.0
	Slabs	Unheated	R-15 for 24 in.	R-20 for 24 in.		
		Heated	R-20 for 24 in.	R-20 for 48 in.	R-25 for 48 in.	
	Doors	Swinging	U-0.50	U-0.50		
		Nonswinging	Roll-up = U-0.25; All other = U-0.07			
		Vehicular/dock infiltration—door closed	0.28 cfm/ft² of door area			
		Vehicular/dock infiltration—door open, truck in place	Weather seals for dock, levelers, trailer hinges			
		Vestibules	At building entrance	Yes		
	View fenestration— all orientations	Thermal transmittance	U-0.45		U-0.40	
		SHGC	0.40		0.45	
		VLT	0.51		0.45	
Daylighting/Lighting	Interior lighting	LPD—ambient lighting	Sales floor = 1.15 W/ft²			
			Stock room = 0.6 W/ft²			
			Average of all other = 0.9 W/ft²			
		LPD—additional specialty sales floor lighting	Sporting goods, small electronics = 0.6 W/ft²			
			Furniture, clothing, cosmetics, art = 0.95 W/ft²			
			Jewelry, crystal, china = 1.5 W/ft²			
			All other = 0.4 W/ft²			
		Light source efficacy (mean lumens per Watt)	T8 and T5 lamps > 2 ft = 92; T8 and T5 lamps ≤ 2 ft = 85; All other > 50			

Item		Component	Climate Zone 5 Recommendation	Climate Zone 6 Recommendation	Climate Zone 7 Recommendation	Climate Zone 8 Recommendation
		T8 ballasts	Nondimming = NEMA Premium Instant Start; Dimming = NEMA Premium Programmed Start			
		All T5/T5HO ballasts	Electronic programmed start			
		All compact fluorescent lamp and high-intensity discharge ballasts	Electronic			
		Lighting controls	Sale floor = Time switch—auto to 25% 3 h before and after store open hours; auto to 2% or less after hours			
			Additional specialty lighting = auto ON only during store open hours			
			Stock room, restrooms = auto ON/OFF occupancy sensors			
			All other = manual ON auto OFF occupancy sensors			
			After hours = max 2% of total building LPD			
	Exterior lighting	Façade and landscape lighting	LPD = 0.075 W/ft ² in LZ3 and LZ4; 0.05 W/ft ² in LZ2 Controls = auto OFF between 12 a.m. and 6 a.m.			
		Parking lot and drives	LPD = 0.1 W/ft ² in LZ3 and LZ4; 0.06 W/ft ² in LZ2 Controls = auto reduce to 25% (12:00 a.m. to 6:00 a.m.)			
		Walkways, plazas, and special feature areas	LPD = 0.16 W/ft ² in LZ3 and LZ4; 0.14 W/ft ² in LZ2 Controls = auto reduce to 25% (12:00 a.m. to 6:00 a.m.)			
		All other exterior lighting	LPD = follow Standard 90.1-2010 Controls = auto reduce to 25% (12:00 a.m. to 6:00 a.m.)			
Plug Loads	Equipment choices	ENERGY STAR equipment	All illuminated signage, security monitors, computers, equipment, and appliances (where available)			
		Vending machines	Delamp in break rooms and specify best-in-class efficiency; specify plug load managing systems for refrigerated vending			
		Procurement	Incorporate control and efficiency options in negotiations for all third-party owned plug loads; consolidate equipment where possible			
		Computers	Specify laptops, tablets, or mini-desktops where feasible			
		Signage	Use light-emitting diodes internally illuminated where applicable; Consolidate/replace static media with dynamic			
	Controls	Sales floor plug control	Auto control all display outlets that can be turned off during nonbusiness hours and all other sales outlets that can be turned off during unoccupied hours; specify auto standby modes for third-party owned/supplied plug loads			
		Computer power control	Network control with power-saving modes and control during unoccupied hours			
		Occupancy sensors	Office/break/security room plug strip occupancy sensors; other equipment as applicable			
		Timer switches	Water coolers, coffee makers, other small appliances auto shut-off during unoccupied			

Item		Component	Climate Zone 5 Recommendation	Climate Zone 6 Recommendation	Climate Zone 7 Recommendation	Climate Zone 8 Recommendation
			hours			
		Policies	Store policy on allowed equipment			
SWH	SWH	Gas water heater efficiency	Condensing water heaters = 95% efficiency			
		Electric storage EF (≤ 12 kW, ≤ 20 gal)	$EF > 0.99 - 0.0012 \times \text{volume (gal)}$			
		Point-of-use heater selection	$0.81 EF$ or $81\% E_t$			
		Electric heat pump water heater	COP 3.0 (interior heat source)			
		Pipe insulation ($d < 1.5$ in./ $d \geq 1.5$ in.)	1 in./1.5 in.			
HVAC	Packaged VAV DX air conditioners	Heating efficiency	80%			
		Cooling efficiency	$< 65 \text{ kBtu/h} = 15.0 \text{ SEER}$ $65\text{--}135 \text{ kBtu/h} = 11.5 \text{ EER}, 12.8 \text{ IEER}$ $135\text{--}240 \text{ kBtu/h} = 11.5 \text{ EER}, 12.3 \text{ IEER}$ $240\text{--}760 \text{ kBtu/h} = 10.5 \text{ EER}, 11.3 \text{ IEER}$ $\geq 760 \text{ kBtu/h} = 9.7 \text{ EER}, 10.9 \text{ IEER}$			
		Maximum external static pressure	Single zone = 0.7 in. w.c. Multizone = 1.8 in. w.c.			
	Packaged CAV DX air conditioners with DOAS	Heating efficiency	80%			
		Cooling efficiency	$< 65 \text{ kBtu/h} = 15.0 \text{ SEER}$ $65\text{--}135 \text{ kBtu/h} = 11.5 \text{ EER}, 12.8 \text{ IEER}$ $135\text{--}240 \text{ kBtu/h} = 11.5 \text{ EER}, 12.3 \text{ IEER}$ $240\text{--}760 \text{ kBtu/h} = 10.5 \text{ EER}, 11.3 \text{ IEER}$ $\geq 760 \text{ kBtu/h} = 9.7 \text{ EER}, 10.9 \text{ IEER}$			
		Maximum external static pressure	0.7 in. w.c.			
	Packaged single-zone ASHPs with DOAS	Heating efficiency	$< 65 \text{ kBtu/h} = 9.0 \text{ heating seasonal performance factor}$ $65\text{--}135 \text{ kBtu/h} = 3.4 \text{ COP at } 47^\circ\text{F}; 2.4 \text{ COP at } 17^\circ\text{F}$ $135\text{--}240 \text{ kBtu/h} = 3.2 \text{ COP at } 47^\circ\text{F}; 2.1 \text{ COP at } 17^\circ\text{F}$ $\geq 240 \text{ kBtu/h} = 3.2 \text{ COP at } 47^\circ\text{F}; 2.1 \text{ COP at } 17^\circ\text{F}$			
		Cooling efficiency	$< 65 \text{ kBtu/h} = 15.0 \text{ SEER}, 12.0 \text{ EER}$ $65\text{--}135 \text{ kBtu/h} = 11.5 \text{ EER}, 12.8 \text{ IEER}$ $135\text{--}240 \text{ kBtu/h} = 11.5 \text{ EER}, 12.3 \text{ IEER}$ $\geq 240 \text{ kBtu/h} = 10.5 \text{ EER}, 11.3 \text{ IEER}$			

Item		Component	Climate Zone 5 Recommendation	Climate Zone 6 Recommendation	Climate Zone 7 Recommendation	Climate Zone 8 Recommendation
		Maximum external static pressure	0.7 in. w.c.			
		Maximum fan power	0.4 W/cfm			
	Packaged single-zone WSHPs with DOAS	Heating efficiency	Full load =15.0 EER; part load= 17.6 EER			
		Cooling efficiency	Full load = 5.0 COP; part load = 5.7 COP			
		Maximum external static pressure	0.7 in. w.c.			
		Maximum fan power	0.4 W/cfm			
		Water circulation pumps	VFD and NEMA premium efficiency			
		Cooling tower/fluid cooler	VFD on fans			
		Boiler efficiency	90% combustion efficiency			
	DOAS	Heating efficiency	See Table 5-10 in AEDG-MBBR			
		Cooling efficiency	See Table 5-10 in AEDG-MBBR			
		Fan external static pressure	Constant volume = 1.0 in. w.c. Variable volume (DCV) = 1.8 in. w.c.			
		Fan and motor	65% mechanical/motor efficiency in absence of whole unit EER rating; motor efficiency as per Standard 90.1-2010 Table 10.8B			
	Ventilation/exhaust	Cooling capacity for which an economizer is required	≥54,000 Btu/h			
		DCV/performance-based ventilation	Control ventilation air based on pollutant concentrations in space (carbon dioxide, VOCs, etc.)			
		Exhaust air energy recovery	A (humid) zones= 75% total effectiveness; B (dry) zones = 75% sensible effectiveness; Capture min. 80% available exhaust air, including general and bathroom, for energy recovery			
		Exhaust airflow control	Control based on occupancy using time clock or occupancy sensor			
	Ducts and dampers	OA damper	Motorized damper			
		Duct seal class	Seal class A			
		Insulation level	R-6			
QA	M&V/benchmarking	Electrical submeters	Design and circuit for separate submeters for lighting, HVAC, general 120V, service water heater, renewables, and whole building			
		Benchmarks	Benchmark monthly energy use			
		Training	Facility operator or continuous benchmarking			

5.2 Energy Savings Results

When the AEDG-MBBR recommendations were compiled and the final low-energy models simulated, the 50% or greater energy savings goal was met or exceeded in all climate zones for all HVAC system types. Table 5–3 and Table 5–4 illustrate the energy savings results.

Table 5–3 Medium Box Percent Energy Savings Over Standard 90.1-2004

Climate Zone	Representative City	Low Plug				High Plug			
		VAV	CAV DOAS	ASHP DOAS	WSHP DOAS	VAV	CAV DOAS	ASHP DOAS	WSHP DOAS
1A	Miami, FL	58.2%	59.7%	59.3%	58.2%	57.0%	58.5%	58.1%	56.9%
2A	Houston, TX	58.7%	59.5%	59.7%	58.9%	57.8%	58.5%	58.5%	57.7%
2B	Phoenix, AZ	56.8%	58.7%	59.3%	58.6%	56.2%	57.9%	58.4%	57.7%
3A	Atlanta, GA	56.6%	56.6%	57.5%	56.5%	56.0%	56.0%	56.6%	55.7%
3B:CA	Los Angeles, CA	54.4%	54.4%	55.2%	54.6%	53.2%	53.9%	54.3%	53.8%
3B	Las Vegas, NV	57.5%	57.5%	58.9%	57.6%	57.0%	57.0%	58.0%	57.0%
3C	San Francisco, CA	54.0%	50.5%	52.9%	51.4%	53.5%	50.7%	52.3%	51.4%
4A	Baltimore, MD	56.8%	55.8%	57.2%	56.3%	56.1%	55.4%	56.3%	55.6%
4B	Albuquerque, NM	58.0%	58.1%	58.9%	58.7%	57.2%	57.6%	58.1%	57.9%
4C	Seattle, WA	54.3%	51.7%	54.4%	52.8%	53.2%	51.9%	53.8%	52.6%
5A	Chicago, IL	57.2%	55.5%	56.6%	56.1%	56.0%	55.1%	55.9%	55.5%
5B	Denver, CO	57.4%	57.8%	58.6%	58.6%	56.8%	57.4%	57.9%	57.9%
6A	Minneapolis, MN	58.1%	56.4%	56.9%	57.2%	56.8%	55.8%	56.1%	56.4%
6B	Helena, MT	56.5%	55.2%	56.3%	56.3%	55.6%	55.0%	55.7%	55.9%
7	Duluth, MN	58.5%	56.3%	56.7%	57.6%	57.5%	55.9%	56.0%	56.9%
8	Fairbanks, AK	54.2%	52.9%	53.5%	55.1%	54.1%	52.9%	53.2%	54.8%

Table 5–4 Big Box Percent Energy Savings Over Standard 90.1-2004

Climate Zone	Representative City	Big Box			
		VAV	CAV DOAS	ASHP DOAS	WSHP DOAS
1A	Miami, FL	56.5%	58.8%	58.4%	56.9%
2A	Houston, TX	59.3%	59.7%	59.9%	59.0%
2B	Phoenix, AZ	57.9%	59.6%	60.2%	59.3%
3A	Atlanta, GA	56.5%	55.9%	56.8%	55.5%
3B:CA	Los Angeles, CA	54.0%	53.9%	54.5%	53.9%
3B	Las Vegas, NV	57.1%	57.0%	58.2%	56.9%
3C	San Francisco, CA	53.9%	50.0%	52.1%	50.7%
4A	Baltimore, MD	56.2%	55.0%	56.5%	55.3%
4B	Albuquerque, NM	57.7%	57.6%	58.6%	57.9%
4C	Seattle, WA	54.0%	51.0%	53.9%	51.9%
5A	Chicago, IL	57.1%	55.3%	56.6%	55.7%
5B	Denver, CO	57.4%	57.6%	58.7%	58.2%
6A	Minneapolis, MN	58.0%	56.1%	56.9%	56.8%
6B	Helena, MT	56.4%	55.0%	56.4%	55.9%
7	Duluth, MN	58.6%	56.3%	57.0%	57.4%
8	Fairbanks, AK	54.4%	53.0%	54.0%	55.2%

Energy savings are relative to the Standard 90.1-2004 (ASHRAE 2004b) baseline energy use, and included unregulated loads in the energy use of the baseline and low-energy models. The analysis shows that the AEDG-MBBR recommendations met the goal of 50% or greater energy savings and that this goal can be met with a range of HVAC system types.

The simulation results are presented in Table 5–5 through Table 5–28, broken out by low-energy model HVAC system type (see Section 3.4.4 for details about the different HVAC system types).

5.2.1 Packaged Variable Air Volume Direct Expansion

Table 5–5 Medium Box Low Plug VAV Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.3	0.5	0.6	0.4	0.7	0.7	0.9
Heating (gas)	0.0	0.4	0.5	1.0	0.2	1.1	2.9	2.0
Cooling (electric)	14.3	10.9	10.2	7.8	7.0	6.6	2.4	6.0
Fans (electric)	3.1	3.2	3.1	3.4	2.7	3.2	1.8	3.6
SWH (electric)	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7
Total	48.4	45.8	45.2	44.0	41.4	42.7	38.9	43.7
Percent Savings	58.2%	58.7%	56.8%	56.6%	54.4%	57.5%	54.0%	56.8%

Table 5–6 Medium Box Low Plug VAV Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	0.7	1.3	0.9	0.7	0.8	0.9	0.9	1.0
Heating (gas)	2.0	1.6	2.5	3.2	3.9	4.2	4.9	17.9
Cooling (electric)	4.2	3.4	4.7	2.9	4.4	3.1	2.5	1.7
Fans (electric)	3.6	3.0	3.4	3.5	3.6	3.6	3.5	4.1
SWH (electric)	0.7	0.7	0.8	0.8	0.8	0.8	0.9	1.0
Total	41.6	40.5	42.9	41.5	44.0	43.1	43.2	56.3
Percent Savings	58.0%	54.3%	57.2%	57.4%	58.1%	56.5%	58.5%	54.2%

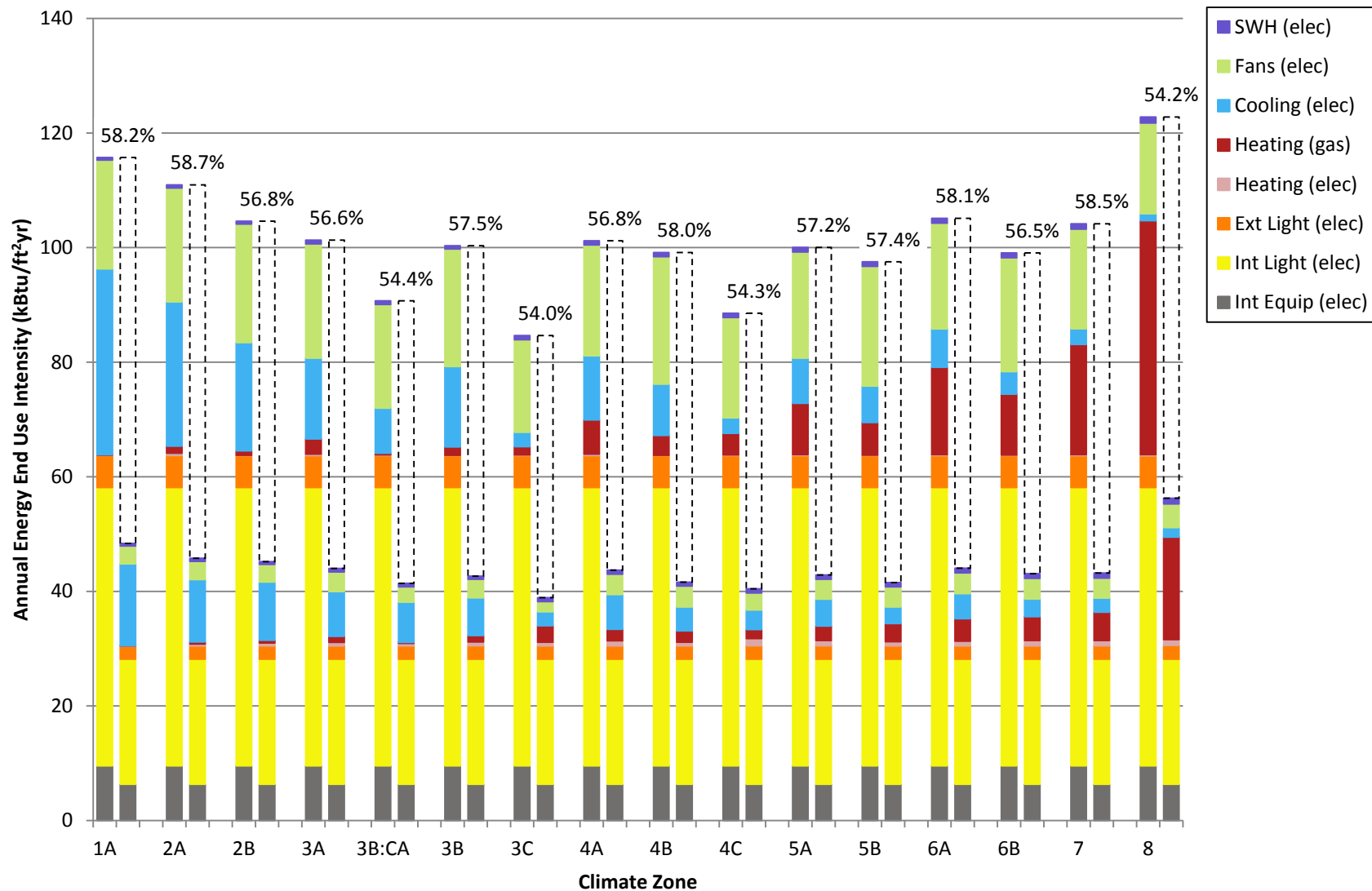


Figure 5–1 Medium box low plug VAV simulation results

Table 5–7 Medium Box High Plug VAV Simulation Results, 1A–4A

End Use (kBtu/ft²yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.3	0.5	0.6	0.3	0.7	0.6	0.9
Heating (gas)	0.0	0.3	0.4	0.9	0.2	0.9	2.5	1.7
Cooling (electric)	15.2	11.2	10.4	7.8	7.7	6.7	2.7	6.1
Fans (electric)	3.3	3.3	3.2	3.5	2.8	3.4	1.8	3.7
SWH (electric)	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7
Total	52.7	49.5	48.8	47.3	45.4	46.0	42.2	46.9
Percent Savings	57.0%	57.8%	56.2%	56.0%	53.2%	57.0%	53.5%	56.1%

Table 5–8 Medium Box High Plug VAV Simulation Results, 4B–8

End Use (kBtu/ft²yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	0.6	1.2	0.9	0.7	0.8	0.9	0.9	1.0
Heating (gas)	1.6	1.4	2.2	2.8	3.4	3.7	4.1	15.7
Cooling (electric)	4.6	3.8	5.1	3.1	4.8	3.4	2.7	1.9
Fans (electric)	3.8	3.1	3.5	3.6	3.7	3.7	3.6	4.3
SWH (electric)	0.7	0.7	0.8	0.8	0.8	0.8	0.9	1.0
Total	45.1	44.1	46.4	44.7	47.4	46.3	46.0	57.8
Percent Savings	57.2%	53.2%	56.0%	56.8%	56.8%	55.6%	57.5%	54.1%

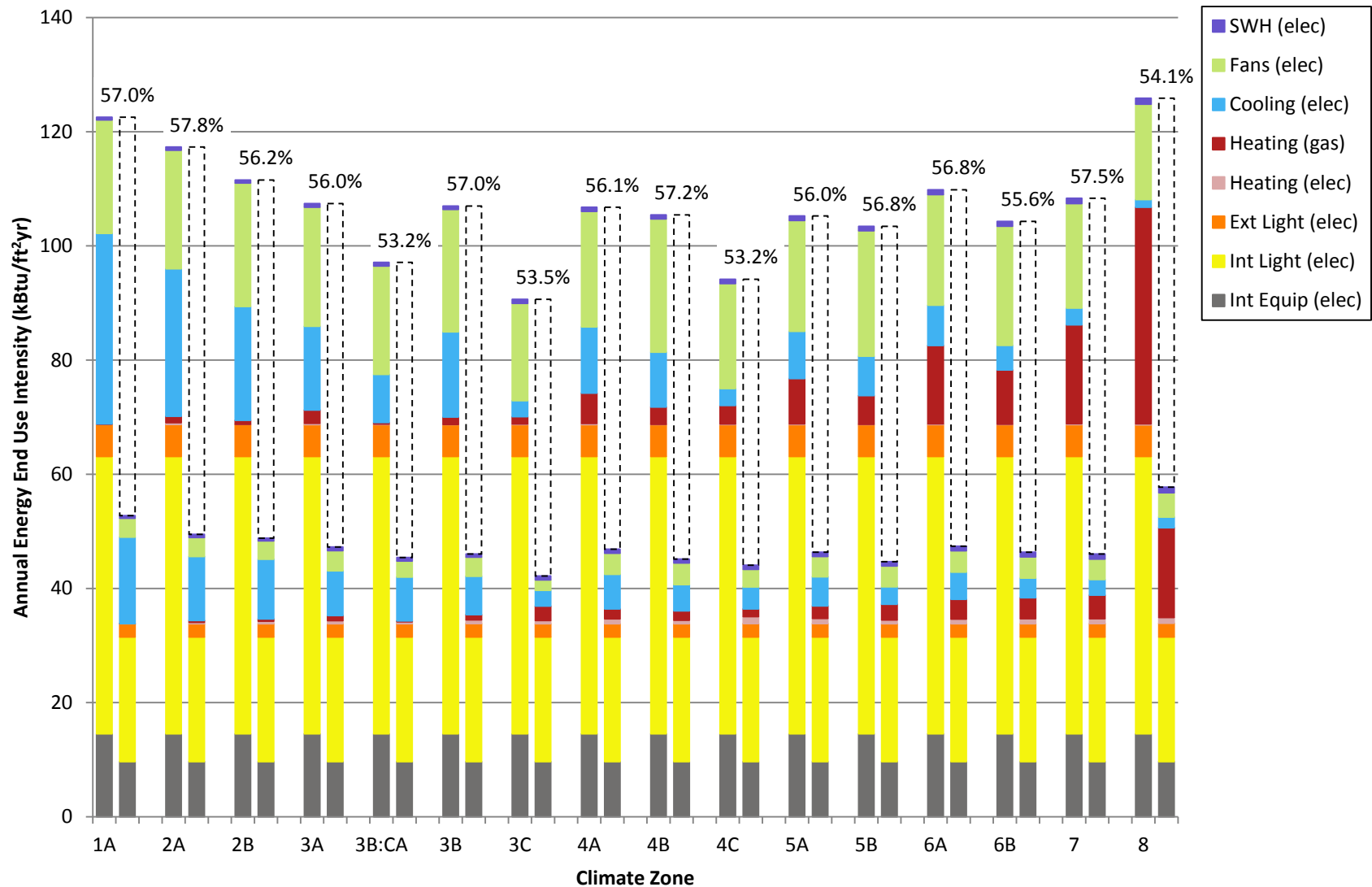


Figure 5-2 Medium box high plug VAV simulation results

Table 5–9 Big Box VAV Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Interior lighting (electric)	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.3	0.4	0.6	0.3	0.6	0.4	0.8
Heating (gas)	0.0	0.2	0.3	0.7	0.1	0.7	2.5	1.5
Cooling (electric)	15.9	10.5	10.2	7.2	7.0	6.5	2.4	5.9
Fans (electric)	3.7	3.1	3.0	3.2	2.5	3.0	1.6	3.3
SWH (electric)	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.3
Total	50.4	45.0	44.8	42.6	40.8	41.8	37.8	42.5
Percent Savings	56.5%	59.3%	57.9%	56.5%	54.0%	57.1%	53.9%	56.2%

Table 5–10 Big Box VAV Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Interior lighting (electric)	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	0.6	1.0	0.8	0.6	0.7	0.8	0.8	0.8
Heating (gas)	1.5	1.3	2.0	2.6	3.2	3.5	4.2	16.2
Cooling (electric)	4.1	3.4	4.6	2.8	4.3	3.0	2.4	1.6
Fans (electric)	3.4	2.7	3.2	3.2	3.3	3.2	3.1	3.6
SWH (electric)	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4
Total	40.4	39.3	41.6	40.3	42.4	41.5	41.6	53.4
Percent Savings	57.7%	54.0%	57.1%	57.4%	58.0%	56.4%	58.6%	54.4%

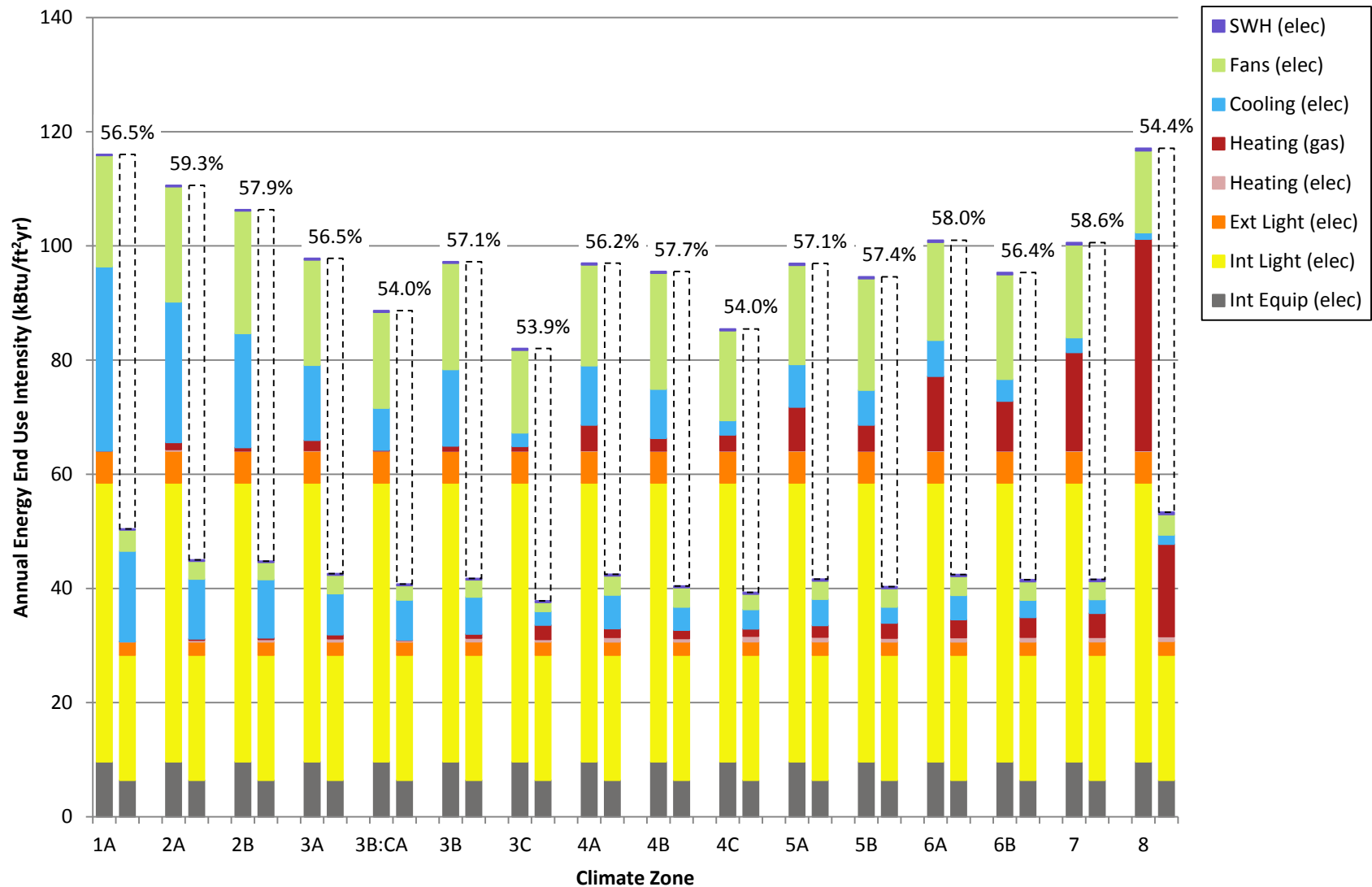


Figure 5–3 Big box VAV simulation results

5.2.2 Constant Air Volume Direct Expansion With Dedicated Outdoor Air System

Table 5–11 Medium Box Low Plug CAV DOAS Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating (gas)	0.0	1.3	1.6	3.1	1.2	3.0	3.4	5.3
Cooling (electric)	12.9	10.0	8.0	7.2	6.8	6.0	5.2	5.6
Fans (electric)	2.9	2.7	2.6	2.6	2.3	2.6	2.2	2.6
SWH (electric)	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7
Total	46.7	45.0	43.2	44.0	41.4	42.6	41.9	44.7
Percent Savings	59.7%	59.5%	58.7%	56.6%	54.4%	57.5%	50.5%	55.8%

Table 5–12 Medium Box Low Plug CAV DOAS Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating (gas)	3.8	5.5	6.2	4.8	7.8	7.8	9.0	21.7
Cooling (electric)	4.0	3.7	4.5	2.7	4.2	2.9	2.6	1.9
Fans (electric)	2.6	2.3	2.5	2.4	2.6	2.4	2.5	2.6
SWH (electric)	0.7	0.7	0.8	0.8	0.8	0.8	0.9	1.0
Total	41.6	42.8	44.5	41.2	45.9	44.4	45.5	57.8
Percent Savings	58.1%	51.7%	55.5%	57.8%	56.4%	55.2%	56.3%	52.9%

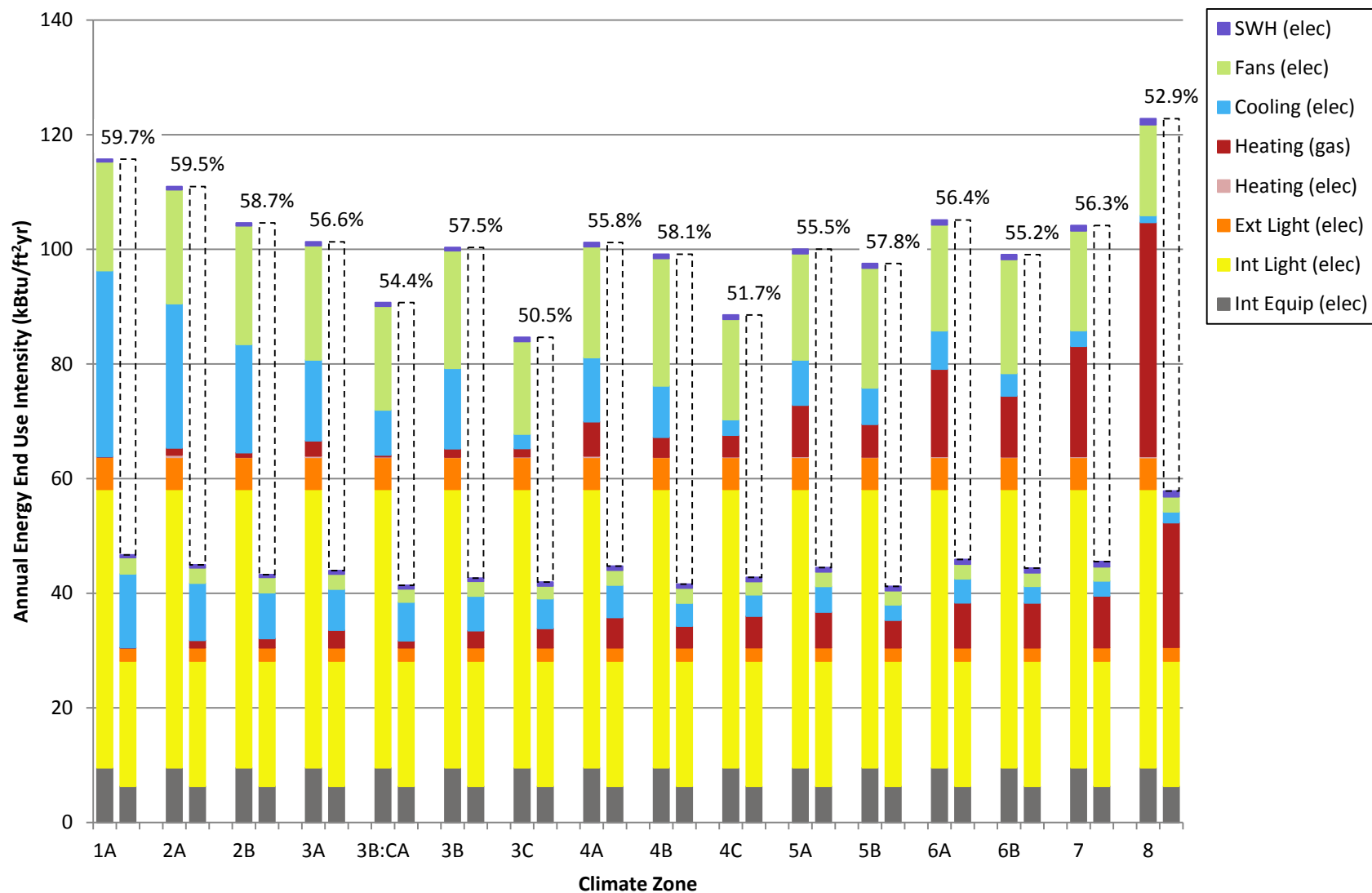


Figure 5-4 Medium box low plug CAV DOAS simulation results

Table 5–13 Medium Box High Plug CAV DOAS Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating (gas)	0.0	1.1	1.3	2.6	0.9	2.5	2.7	4.5
Cooling (electric)	13.5	10.5	8.5	7.5	7.1	6.4	5.4	5.9
Fans (electric)	3.0	2.8	2.8	2.7	2.4	2.7	2.2	2.7
SWH (electric)	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7
Total	50.9	48.7	46.9	47.3	44.8	46.0	44.7	47.7
Percent Savings	58.5%	58.5%	57.9%	56.0%	53.9%	57.0%	50.7%	55.4%

Table 5–14 Medium Box High Plug CAV DOAS Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating (gas)	3.2	4.6	5.3	4.1	6.9	6.8	7.9	19.8
Cooling (electric)	4.4	3.9	4.7	2.9	4.4	3.1	2.7	2.0
Fans (electric)	2.7	2.3	2.6	2.5	2.6	2.4	2.5	2.6
SWH (electric)	0.7	0.7	0.8	0.8	0.8	0.8	0.9	1.0
Total	44.7	45.3	47.2	44.1	48.5	46.9	47.8	59.3
Percent Savings	57.6%	51.9%	55.1%	57.4%	55.8%	55.0%	55.9%	52.9%

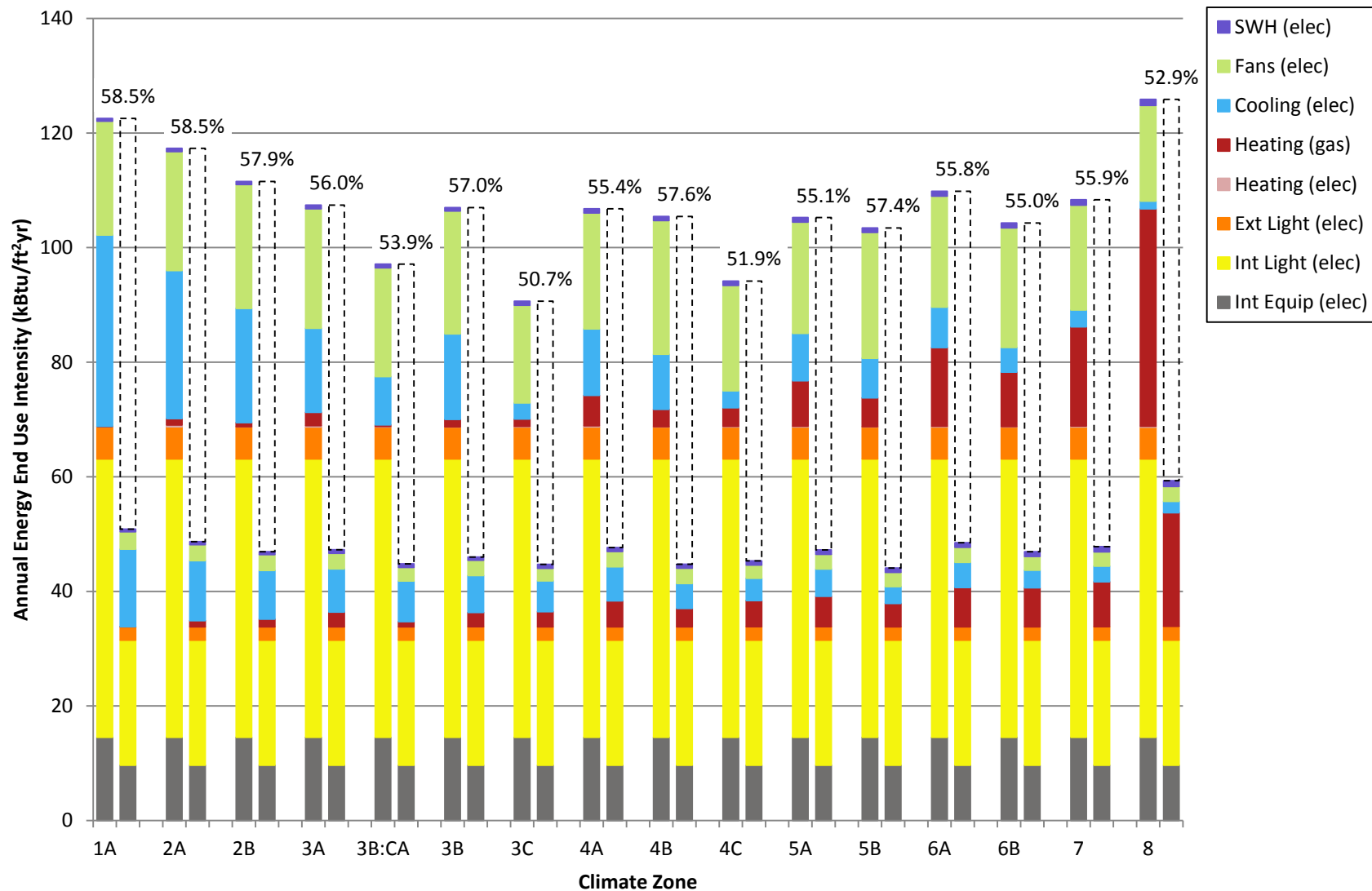


Figure 5-5 Medium box high plug CAV DOAS simulation results

Table 5–15 Big Box CAV DOAS Simulation Results, 1A–4A

End Use (kBtu/ft²yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Interior lighting (electric)	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating (gas)	0.0	1.1	1.4	2.6	1.0	2.4	2.7	4.6
Cooling (electric)	13.8	9.9	8.1	7.1	6.7	6.0	5.2	5.5
Fans (electric)	3.2	2.7	2.6	2.6	2.3	2.5	2.1	2.6
SWH (electric)	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.3
Total	47.8	44.6	42.9	43.2	40.9	41.8	41.0	43.6
Percent Savings	58.8%	59.7%	59.6%	55.9%	53.9%	57.0%	50.0%	55.0%

Table 5–16 Big Box CAV DOAS Simulation Results, 4B–8

End Use (kBtu/ft²yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Interior lighting (electric)	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating (gas)	3.2	5.0	5.5	4.1	6.7	6.8	8.0	19.5
Cooling (electric)	3.9	3.7	4.4	2.6	4.1	2.9	2.6	1.9
Fans (electric)	2.5	2.2	2.5	2.4	2.5	2.3	2.4	2.5
SWH (electric)	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4
Total	40.5	41.8	43.3	40.1	44.3	42.9	44.0	55.0
Percent Savings	57.6%	51.0%	55.3%	57.6%	56.1%	55.0%	56.3%	53.0%

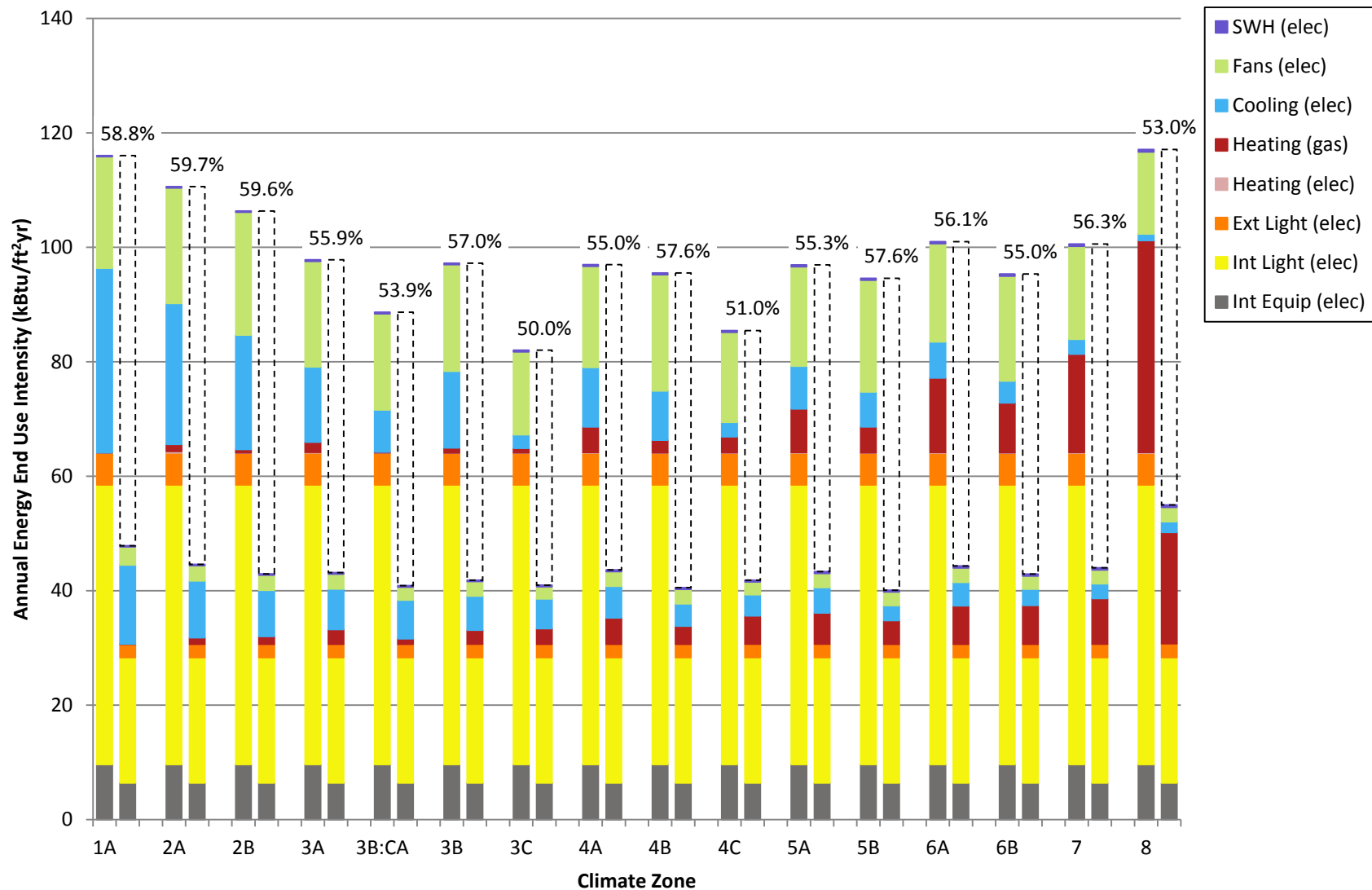


Figure 5-6 Big box CAV DOAS simulation results

5.2.3 Air Source Heat Pump With Dedicated Outdoor Air System

This model used the all-electric baseline for energy savings comparisons.

Table 5–17 Medium Box Low Plug ASHP DOAS Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.7	0.7	1.7	0.4	1.3	1.1	3.0
Cooling (electric)	13.2	10.2	8.2	7.3	6.9	6.2	5.2	5.8
Fans (electric)	2.9	2.7	2.6	2.7	2.3	2.6	2.2	2.9
SWH (electric)	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7
Total	47.1	44.6	42.5	42.8	40.6	41.2	39.8	42.8
Percent Savings	59.3%	59.7%	59.3%	57.5%	55.2%	58.9%	52.9%	57.2%

Table 5–18 Medium Box Low Plug ASHP DOAS Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	2.3	2.6	3.8	3.1	5.1	5.1	6.1	15.3
Cooling (electric)	4.2	3.8	4.6	2.8	4.3	3.0	2.6	1.9
Fans (electric)	2.7	2.5	3.0	2.8	3.3	3.0	3.3	4.5
SWH (electric)	0.7	0.7	0.8	0.8	0.8	0.8	0.9	1.0
Total	40.4	40.1	42.6	39.9	44.0	42.4	43.4	53.3
Percent Savings	58.9%	54.4%	56.6%	58.6%	56.9%	56.3%	56.7%	53.5%

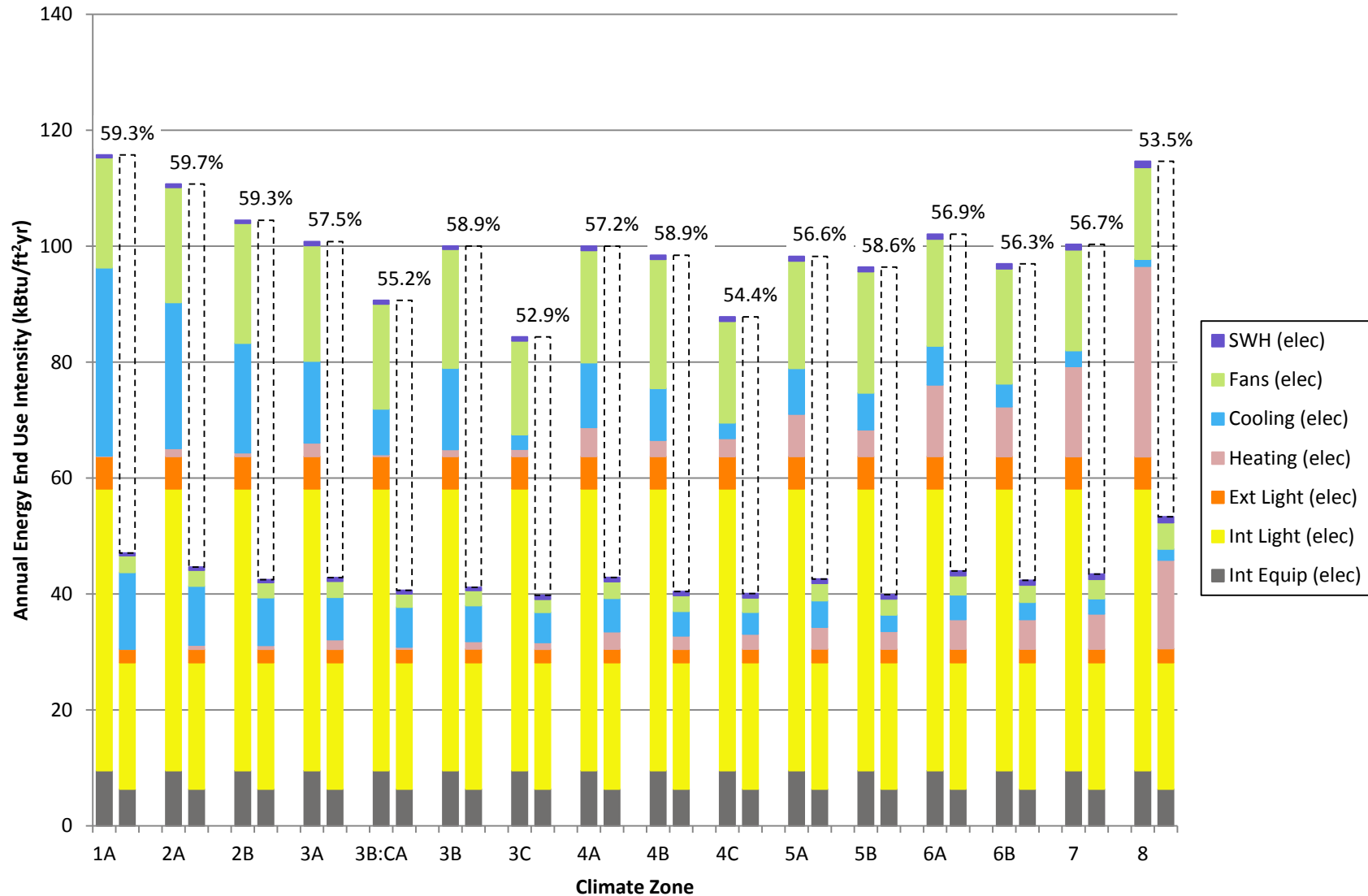


Figure 5–7 Medium box low plug ASHP DOAS results

Table 5–19 Medium Box High Plug ASHP DOAS Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.6	0.6	1.5	0.3	1.1	0.9	2.7
Cooling (electric)	14.0	10.8	8.8	7.7	7.3	6.7	5.4	6.1
Fans (electric)	3.1	2.8	2.7	2.8	2.3	2.6	2.2	2.9
SWH (electric)	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7
Total	51.3	48.6	46.4	46.4	44.3	44.8	43.1	46.2
Percent Savings	58.1%	58.5%	58.4%	56.6%	54.3%	58.0%	52.3%	56.3%

Table 5–20 Medium Box High Plug ASHP DOAS Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	2.0	2.3	3.3	2.7	4.6	4.6	5.4	14.1
Cooling (electric)	4.6	4.0	4.9	3.1	4.5	3.2	2.8	2.0
Fans (electric)	2.8	2.4	3.0	2.8	3.3	2.9	3.3	4.4
SWH (electric)	0.7	0.7	0.8	0.8	0.8	0.8	0.9	1.0
Total	43.9	43.2	45.8	43.2	47.0	45.4	46.2	55.4
Percent Savings	58.1%	53.8%	55.9%	57.9%	56.1%	55.7%	56.0%	53.2%

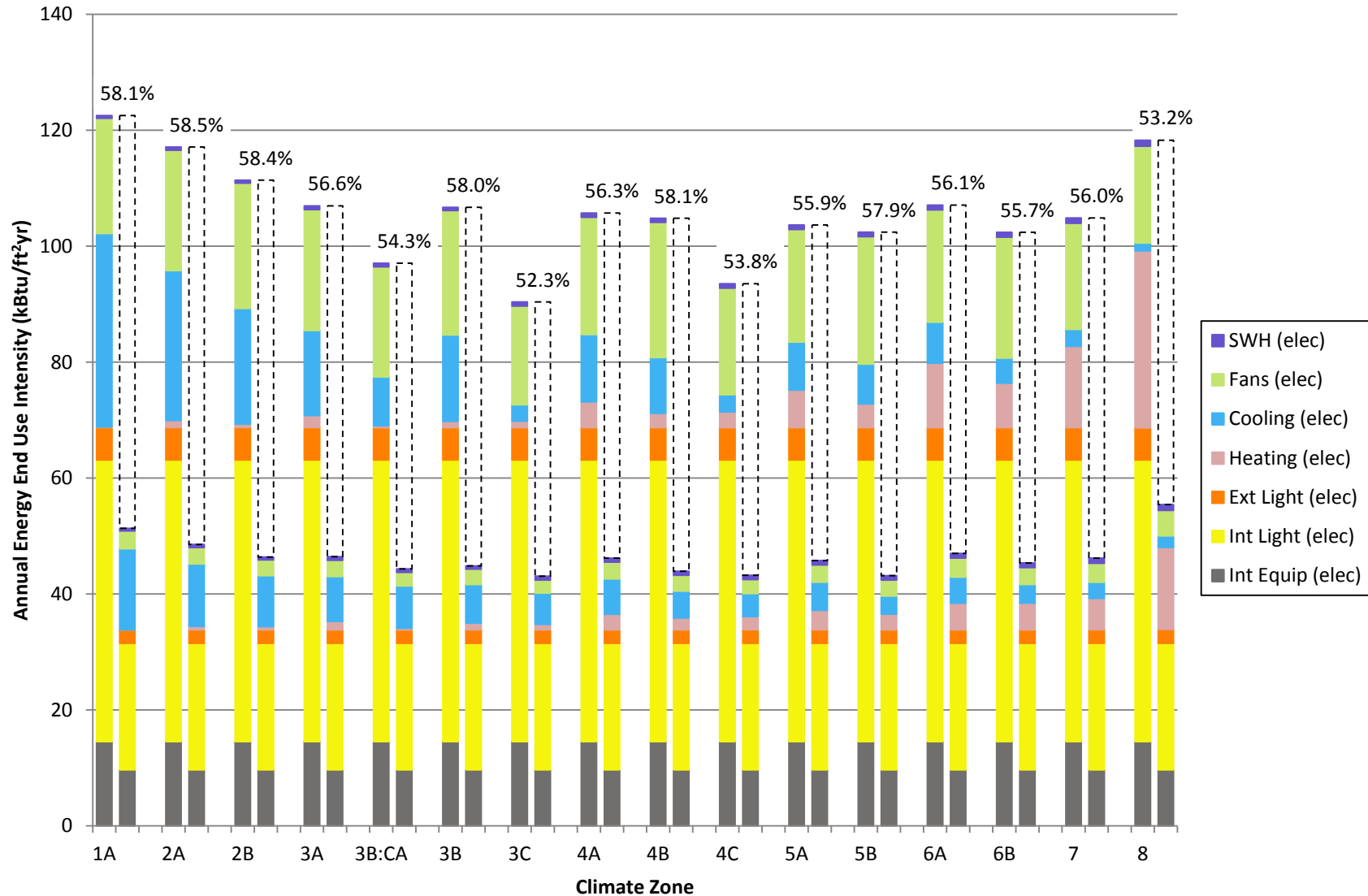


Figure 5–8 Medium box high plug ASHP DOAS results

Table 5–21 Big Box ASHP DOAS Simulation Results, 1A–4A

End Use (kBtu/ft²yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Interior lighting (electric)	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.5	0.5	1.2	0.3	1.0	0.9	2.4
Cooling (electric)	14.3	10.2	8.3	7.2	6.9	6.1	5.2	5.6
Fans (electric)	3.2	2.7	2.6	2.7	2.3	2.5	2.2	2.8
SWH (electric)	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.3
Total	48.3	44.3	42.3	42.1	40.3	40.5	39.2	41.8
Percent Savings	58.4%	59.9%	60.2%	56.8%	54.5%	58.2%	52.1%	56.5%

Table 5–22 Big Box ASHP DOAS Simulation Results, 4B–8

End Use (kBtu/ft²yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Interior lighting (electric)	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	1.7	2.1	3.0	2.3	4.0	4.1	4.9	13.2
Cooling (electric)	4.1	3.7	4.5	2.7	4.2	2.9	2.6	1.9
Fans (electric)	2.6	2.4	2.9	2.7	3.2	2.8	3.2	4.2
SWH (electric)	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4
Total	39.4	39.2	41.4	38.7	42.4	40.8	41.7	50.4
Percent Savings	58.6%	53.9%	56.6%	58.7%	56.9%	56.4%	57.0%	54.0%

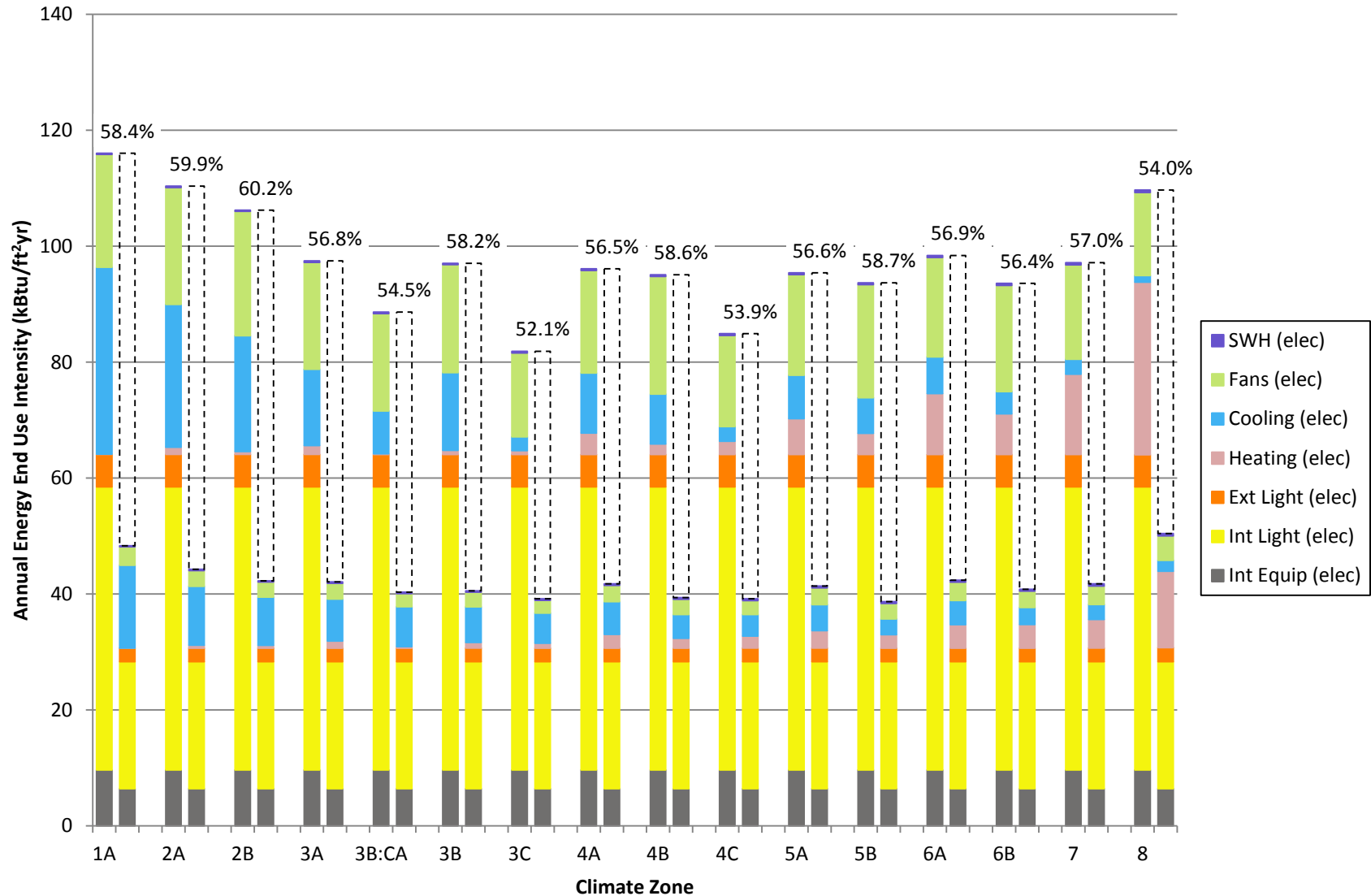


Figure 5–9 Big box ASHP DOAS simulation results

5.2.4 Water Source Heat Pump With Dedicated Outdoor Air System

Table 5–23 Medium Box Low Plug WSHP DOAS Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.3	0.4	0.7	0.3	0.6	0.7	1.1
Heating (gas)	0.0	0.5	0.6	1.5	0.3	1.4	1.5	2.7
Cooling (electric)	13.4	10.2	8.0	7.4	6.8	6.1	5.2	5.8
Fans (electric)	2.9	2.6	2.6	2.6	2.3	2.6	2.2	2.6
Pumps (electric)	1.2	0.9	0.8	0.8	0.4	0.7	0.3	0.8
SWH (electric)	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7
Total	48.4	45.6	43.4	44.1	41.2	42.5	41.1	44.2
Percent Savings	58.2%	58.9%	58.6%	56.5%	54.6%	57.6%	51.4%	56.3%

Table 5–24 Medium Box Low Plug WSHP DOAS Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	0.8	1.2	1.3	1.0	1.6	1.5	1.8	3.9
Heating (gas)	1.4	2.9	3.3	2.2	4.4	4.4	5.1	13.8
Cooling (electric)	4.2	3.8	4.6	2.8	4.3	3.0	2.6	1.9
Fans (electric)	2.8	2.4	2.6	2.7	2.6	2.7	2.6	3.4
Pumps (electric)	0.6	0.4	0.8	0.5	0.8	0.4	0.6	0.5
SWH (electric)	0.7	0.7	0.8	0.8	0.8	0.8	0.9	1.0
Total	40.9	41.8	43.9	40.4	45.0	43.3	44.2	55.2
Percent Savings	58.7%	52.8%	56.1%	58.6%	57.2%	56.3%	57.6%	55.1%

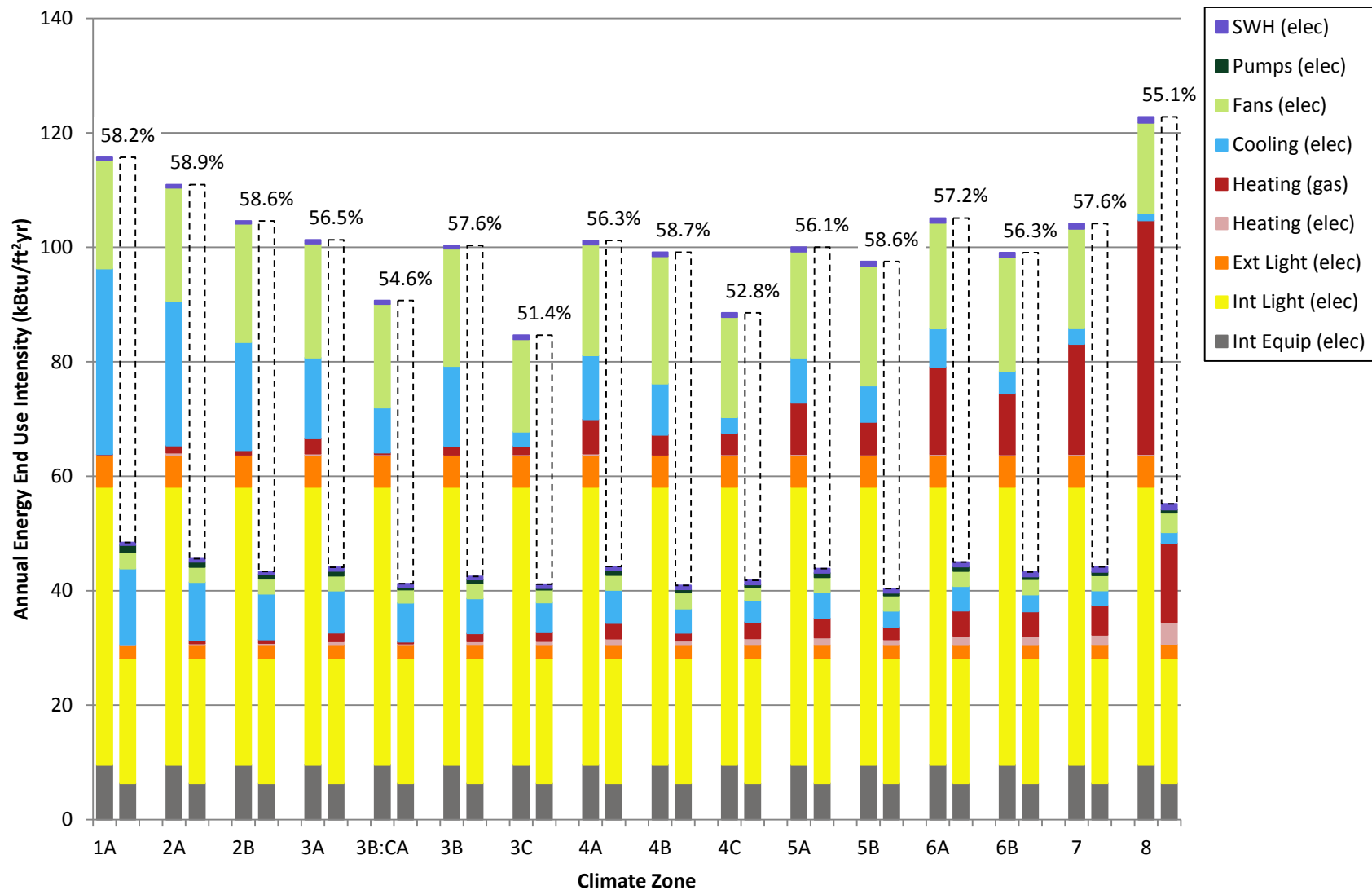


Figure 5-10 Medium box low plug WSHP DOAS results

Table 5–25 Medium Box High Plug WSHP DOAS Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.2	0.3	0.6	0.2	0.5	0.6	1.0
Heating (gas)	0.0	0.4	0.5	1.2	0.1	1.0	1.1	2.2
Cooling (electric)	14.1	10.8	8.5	7.8	7.2	6.6	5.4	6.1
Fans (electric)	3.0	2.8	2.7	2.7	2.4	2.7	2.2	2.7
Pumps (electric)	1.4	1.1	0.9	0.9	0.5	0.8	0.3	0.9
SWH (electric)	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7
Total	52.9	49.6	47.2	47.6	44.9	46.0	44.1	47.4
Percent Savings	56.9%	57.7%	57.7%	55.7%	53.8%	57.0%	51.4%	55.6%

Table 5–26 Medium Box High Plug WSHP DOAS Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Interior lighting (electric)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	0.7	1.0	1.1	0.8	1.4	1.3	1.6	3.5
Heating (gas)	1.0	2.3	2.8	1.7	3.8	3.7	4.3	12.6
Cooling (electric)	4.6	3.9	4.9	3.1	4.6	3.2	2.8	2.0
Fans (electric)	2.9	2.4	2.6	2.7	2.7	2.7	2.6	3.3
Pumps (electric)	0.6	0.5	0.8	0.5	0.8	0.5	0.6	0.5
SWH (electric)	0.7	0.7	0.8	0.8	0.8	0.8	0.9	1.0
Total	44.4	44.6	46.8	43.5	47.8	46.0	46.7	56.9
Percent Savings	57.9%	52.6%	55.5%	57.9%	56.4%	55.9%	56.9%	54.8%

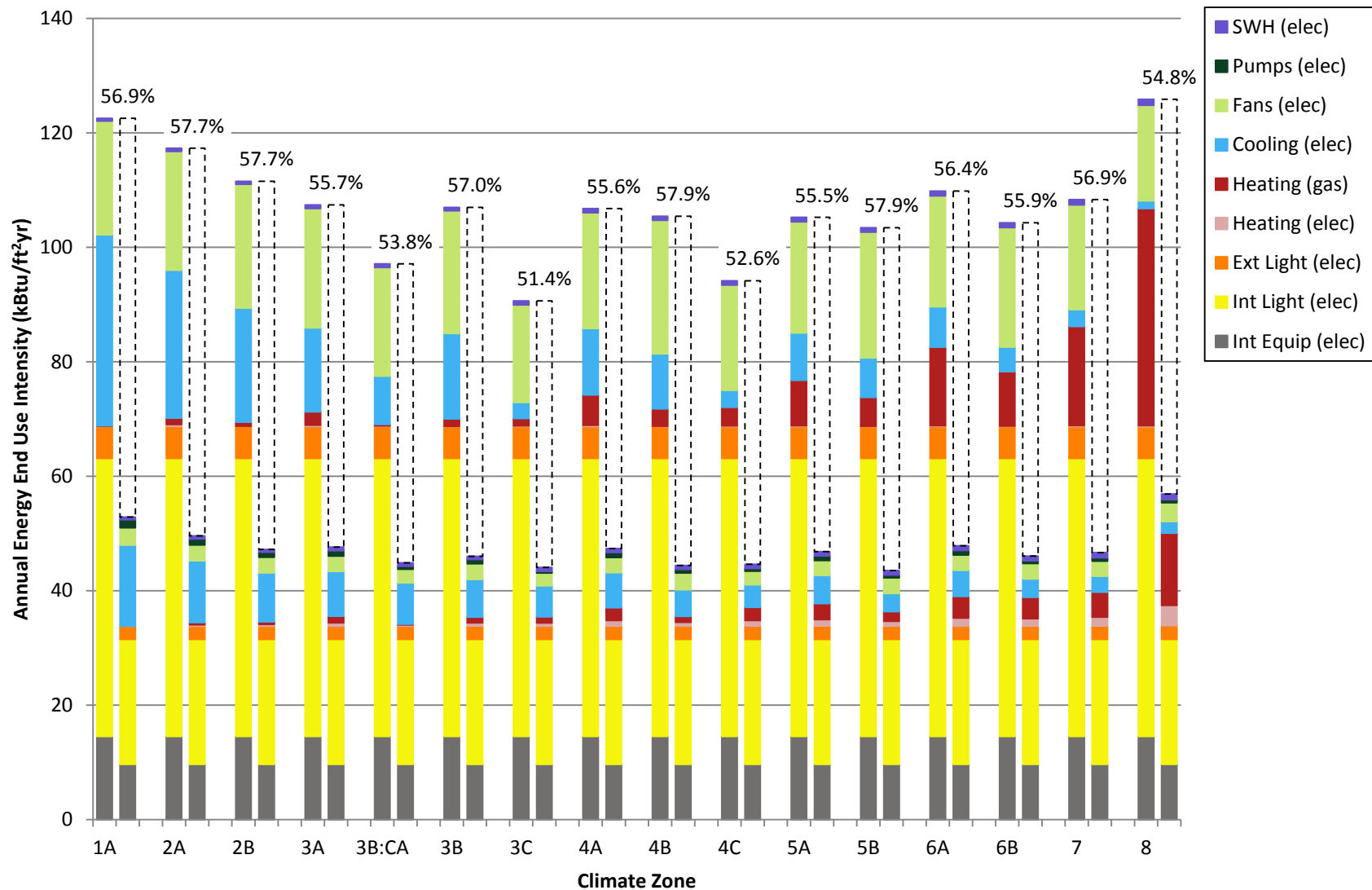


Figure 5–11 Medium box high plug WSHP DOAS results

Table 5–27 Big Box WSHP DOAS Simulation Results, 1A–4A

End Use (kBtu/ft ² yr)	1A	2A	2B	3A	3B:CA	3B	3C	4A
Interior equipment (electric)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Interior lighting (electric)	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9
Exterior lighting (electric)	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Heating (electric)	0.0	0.3	0.3	0.6	0.2	0.5	0.6	1.0
Heating (gas)	0.0	0.5	0.6	1.3	0.3	1.2	1.3	2.5
Cooling (electric)	14.5	10.2	8.1	7.3	6.8	6.1	5.2	5.7
Fans (electric)	3.2	2.6	2.6	2.6	2.3	2.6	2.2	2.6
Pumps (electric)	1.6	0.9	0.8	0.8	0.4	0.6	0.2	0.8
SWH (electric)	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.3
Total	50.0	45.4	43.3	43.5	40.9	41.9	40.4	43.4
Percent Savings	56.9%	59.0%	59.3%	55.5%	53.9%	56.9%	50.7%	55.3%

Table 5–28 Big Box WSHP DOAS Simulation Results, 4B–8

End Use (kBtu/ft ² yr)	4B	4C	5A	5B	6A	6B	7	8
Interior equipment (electric)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Interior lighting (electric)	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9
Exterior lighting (electric)	2.3	2.3	2.4	2.3	2.3	2.3	2.3	2.4
Heating (electric)	0.7	1.0	1.1	0.9	1.4	1.3	1.6	4.8
Heating (gas)	1.4	2.7	3.0	2.0	3.8	3.8	4.6	10.9
Cooling (electric)	4.1	3.7	4.5	2.7	4.2	2.9	2.6	1.9
Fans (electric)	2.7	2.3	2.5	2.6	2.6	2.6	2.6	3.4
Pumps (electric)	0.5	0.4	0.7	0.4	0.7	0.4	0.5	0.4
SWH (electric)	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4
Total	40.3	41.1	42.9	39.5	43.6	42.0	42.9	52.5
Percent Savings	57.9%	51.9%	55.7%	58.2%	56.8%	55.9%	57.4%	55.2%

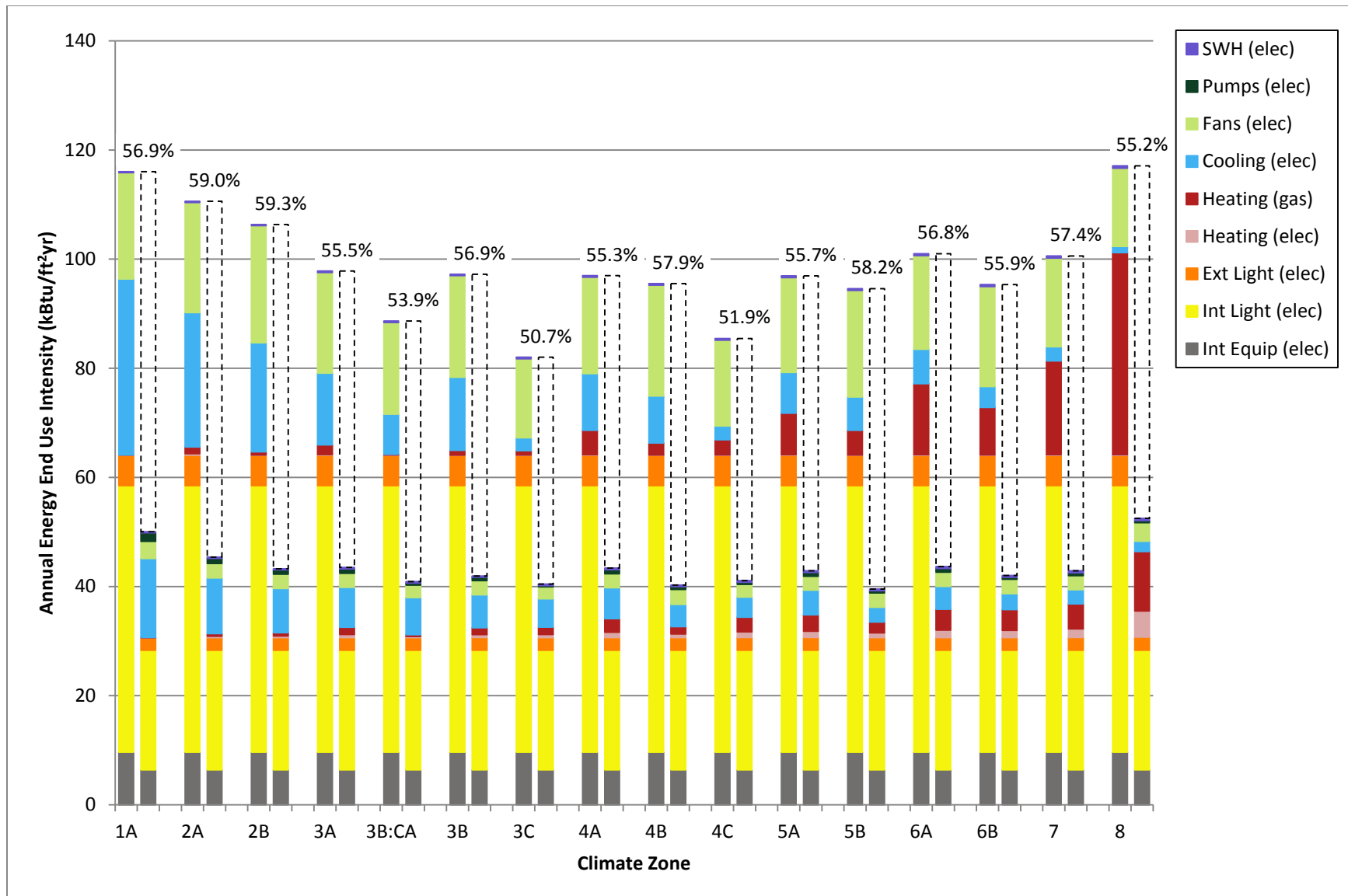


Figure 5-12 Big box WSHP DOAS simulation results

6. Conclusion

This TSD describes the process and methodology used to develop the AEDG-MBBR, which is intended to provide recommendations for achieving 50% whole-building energy savings in retail facilities over levels achieved by following Standard 90.1-2004. The AEDG-MBBR was developed in collaboration with ASHRAE, AIA, IES, USGBC, and DOE. One of NREL's tasks was to provide the analysis and modeling support to verify energy savings and develop recommendations that met the 50% savings goal. The 50% energy savings target represents a step toward achieving net-zero energy retail facilities. Net-zero energy buildings draw equal (or less) energy from outside sources than they generate on site from renewable energy sources during a given year. The AEDG-MBBR provides user-friendly design assistance and recommendations to design, architectural, and engineering firms to help achieve energy savings. It includes prescriptive recommendations by climate zone for designing the building envelope, fenestration lighting systems (including electrical lights and daylighting), HVAC systems, building automation and controls, OA treatment, and the SWH system. Additional savings recommendations are also included, but are not necessary for 50% savings. These are provided for alternative HVAC systems and renewable energy systems. The AEDG-MBBR contains recommendations only and is not a code or standard.

The AEDG-MBBR provides a simple, easy-to-use guide to help the building designer, contractor, and owner identify a clear, prescriptive path to 50% energy savings over Standard 90.1-2004. In many ways, it is a simple interface to a complex analysis performed using EnergyPlus. The combination of a set of recommendations contained on a single page, along with numerous how-to tips to help the construction team complete the project successfully, should help facilitate increased energy efficiency in new buildings. Case studies of actual retail applications add to the resources of energy efficiency opportunities. The ultimate goal of the AEDG partner organizations is to achieve net-zero energy buildings, and the 50% savings guides represent a step in reaching this goal.

Separate from the AEDG-MBBR, this TSD was created to document the process used to develop the guide and the analysis performed to support that development. The specific objectives were to:

- Document the process and schedule used to develop the AEDG-MBBR.
- Document prototypical medium and big box retail store characteristics.
- Document the EnergyPlus modeling assumptions used to establish 50% energy savings.
- Document the baseline and low-energy EnergyPlus retail store models.
- Present the recommendations for achieving at least 50% savings over Standard 90.1-2004.
- Demonstrate that the recommendations result in 50% or greater energy savings by climate zone.

A partial subset of the information contained in this TSD is included in the AEDG-MBBR, but the information is too extensive for full inclusion. This TSD provides complete documentation of all the simulation results for each climate zone and HVAC system type covered by the guide. It also provides a technical resource to industry members who are looking to implement AEDG recommendations in real projects.

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Appendix A. Scoping Document

This appendix contains an exact copy of the scoping document for the AEDG-MBBR.

Purpose

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 medium-box retail buildings in order to achieve energy savings of 50% over ASHRAE Standard 90.1-2004. To install skills and knowledge in practitioners that can be used in a wide variety of buildings.

Background

The ASHRAE Advanced Energy Design Guides (AEDGs) are a series of publications designed to provide recommendations for achieving energy savings over the minimum code requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999. Designers, while complying with minimum energy code requirements, often lack the opportunity or have insufficient design fees to pursue innovative, energy efficient concepts in the design of retail buildings. The 50% AEDG for medium-box retail buildings will provide prescriptive design assistance in a user-friendly presentation to owners and designers who want to achieve greater energy savings than obtained through minimum code compliance. In a departure from 30% AEDG work, the intent of this work is not to replace energy modeling entirely, but to supplement the recommendations of the guide with user-friendly modeling tools to help owners and designers predict project-specific energy savings achievable through design recommendation implementation.

Goal

To provide owners and designers of medium-box retail buildings design recommendations and user-friendly modeling tools that will enable them to achieve 50% site energy savings beyond a Standard 90.1-2004 minimally-compliant baseline.

- The recommendations of the guide will meet the 50% savings goal for each of the climate zones covered by the guide. The list of representative cities for each climate zone will be consistent with that for the 50% Technical Support Document (TSD) for General Merchandise (Hale et al. 2009).
- The 50% savings goal is a hard goal as opposed to an approximate target, and represents a significant step towards increased energy-efficiency from the goal of the 30% AEDG.
- Energy savings will be achieved through the identification of packages of design measures and state-of-the-art building systems and design concepts that result in energy-efficient spaces.

Audience

- Owners and design teams of medium-box retail buildings interested in 50% energy savings and supported by energy modeling expertise. This is typically a more sophisticated design team capable of using modeling to evaluate prospective designs to ensure they meet AEDG recommendations.
- Engineers and designers interested in developing the skills needed to produce 50% energy savings in medium-box retail buildings.

Recommendation Development Guidelines

- Recommendations are divided into two distinct paths: (1) a prescriptive path, for which tables of recommendations will be 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 will be assigned performance-based benchmarks. The performance-based path will allow increased design freedom, requiring adherence to a performance-based benchmark only with respect to whole-building energy use intensity.
- Recommendations will be presented in a user-friendly, “how-to” format to ease the burden for the designers and give decision-makers an easy-to-follow overview of the design process. Modeling tools designed to enhance the speed and scope of recommendation deployment and adoption will be packaged in a similarly user-friendly manner that minimizes energy modeling experience requirements insofar as possible. Design recommendations need to contain practical design information that can be used within the constraints of typical construction and design fees.
- Recommendations will not specify the implementation of unique products – we will require that all recommended products be available from at least two manufacturers.
- Recommendations will be developed using best practice examples of design and technology, modeled using up-to-date performance and cost inputs.
- Focus will be given to illustrate how to use integrated design concepts, design process, and team working relationships to minimize the cost of implementation for AEDG recommendations.

Case Studies

A number of case studies will be included to provide examples of both whole-building integrated design concepts and the implementation of energy-efficient components or techniques. In many instances, case studies will be specific to particular geographic regions (as in the 30% AEDG).

Scope

The 50% AEDG for medium-box retail buildings, representing a progression of the 30% AEDG series with respect to energy-efficient design guidelines, will provide prescriptive and performance-based paths to achieving 50% site energy savings in medium-box retail buildings. Energy savings will be measured against “baseline” or “reference” buildings for each climate that are minimally code-compliant with respect to ASHRAE Standard 90.1-2004.

For the purposes of this 50% AEDG, we define a medium-box retail 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

The 50% AEDG for medium-box retail buildings will apply primarily to retail buildings with 20,000 ft² to 100,000 ft² of floor area; however, many of the recommendations will apply to smaller and larger retail buildings as well. Recommendations will be based on the medium-box

retail prototype design from the 50% General Merchandise TSD (Hale et al. 2009). Whole-building models adapted from the prototype designs will be equipped with HVAC systems designed to meet minimum ventilation requirements and maintain ASHRAE comfort standards year-round.

Design recommendations will apply to the following building aspects:

- Opaque envelope and exterior glazing
- Lighting and daylighting systems
- HVAC system design and components
- Building automation and control systems
- Treatment of outside air, including energy recovery systems, and dehumidification systems
- Service water heating (SWH) for bathrooms and dining areas
- Plug and process loads
- Commissioning

Design recommendations will not be provided for building aspects considered out of the scope of this task, including:

- Commercial refrigeration equipment
- Domestic water well pumping
- Sewage disposal

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

Appendix B. Project Committee Meeting Agendas

B.1 Meeting 1

Medium-Big Box Retail Advanced Energy Design Guide

50% Energy Savings

Project Committee Meeting 1 Agenda

ASHRAE Headquarters

1791 Tullie Circle

Atlanta, GA 30329

404-636-8400

Friday, April 15, 2011, 8:00AM – 5:00PM

Saturday, April 16, 2011, 8:00AM – 1:30PM

The Marriott Courtyard serves breakfast to guests. You should have received a breakfast coupon when you checked in with your ASHRAE rate. We can meet in the breakfast area informally at 7:00AM for breakfast. We will identify a place to have dinner as a group on Friday night. Lunches will be brought in by ASHRAE.

Pre meeting action items

- Review scoping document
- Review 30% AEDGs
- Be prepared to share the energy efficiency strategies that you have used in retail stores
- Bring calendars for this summer/fall
- Bring case studies to share

Meeting objectives

- Common understanding of the scope
- Define development process and integration with energy modeling
- Identify team member experiences and roles
- Define general concept on what it takes to get to 50% savings in a retail store
- Form working groups and section assignments

Agenda

Friday, April 15, 2011

1	Welcome/review agenda	Pless	8:00
2	Introductions • Give name/affiliation and experience • Be ready to share the energy efficiency strategies that you have used (what do you think it takes to get to 50% energy savings)	All	8:15
3	AEDG-MBBR overview • Organization of AEDG series • Committee makeup structure/partnering organization • Scoping document formation • Reference case determination	Pratt/Pless	9:15

4	Review and questions on scoping document - Context of the other AEDGs - Goals and objectives of the AEDG-MBBR - Target audience - Review of scoping document - Peer review process	Pratt/Pless	9:30
5	Break	All	10:00
6	AEDG-MBBR development schedule Future meeting schedule Bring your calendars for this summer/fall	Pratt/Pless	10:15
7	Outline of AEDG-MBBR - Review outline of previous guides - Discuss possible modifications/changes How will this guide be unique? - What will be different about this guide? - What new information will be provided? Assignments of staff to guide sections - Identify section leaders and section contributors	Pratt/Pless	10:45
8	Lunch	All	12:00
9	ASHRAE headquarters tour	All	12:45
10	Energy modeling - Analysis engine and modeling background - Baseline building discussion - Preliminary modeling results - Plans for modeling going forward How to use model results to develop the guide? What additional modeling can we do?	Bonnema	1:30
11	Break	All	3:00
12	Group breakout - Lighting/daylighting - Architecture, envelope, and integrated design - HVAC - O&M, commissioning	All	3:15

Saturday, April 16, 2011

1	Group breakout	Groups	8:00
2	Break	All	10:15
3	Group breakout	Groups	10:45
4	Working lunch (discuss case studies) Bring case studies to share	All	12:00
5	Review - Group breakout sessions - Action items for next meeting	All	1:00
6	Adjourn	All	1:30

B.2 Meeting 2

Medium-Big Box Retail Advanced Energy Design Guide
50% Energy Savings
Project Committee Meeting 2 Agenda

ASHRAE Headquarters
1791 Tullie Circle
Atlanta, GA 30329
404-636-8400

Sunday, May 15, 2011, 8:00AM – 5:00PM

Monday, May 16, 2011, 8:00AM – 2:00PM

The Marriott Courtyard serves breakfast to guests. You should have received a breakfast coupon when you checked in with your ASHRAE rate. We can meet in the breakfast area informally at 7:00AM for breakfast. We will identify a place to have dinner as a group on Sunday night. Lunches will be brought in by ASHRAE.

Pre meeting action items

- Complete action items from 4/29/11 conference call
- Bring case studies to share

Meeting objectives

- Everyone should have all the information they need to complete the first draft by May 30.

Agenda

Sunday, May 15, 2011

1	Welcome/review agenda	Pless	8:00
2	Review action items from 4/29/11 conference call	All	8:15
3	Section updates • Foreword – Williams • Integrated design – Pless • Lighting – Lane, Bauer • HVAC – Nall, Marriott • Envelope – McBride	All	8:30
4	Recommendation table review • Any changes to the content or structure?	Leach	9:00
5	Modeling Update	Leach	9:15
6	Break	All	10:00
7	Group breakout • Lighting/daylighting • Architecture, envelope, and integrated design • HVAC • O&M, commissioning	Pratt/Pless	10:15
8	Lunch	All	12:00
9	Group breakout • Lighting/daylighting	All	1:00

	• Architecture, envelope, and integrated design • HVAC • O&M, commissioning		
10	Discuss plan for Chapter 3 (performance option) • Determine outline for chapter, who will contribute • What will be covered in the chapter	All	3:30
11	Discuss M&V for retail and how to handle it in the guide	All	4:30

Monday, May 16, 2011

1	Group breakout • Lighting/daylighting • Architecture, envelope, and integrated design • HVAC • O&M, commissioning	All	8:00
2	Break	All	10:00
3	Group breakout • Lighting/daylighting • Architecture, envelope, and integrated design • HVAC • O&M, commissioning	All	10:15
4	Lunch	All	12:00
5	Review • Group breakout sessions • Action items for next meeting	All	1:00
6	Adjourn	All	2:00

B.3 Meeting 3

Medium-Big Box Retail Advanced Energy Design Guide
50% Energy Savings
Project Committee Meeting 3 Agenda

Target® Headquarters
1000 Nicollet Mall
Minneapolis, MN 55403
612-304-6073

Friday, July 15, 2011, 8:00AM – 5:00PM
Saturday, July 16, 2011, 8:00AM – 4:00PM

The hotels that folks are staying at have restaurants nearby or on site, please get whatever level of breakfast you would like on your own. We will meet in the lobby of the Double Tree at 7:45AM and walk to Target Headquarters together both days. Since this is a small group, we are going to go to the Target Headquarters cafe for lunch on Friday and someplace close by for lunch on Saturday. We will identify a place to have dinner as a group on Friday night.

Pre meeting action items

- Review comments assigned to each member and prepare responses to discuss at the meeting
- Conduct detailed review of the first draft
- Bring case studies that you would like to include in the guide

Meeting objectives

- Address and document responses to remarks
- Identify holes in the draft
 - Assign case studies to PC members
- Develop action item list to get next draft completed by COB Wednesday July 20
 - Conference call Friday July 22, 2:30 pm EDT to discuss progress
 - “Final” deadline COB Wednesday July 27
 - Draft posted August 1

Agenda

Friday, July 15, 2011

1	Welcome/review agenda • Next meeting in Denver August 29-30 • Conference call Friday August 19, 2:30 pm EDT to discuss progress for the meeting • Revisions due COB Wednesday September 7 for action items generated during the second meeting • Conference call Friday September 9, 2:30 pm EDT to discuss progress towards final draft	Pless	8:00
2	Review general draft remarks and determine responses • Overall observations	Pratt	8:15

	• Problems based on first look? • Major holes in draft? • Major additions needed?		
3	Break	All	9:45
4	Break into chapter groups and talk with Target subject matter experts (Cheryl Penkivech: Lighting, Ed Doyle: Architecture) • Are there any issues with our recommendations that we may be overlooking? • Real-life problems they run into? • Other discussion topics?	All	10:00
5	Review recommendation table as a group • Any oversights? Additions necessary?	Pless/Leach	11:30
6	Lunch	All	12:00
7	Comments on Meeting 2 minutes	All	1:00
8	Old action items review and update	Pratt	1:15
9	Retail store and technology case study assignments	Pless	1:45
10	Discuss simulation results	Leach	2:00
11	Break – Tour Target® store	All interested	2:30
12	Break into chapter groups to address specific remarks and work on solutions to remarks	All	3:30
13	Break for the day	All	4:00

Saturday, July 16, 2011

1	Break into chapter groups to address specific remarks and work on solutions to remarks	All	8:00
2	Break	All	10:00
3	Break into chapter groups to address specific remarks and work on solutions to remarks	All	10:15
4	Lunch	All	12:00
5	Break into chapter groups to address specific remarks and work on solutions to remarks	All	1:00
6	Adjourn	All	4:00

B.4 Meeting 4

Medium-Big Box Retail Advanced Energy Design Guide
50% Energy Savings
Project Committee Meeting 4 Agenda
NREL Research Support Facility
15301 Denver West Parkway
Golden, CO 80401
303-275-3000

Monday, August 29, 2011, 8:00AM – 5:00PM

Tuesday, August 30, 2011, 8:00AM – 2:00PM

Continental breakfast will be served each morning at 7:45 at NREL. On Monday, please meet in the hotel lobby at 7:30 to ride in a shuttle to the NREL visitor's center to be badged. The badges are good for two days, so we can leave the hotel at 7:45 on Tuesday. We will identify a place to have dinner as a group on Monday night. Lunches will be brought in by NREL.

Pre meeting action items

- Conduct detailed review of the second draft
- Review comments assigned to each member and prepare responses to discuss at the meeting
- Bring any additional case studies that you would like to include in the guide

Meeting objectives

- Address and document responses to remarks
- Identify holes in the draft
 - Acknowledgements
 - Adding how-to tips references to the tables
 - Complete all bibliographical reference information
- Develop action item list to get 95% draft completed by September 7

Agenda

Monday, August 29, 2011

1	Welcome/review agenda	Pless	8:00
2	Cover pictures (decide on 2-3 for front, 12 or so for back) • One shot on the front of whole building • Three shots on the back, more freedom here	Pratt/All	8:15
3	Graphics – schedule, content, and process	Pratt	8:30
4	Old action item review and update	Pratt	8:45
5	Case studies • More whole building case studies • Technology examples (daylighting, HVAC, others?)	Bonnema	9:15
6	Break	All	9:45
7	Final energy modeling results	Leach	10:00
8	Review general draft remarks and determine responses • Overall observations	Pratt	10:30

	Problems based on first look? Major holes in draft?		
9	Lunch	All	12:00
10	Break into chapter groups to address specific remarks and work on solutions to remarks	All	1:00
11	Break	All	3:00
12	Break into chapter groups to address specific remarks and work on solutions to remarks	All	3:15
13	Break for the day	All	5:00

Tuesday, August 30, 2011

1	Review final schedule for completion of the document Schedule conference call times	Pratt	8:00
2	Galley proof review process	Pratt	9:00
3	Break	All	10:00
4	Break into chapter groups to address specific remarks and work on solutions to remarks	All	10:15
5	Meeting summary review - Define the work that will need to be done - Define the timing for getting everything done	All	11:00
6	Lunch	All	12:00
7	Break into chapter groups to address specific remarks and work on solutions to remarks	All	1:00
8	Adjourn	All	2:00

Appendix C. Schedule Tabular Data

Table C–1 Building Occupancy Schedule, January–November, Fraction of Peak

Schedule	1-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-24
Weekday	0.00	0.05	0.05	0.15	0.20	0.20	0.25	0.25	0.20	0.20	0.20	0.20	0.25	0.25	0.20	0.20	0.15	0.05
Saturday	0.00	0.05	0.05	0.15	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.15	0.05
Sunday	0.00	0.05	0.05	0.15	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.15	0.05	0.05	0.00

Table C–2 Building Occupancy Schedule, December, Fraction of Peak

Schedule	1-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-24
Weekday	0.00	0.10	0.10	0.20	0.30	0.30	0.40	0.40	0.30	0.30	0.30	0.30	0.40	0.40	0.30	0.30	0.20	0.10
Saturday	0.00	0.10	0.10	0.20	0.30	0.30	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.30	0.30	0.20	0.10
Sunday	0.00	0.10	0.10	0.20	0.30	0.30	0.40	0.40	0.40	0.40	0.40	0.40	0.30	0.30	0.20	0.10	0.10	0.00

Table C–3 Infiltration Schedule, Fraction of Peak

Schedule	1-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-24
Weekday, Saturday	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Sunday	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.00

Table C–4 Heating and Cooling Set Point Schedule, Degrees Fahrenheit

Schedule	1-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-24
Heating Weekday, Saturday	60.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
Heating Sunday	60.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	60.0
Cooling Weekday, Saturday	86.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0
Cooling Sunday	86.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	86.0

Table C–5 Baseline Lighting Schedule, Fraction of Peak

Schedule	1-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-24
Weekday, Saturday	0.10	0.50	0.50	0.50	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.50	0.10
Sunday	0.10	0.50	0.50	0.50	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.50	0.50	0.50	0.10

Table C–6 Baseline Electric Equipment Schedule, Fraction of Peak

Schedule	1-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-24
Weekday, Saturday	0.40	0.60	0.60	0.60	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.60	0.60
Sunday	0.40	0.60	0.60	0.60	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.60	0.60	0.60	0.40

Table C–7 Low-Energy Lighting Schedule, Fraction of Peak

Schedule	1-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-24
Weekday, Saturday	0.00	0.16	0.16	0.16	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.16	0.16
Sunday	0.00	0.16	0.16	0.16	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.16	0.00

Table C–8 Low-Energy Electric Equipment Schedule, Fraction of Peak

Schedule	1-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-24
Weekday, Saturday	0.10	0.60	0.60	0.60	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.60	0.60
Sunday	0.10	0.60	0.60	0.60	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.60	0.60	0.60	0.10

Appendix D. Energy Management System Code

The EnergyPlus EMS code in this section uses the following variables:

- CleanSystemName: this refers to the name of the air system serving the zone. This is the same as the system name, except all illegal characters (spaces, etc.) are removed so that the system name can be used as a variable
- SystemName: this refers to the name of the air system serving the zone
- ZoneName: the name of the zone being served by the system

D.1 VAV Supply Air Temperature Reset

This EMS code determined the supply air temperature of the VAV system.

```
!- Sensors
EnergyManagementSystem:Sensor,
  #(CleanSystemName)_OA_Enth,
  Environment,
  Outdoor Enthalpy;

EnergyManagementSystem:Sensor,
  #(CleanSystemName)_OA_Tdb,
  Environment,
  Outdoor Dry Bulb;

EnergyManagementSystem:Sensor,
  #(CleanSystemName)_Pb,
  Environment,
  Outdoor Barometric Pressure;

EnergyManagementSystem:Sensor,
  #(CleanSystemName)_RA_Enth,
  #(SystemName) Supply Equipment Inlet Node,
  System Node Enthalpy;

EnergyManagementSystem:Sensor,
  #(CleanSystemName)_Heat_Load,
  #(ZoneName),
  Zone/Sys Sensible Load to Heating Setpoint Predicted;

EnergyManagementSystem:Sensor,
  #(CleanSystemName)_FanFraction,
  #(ZoneName) VAV Box Component,
  VAV Terminal Damper Position;

EnergyManagementSystem:Sensor,
  #(CleanSystemName)_MinFlowFraction,
  #(ZoneName) VAV Box Component,
  VAV Terminal Minimum Air Flow Fraction;

EnergyManagementSystem:Sensor,
  #(CleanZoneName)_RH,
  #(ZoneName),
  Zone Air Relative Humidity;

EnergyManagementSystem:Sensor,
  #(CleanZoneName)_Tdb,
```

```

    #(ZoneName),
    Zone/Sys Air Temperature;

EnergyManagementSystem:Sensor,
    #(CleanSystemName)_ClgSetP,
    ClgSetP_Sch,
    Schedule Value;

EnergyManagementSystem:Sensor,
    #(CleanSystemName)_SAT,
    VAV_SAT_Schedule,
    Schedule Value;

EnergyManagementSystem:Sensor,
    #(CleanSystemName)_SAT_Econ,
    VAV_Econ_SAT_Schedule,
    Schedule Value;

!- Trend Variables
EnergyManagementSystem:TrendVariable,
    #(CleanSystemName)_FanFractionLog,
    #(CleanSystemName)_FanFraction,
    4;

!- Global Variables
EnergyManagementSystem:GlobalVariable,
    #(CleanSystemName)_SAT_Value;

!- Actuators
EnergyManagementSystem:Actuator,
    #(CleanSystemName)_SAT_Sch_Act,
    #(SystemName)_SAT_Sch,
    Schedule:Compact,
    Schedule Value;

EnergyManagementSystem:Actuator,
    #(CleanSystemName)_Fan_Sch_Act,
    #(SystemName)_Fan_Sch,
    Schedule:Compact,
    Schedule Value;

EnergyManagementSystem:Actuator,
    #(CleanZoneName)_PTAC_Fan_Sch_Act,
    #(ZoneName)_PTAC_Fan_Sch,
    Schedule:Compact,
    Schedule Value;

!- Calling Managers
EnergyManagementSystem:ProgramCallingManager,
    #(CleanSystemName)_Initialize_Globals_Call,
    BeginNewEnvironment,
    #(CleanSystemName)_Initialize_Globals;

EnergyManagementSystem:ProgramCallingManager,
    #(CleanSystemName)_SAT_Reset_Call,
    AfterPredictorBeforeHVACManagers,
    #(CleanSystemName)_SAT_Reset;

```

```

!- Programs
EnergyManagementSystem:Program,
  # (CleanSystemName)_Initialize_Globals,
  SET # (CleanSystemName)_SAT_Value = # (CleanSystemName)_SAT;

EnergyManagementSystem:Program,
  # (CleanSystemName)_SAT_Reset,
  !- Check for heating mode
  IF # (CleanSystemName)_Heat_Load > 0,
    !- System is in heating mode; turn off VAV and turn on PTAC
    SET # (CleanSystemName)_Fan_Sch_Act = 0,
    SET # (CleanZoneName)_PTAC_Fan_Sch_Act = 1,
  ELSE,
    !- Not in heating mode; turn on VAV and turn off PTAC
    SET # (CleanSystemName)_Fan_Sch_Act = 1,
    SET # (CleanZoneName)_PTAC_Fan_Sch_Act = 0,
    !- Check for extended economizing conditions
    IF (# (CleanSystemName)_OA_Tdb > # (CleanSystemName)_SAT_Value),
      IF # (CleanSystemName)_OA_Enth < # (CleanSystemName)_RA_Enth,
        !- Economizing Conditions
        SET # (CleanSystemName)_SAT_Sch_Act = # (CleanSystemName)_SAT_Econ,
        SET # (CleanSystemName)_SAT_Value = # (CleanSystemName)_SAT_Econ,
      ENDIF,
    ELSE,
      SET # (CleanSystemName)_SAT_Sch_Act = # (CleanSystemName)_SAT_Value,
    ENDIF,
    !- Check for low load case; min flow stop indicates low load
    IF (@TrendSum # (CleanSystemName)_FanFractionLog
3)<3* (# (CleanSystemName)_MinFlowFraction + 0.01),
      !- Low load case; increase SAT 5 F as per 90.1-2010
      SET # (CleanSystemName)_SAT_Sch_Act = # (CleanSystemName)_SAT + 2.78,
      SET # (CleanSystemName)_SAT_Value = # (CleanSystemName)_SAT + 2.78,
    ELSE,
      !- Not low load case
      SET # (CleanSystemName)_SAT_Sch_Act = # (CleanSystemName)_SAT_Value,
    ENDIF,
    !- Check if near top of deadband
    IF # (CleanZoneName)_Tdb > (# (CleanSystemName)_ClgSetP - 1.0),
      !- Near cooling set point; revert to original SAT
      SET # (CleanSystemName)_SAT_Sch_Act = # (CleanSystemName)_SAT,
      SET # (CleanSystemName)_SAT_Value = # (CleanSystemName)_SAT,
    ELSE,
      !- Not near cooling set point
      SET # (CleanSystemName)_SAT_Sch_Act = # (CleanSystemName)_SAT_Value,
    ENDIF,
  ENDIF,
  !- Humidity check
  !- Determine dewpoint at 75 F, 60% RH
  SET # (CleanSystemName)_W = @WFnTdbRhPb 23.89 0.6 # (CleanSystemName)_Pb,
  SET # (CleanSystemName)_Tdp = @TdpFnWPb # (CleanSystemName)_W
# (CleanSystemName)_Pb,
  !- Compare zone conditions to threshold value
  SET # (CleanZoneName)_W = @WFnTdbRhPb # (CleanZoneName)_Tdb
# (CleanZoneName)_RH/100 # (CleanSystemName)_Pb,
  SET # (CleanZoneName)_Tdp = @TdpFnWPb # (CleanZoneName)_W
# (CleanSystemName)_Pb,

```

```

IF #(CleanZoneName)_Tdp > #(CleanSystemName)_Tdp,
  !- High humidity case; set SAT to default
  SET #(CleanSystemName)_SAT_Sch_Act = #(CleanSystemName)_SAT,
  SET #(CleanSystemName)_SAT_Value = #(CleanSystemName)_SAT,
ELSE,
  !- Not high humidity
  SET #(CleanSystemName)_SAT_Sch_Act = #(CleanSystemName)_SAT_Value,
ENDIF;

```

D.2 Energy Recovery Ventilator/Evaporative Cooler Selector

This EMS code switched between an ERV and an evaporative cooler to model using an evaporative cooler and a sensible heat exchanger.

```

!- Sensors
EnergyManagementSystem:Sensor,
  #(CleanSystemName)_Warm_Season,
  Warm_Season_Sch,
  Schedule Value;

EnergyManagementSystem:Sensor,
  #(CleanSystemName)_Cold_Season,
  Cold_Season_Sch,
  Schedule Value;

!- Internal Variables
EnergyManagementSystem:InternalVariable,
  #(CleanSystemName)_FanSP,
  #(SystemName)_Fan,
  Fan Nominal Pressure Rise;

!- Actuators
EnergyManagementSystem:Actuator,
  #(CleanSystemName)_FanSP_Act,
  #(SystemName)_Fan,
  Fan,
  Fan Pressure Rise;

!- Calling Manager
EnergyManagementSystem:ProgramCallingManager,
  #(CleanSystemName)_ERV_IDEC_Control_Call,
  AfterPredictorBeforeHVACManagers,
  #(CleanSystemName)_ERV_IDEC_Control;

!- Program
EnergyManagementSystem:Program,
  #(CleanSystemName)_ERV_IDEC_Control, !- Name
  SET #(CleanSystemName)_ERV_SP = #(CleanSystemName)_Cold_Season * 253,
  SET #(CleanSystemName)_IDEC_SP = #(CleanSystemName)_Warm_Season * 295,
  SET #(CleanSystemName)_FanSP_Act = #(CleanSystemName)_FanSP +
  #(CleanSystemName)_ERV_SP,
  SET #(CleanSystemName)_FanSP_Act = #(CleanSystemName)_FanSP_Act +
  #(CleanSystemName)_IDEC_SP;

```