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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Analysis of IECC (2003, 2006, 2009) and ASHRAE 90.1-2007 Commercial Energy Code Requirements for Mesa, AZ

Y Huang
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February 2011

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Richland, Washington 99352

Executive Summary

This report summarizes code requirements and energy savings for commercial buildings in climate zone 2B built to the 2009 IECC and ASHRAE Standard 90.1-2007 when compared to the 2003 IECC and the 2006 IECC.

In general, the 2009 IECC and ASHRAE Standard 90.1-2007 have higher insulation requirements for exterior walls, roof, and windows and have higher efficiency requirements for heating, ventilating and air-conditioning (HVAC) equipment. HVAC equipment efficiency requirements are governed by the National Appliance Energy Conservation Act of 1987 (NAECA), and are applicable regardless of the IECC version adopted.

The energy analysis results show that commercial buildings meeting the 2009 IECC requirements save between 4.4% and 9.5% site energy and between 4.1% and 9.9% energy cost when compared to the 2006 IECC; and save between 10.6% and 29.4% site energy and between 10.3% and 29.3% energy cost when compared to the 2003 IECC. Similar analysis comparing ASHRAE Standard 90.1-2007 requirements to the 2006 IECC shows that the energy savings are between 4.0% and 10.7% for multifamily and retail buildings, but less than 2% for office buildings. Further comparison of ASHRAE Standard 90.1-2007 requirements to the 2003 IECC shows site energy savings in the range of 7.7% to 30.6% and an energy cost savings ranging from 7.9% to 30.3%. Both the 2009 IECC and ASHRAE Standard 90.1-2007 have the potential to save energy by comparable levels for most building types.

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1. Background and Scope

The city of Mesa, AZ is considering adoption of 2009 IECC/ASHRAE Standard 90.1-2007 and requested the assistance of the Department of Energy's (DOE's) Building Energy Codes Program to determine energy savings and environmental impact of adopting the 2009 IECC/ASHRAE Standard 90.1-2007 compared to the 2003 and 2006 IECC. Because Mesa currently has not adopted any energy code and most new construction is based on the 2006 IECC, both 2003 IECC and 2006 IECC are used as baselines to compare the impact of 2009 IECC and ASHRAE 90.1-2007. The 2003 IECC baseline is included in this study to represent buildings that are less efficient and do not meet the 2006 IECC.

The following four building types have been chosen for energy simulation and analysis:

1. Multifamily residential: Mid-rise apartment building
2. Nonresidential: Small three-story office building
3. Nonresidential: Small retail building
4. Semiheated: Industrial office/warehouse building

DOE Commercial Reference Building Models[a] for the above building types were adapted for the analysis. Four sets of energy simulation using EnergyPlus were carried out to estimate energy consumption for each building model meeting the envelope, lighting and mechanical requirements of the 2003 IECC, the 2006 IECC, the 2009 IECC and ASHRAE Standard 90.1-2007.

This report focuses on the comparison of code requirements and energy analysis results for the above building types. In addition to energy savings estimates, the analysis also includes annual energy cost and CO_2 emissions estimates. This study does not address cost effectiveness analysis or payback period for the additional cost of complying with the newer codes.

[a] http://www1.eere.energy.gov/buildings/commercial_initiative/reference_buildings.html

2. Comparison of Code Requirements

The commercial code requirements in the 2003 IECC, the 2006 IECC, the 2009 IECC and ASHRAE Standard 90.1-2007 for envelope, mechanical and lighting systems are listed in Tables 1 and 2. All code requirements for climate zone 2B from the 2006 IECC, 2009 IECC and ASHRAE Standard 90.1-2007, and climate zone 3C from the 2003 IECC are used in this comparison. The scope of comparison is limited to building characteristics that can be modeled for detailed energy simulation and analysis. Major differences are summarized below:

- Insulation requirements for roofs and above-grade walls in the 2009 IECC are significantly more stringent for all construction types when compared to the 2003/2006 IECC.
- Both the 2009 IECC and ASHRAE Standard 90.1-2007 have separate sets of requirements for residential (Group "R") and non-residential buildings. However, the insulation requirements for residential and non-residential construction in the 2009 IECC are the same except for mass walls.
- Below-grade wall insulation and slab insulation requirements remain the same in all codes except for the 2009 IECC, which requires a more stringent F-factor (F-0.54) for a residential unheated slab.
- The 2003 IECC has no requirements for window U-factors, and solar heat gain coefficient (SHGC) requirements were less stringent compared to the 2006 IECC, the 2009 IECC and ASHRAE Standard 90.1-2007.
- Metal building insulation requirements in the 2009 IECC are more stringent, and mandatory continuous insulated sheathing on metal building walls is required.
- Plastic skylight requirements are removed in the 2009 IECC, and all skylights are required to meet more stringent U-factor and SHGC requirements.
- HVAC equipment efficiency requirements for unitary air conditioners, chilled water systems and boilers are more stringent in the 2009 IECC and ASHRAE Standard 90.1-2007 (these are based on National Appliance Energy Conservation Act (NAECA) requirements and are applicable regardless of the version of IECC adopted).
- Economizer requirements in the 2009 IECC require economizers when cooling capacity exceeds 54 kBtu/h.
- Interior lighting power allowances remain the same in all codes for the area categories of buildings analyzed in this study, although there are variations for some space types.
- Lighting zone based power allowance requirements are specified for exterior lighting in the 2009 IECC and ASHRAE Standard 90.1-2007.

A detailed comparison of code requirements in the 2009 IECC and ASHRAE Standard 90.1-2007 can be found at: http://www.energycodes.gov/publications/research/documents/codes/90-1_iecc_comparison_final_12-16-2009.pdf

Table 1: Comparison of Envelope Requirements

Mesa, AZ (Climate Zone 2B) Section	Sub-category	2003 IECC	2006 IECC	2009 IECC		ASHRAE 90.1-2007	
502 Envelope							
502.2 Specific insulation requirements		WWR<25%		**All other**	**Group R**	**Non-Res**	**Residential**
Roofs	Insulation above deck	U-0.057	U-0.063	U-0.048	U-0.048	U-0.048	U-0.048
	Metal building	U-0.057	U-0.065	U-0.055	U-0.055	U-0.065	U-0.065
	Wood joist attic roof	U-0.093	U-0.034	U-0.027	U-0.027	U-0.027	U-0.027
Above-grade wall	Metal building	U-1.180	U-0.124	U-0.084	U-0.084	U-0.113	U-0.123
	Metal frame	U-0.352	U-0.124	U-0.064	U-0.064	U-0.124	U-0.064
	Wood frame	U-0.282	U-0.089	U-0.089	U-0.089	U-0.089	U-0.089
	Mass	U-0.058	U-0.058	U-0.151	U-0.123	U-0.151	U-0.123
Below-grade wall		C-1.104	C-1.104	C-1.104	C-1.104	C-1.104	C-1.104
Slab-on-grid floors	Unheated slab	F-0.73	F-0.73	F-0.73	F-0.54	F-0.73	F-0.73
Opaque doors	Swinging	NA (use U-0.7)	U-0.70	U-0.70	U-0.7	U-0.70	U-0.70
	Roll-up or sliding		U-1.45	U-0.048	U-0.048	U-1.45	U-0.5
502.3 Fenestration							
Vertical fenestration (WWR: 0%-10%)	Framing other than metal	NA	U-0.75	U-0.75	-	U-0.75	U-0.75
	Metal framing - curtain wall		U-0.70	U-0.70	-	U-0.70	U-0.70
	Metal framing - entrance dr		U-1.10	U-1.10	-	U-1.10	U-1.10
	Metal framing - all other		U-0.75	U-0.75	-	U-0.75	U-0.75
	PF<0.25		SHGC-0.25	SHGC-0.25	-	SHGC-0.25	SHGC-0.25
	0.25<=PF<0.5		SHGC-0.33	SHGC-0.33	-	SHGC-0.25	SHGC-0.25
	PF>=0.5		SHGC-0.40	SHGC-0.40	-	SHGC-0.25	SHGC-0.25
Vertical fenestration (WWR: 10%-25%)	Framing other than metal	NA	U-0.75	U-0.75	-	U-0.75	U-0.75
	Metal framing - Curtain Wall		U-0.70	U-0.70	-	U-0.70	U-0.70
	Metal framing - Entrance dr		U-1.10	U-1.10	-	U-1.10	U-1.10
	Metal framing - all other		U-0.75	U-0.75	-	U-0.75	U-0.75
	PF<0.25	SHGC-0.5	SHGC-0.25	SHGC-0.25	-	SHGC-0.25	SHGC-0.25
	0.25<=PF<0.5	SHGC-0.6	SHGC-0.33	SHGC-0.33	-	SHGC-0.25	SHGC-0.25
	PF>=0.5	SHGC-0.7	SHGC-0.40	SHGC-0.40	-	SHGC-0.25	SHGC-0.25

Table 2: Comparison of Mechanical and Lighting Requirements

Mesa, AZ (Climate Zone 2B) Section	Sub-category	2003 IECC	2006 IECC	2009 IECC	ASHRAE 90.1-2007
503 Mechanical					
503.2.3 HVAC equipment performance requirements					
Unitary AC, Electrical	<65 kBtu/h Single package	10.0 SEER	10.0 SEER	13.0 SEER	13.0 SEER
	<65 kBtu/h Split	9.7 SEER	9.7 SEER	13.0 SEER	13.0 SEER
	>= 65 kBtu/h & < 135 kBtu/h	N.A	10.3 EER	11.2 EER	11.2 EER
	>= 135 kBtu/h & < 240 kBtu/h		9.7 EER	11.0 EER	11.0 EER
	>= 240 kBtu/h & < 760 kBtu/h		9.5 EER	10.0 EER	10.0 EER
	> 760 kBtu/h		9.2 EER	9.7 EER	9.7 EER
Warm air furnaces	Gas fired	80% Et	80% Et	80% Et	80% Et
DCV	space >500 sqft + 40 person/1000sqft	NA	NA	Required	Required
ERV	Fan >=5000 cfm + 70% min fraction	NA	ERV+exceptions	ERV+exceptions	ERV+exceptions
503.2.10 Air System design and control					
	fan motor>5 hp	NA	NA	CAV: hp<= CFM*0.0011 VAV: hp<= CFM*0.0015	CAV: hp<= CFM*0.0011 VAV: hp<= CFM*0.0015
505 Lighting					
505.5 Interior lighting power requirements (use building type overall LPD)					
	Multifamily building	0.7 w/ft^2	0.7 w/ft^2	0.7 w/ft^2	0.7 w/ft^2
	Retail	1.5 w/ft^2	1.5 w/ft^2	1.5 w/ft^2	1.5 w/ft^2
	Warehouse	0.8 w/ft^2	0.8 w/ft^2	0.8 w/ft^2	0.8 w/ft^2
	Office	1.0 w/ft^2	1.0 w/ft^2	1.0 w/ft^2	1.0 w/ft^2
505.6 Exterior Lighting					
	Multifamily building	Parking: 0.06 W/ft^2 Façade: 0.1 W/ft^2	Parking: 0.15 W/ft^2 Façade: 0.2 W/ft^2	No specific LPD requirements.	Parking: 0.15 W/ft^2 Façade: 0.2 W/ft^2
	Retail Warehouse Small Office	Parking: 0.10 W/ft^2 Main entries: 30 W/ft Other doors: 20 W/ft Façade: 0.15 W/ft^2	Parking: 0.15 W/ft^2 Main entries: 30 W/ft Other doors: 20 W/ft Façade: 0.2 W/ft^2		Parking: 0.15 W/ft^2 Main entries: 30 W/ft Other doors: 20 W/ft Façade: 0.2 W/ft^2

3. Energy Analysis

The impact of code requirements are quantified by analyzing building models representing the envelope, lighting and mechanical requirements identified in the comparison Tables 1 and 2. DOE Commercial Reference Building models for four representative building types were used for the analysis. A brief description of each e building type is given below:

1. **Residential – Multifamily/Mid-rise apartment building** (33,700 sf): This is a four story building with 15% window-wall ratio. This building is assumed to have steel frame walls, metal deck roof with insulation above deck and a slab-on-grade floor. Each apartment unit is assumed to have a packaged air-conditioning unit with a gas furnace and a 20-gallon electric service water heating system. More details of the thermal model with the baseline properties are listed in Appendix-A, Table A-1.
2. **Nonresidential – Medium office building** (53,600 sf): This is a three-story building with a 33% window-wall ratio. This building is assumed to have steel frame walls, metal deck roof with insulation above deck and a slab-on-grade floor. The HVAC system is multi-zone variable air volume (VAV) system with electric reheat, and packaged air-conditioner with gas furnace. Service water heating is assumed to be 260-gallon gas water heater. Further details on the energy model are provided in Appendix-A, Table A-2.
3. **Nonresidential – Small retail / strip mall building** (22,500 sf): This is a single-story strip mall building with 10% window-wall ratio. The floor plan is assumed to have ten store spaces including two large stores of 3750 sf each and eight smaller stores of 1875 sf each. This building is assumed to have steel frame walls, metal deck rook with insulation above deck and a slab-on-grade floor. Each store is assumed to have a rooftop packaged air-conditioning unit with a gas furnace and a 6 gallon natural gas service water heating system.
4. **Semiheated – Large warehouse building** (52,045 sf): This is a non-refrigerated warehouse building with an office area, fine storage and bulk storage areas. This building is assumed to have metal building walls, metal deck rook with insulation above deck and a slab-on-grade floor. The office area is conditioned by a packaged air conditioning unit with gas furnace and the storage areas are heated with a natural gas unit heater. Service water heating is assumed to be a 20 gallon electric storage water heater.

Hourly energy simulation of the building model was performed for each of the four codes: 2003 IECC, 2006 IECC, 2009 IECC and ASHRAE 90.1-2007. EnergyPlus simulation software was used for the analysis. A typical design day simulation was done to determine the HVAC equipment size, and then the annual simulation was run to determine the building energy use. The total building site energy is extracted from the simulation results for code comparisons.

To assess the economic impacts of the code requirements, current utility tariffs for Mesa City[b] are used to calculate the total annual energy cost. Table 3 shows the fuel prices, demand charges and rate structure used, assuming a basic rate plan.

[b] http://www.mesaaz.gov/custserv/pdf/Utilityratebook.pdf

Table 3: Utility tariffs used for Mesa City (2010-2011)

	Nonresidential		Residential	
	Gas	Electricity	Gas	Electricity
Monthly Charge	Winter: $37.77/month	$6.22/month	Winter: $12.3/month	$5.71/month
	Summer:$28.32/month		Summer:$9.44/month	
Energy Charge	Winter:	Winter:	Winter:	Winter:
	<1200therm: $0.5579/therm	<15000kWh: $0.07595/kWh	<25therm: $0.6522/therm	<800kWh: $0.07065/kWh
	Remaining: $0.4462/therm	>15000kWh& <60000 kWh: $0.05912/ kWh	Remaining: $0.4806/therm	Remaining: $0.04933 kWh
		Remaining: $0.0428 kWh		
	Summer:	Summer:	Summer:	Summer:
	<1200therm: $0.5151/therm	<15000 kWh: $0.08941/ kWh	<25therm: $0.6522/therm	<1200 kWh: $0.08768/ kWh
	Remaining: $0.3089/therm	>15000 kWh & <60000 kWh:	Remaining: $0.2114/therm	Remaining: $0.08462 kWh
		Remaining: $0.05351 kWh		
Demand Charge	N.A.	Winter: >50W:	N.A.	N.A.
		Summer: >50W: $3.9168/W		
Winter: Nov. – April; Summer: May-Oct				

In addition to calculating the annual energy consumption and cost savings, the analysis also includes estimates for carbon emissions based on state-average CO_2 emission factors available in the EnergyPlus data set. For the state of Arizona, CO_2 emission factors assumed are: 50.23 g/MJ for natural gas and 132.3 g/MJ for electricity.

The energy simulation results are summarized in Table 4 for all the building types and codes considered in this study. This summary includes total annual electricity consumption, natural gas consumption, electricity demand, annual energy cost and CO_2 emissions. It can be observed that the overall savings are significantly higher for residential construction than nonresidential or semiheated buildings. This can be attributed to the increased insulation requirements for above-grade envelope components for residential buildings in the 2009 IECC and ASHRAE 90.1.

Table 4: Detailed Simulation Results

Mesa, AZ -- Energy End Use Detailed Results								
Building Prototype	Code	Energy Use Intensity						
		Electricity (kWh/sf/yr)	Natural Gas (kBtu/sf/yr)	EUI (kBtu/sf)	Elec.Demand (kW)	Utility Cost ($)	CO_2 Emission (tons)
Multifamily	2003 IECC	14.1	1.6	49.7	108.3	$33,734	230.7
	2006 IECC	12.0	1.0	42.0	87.6	$28,670	196.4
	2009 IECC	11.0	0.7	38.4	75.3	$26,091	179.8
	ASHRAE 90.1-2007	11.0	0.6	38.1	74.8	$25,890	178.5
Medium office	2003 IECC	14.5	2.4	52.0	304.2	$61,813	382.2
	2006 IECC	13.7	2.5	49.1	285.1	$58,363	360.0
	2009 IECC	13.1	2.5	47.0	276.8	$56,065	344.3
	ASHRAE 90.1-2007	13.4	2.5	48.3	276.8	$57,303	353.8
Small retail	2003 IECC	20.2	4.1	72.9	164.1	$36,674	222.9
	2006 IECC	18.9	3.3	68.0	152.3	$34,394	208.7
	2009 IECC	17.8	3.0	63.7	144.3	$32,450	195.7
	ASHRAE 90.1-2007	18.2	3.0	65.2	144.3	$33,071	200.5
Large warehouse	2003 IECC	6.9	2.1	25.8	129.0	$29,608	179.5
	2006 IECC	5.9	1.5	21.5	96.5	$24,788	150.4
	2009 IECC	5.6	1.4	20.5	92.1	$23,717	143.3
	ASHRAE 90.1-2007	5.8	1.5	21.2	95.1	$24,482	148.5

Table 5: Energy Cost Summary ($/sf/year)

Mesa, AZ – Annual Energy Cost Comparison ($/sf)				
Building Prototype	2003 IECC	2006 IECC	2009 IECC	ASHRAE 90.1-2007
Multifamily	1.00	0.85	0.77	0.77
Medium office	1.15	1.09	1.05	1.07
Small retail	1.63	1.53	1.44	1.47
Large warehouse	0.57	0.48	0.46	0.47

4. Conclusions

Assuming that the current buildings in Mesa, AZ are complying with the 2003 IECC or the 2006 IECC commercial building requirements, Tables 6 and 7 show the comparison of energy savings and CO_2 emission reductions if these are built to comply with the 2009 IECC and ASHRAE Standard 90.1-2007, given the assumptions used in the analysis.

Table 6: Energy Use and Cost Savings Comparison (percentage)

Mesa, AZ -- Energy End Use Percentage Savings								
	2009 IECC				ASHRAE 90.1-2007			
	vs. 2003 IECC		vs. 2006 IECC		vs. 2003 IECC		vs. 2006 IECC	
Building Prototype	EUI	Cost	EUI	Cost	EUI	Cost	EUI	Cost
Multifamily	29.4%	29.3%	9.5%	9.9%	30.6%	30.3%	10.5%	10.7%
Medium office	10.6%	10.3%	4.4%	4.1%	7.7%	7.9%	1.7%	1.9%
Small retail	14.5%	13.0%	6.8%	6.0%	11.8%	10.9%	4.3%	4.0%
Large warehouse	26.1%	24.8%	5.0%	4.5%	21.6%	20.9%	1.2%	1.3%

Table 7: CO_2 Emission Reduction Comparison (percentage)

Mesa, AZ – CO_2 Emission Reduction				
	2009 IECC		ASHRAE 90.1-2007	
Building Prototype	vs. 2003 IECC	vs. IECC 2006	vs. 2003 IECC	vs. IECC 2006
Multifamily	22.00%	8.45%	22.67%	9.15%
Medium office	9.92%	4.35%	7.44%	1.70%
Small retail	12.19%	6.23%	10.05%	3.94%
Large warehouse	20.18%	4.72%	17.31%	1.28%

Based on the analysis, it can be observed that:

- Multifamily buildings built to the 2009 IECC or ASHRAE Standard 90.1-2007 would use 30% less energy and save 30% in energy cost compared to the 2003 IECC, and reduce CO_2 emissions by 20%. They would use 10% less energy and save 10% in energy cost compared to the 2006 IECC, and reduce CO_2 emissions between 8 and 9%.
- All nonresidential buildings built to the 2009 IECC save between 10 and 25% energy and cost compared to the 2003 IECC and reduce CO_2 emissions by 10-20% depending on the building type. They would save between 4 and 6% energy and cost, and reduce CO_2 emissions by 5% compared to the 2006 IECC.
- All nonresidential buildings built to ASHRAE Standard 90.1-2007 have similar but relatively lower savings than buildings complying with 2009 IECC.

Appendix A – Prototype Building Descriptions

Table A-1: Residential Prototype Building Characteristics

Multifamily Building Characteristics		
General		
	Building type	Mid-rise Apartment
	Total floor area	33,700 sqft
	Building shape	Rectangle (152 ft x 55.5 ft)
	Aspect ratio	2.74
	Number of floors	4
	Window fraction	15 %
	Window shading	None
	Thermal zoning	Ground floor: 7 apartments and 1 lobby with equivalent apartment area Floors above: 8 apartments with corridor in center Zone depth is 25 ft for each apartment from side walls and each apt is 25' x 38' (950 ft²).
	Floor to floor height (feet)	10 ft
	Floor to ceiling height (feet)	10 ft (no drop down ceiling modeled)
	Glazing sill height (feet)	3 ft. (14 ft. wide x 4 ft. high)
	Exterior walls	Steel-framed wall
	Roof	Insulation entirely above deck, metal deck roof
	Foundation	8 inch concrete slab-on-grade floors (unheated)
	Interior partitions	2 x 4 uninsulated stud wall
	Internal mass	6 inches standard wood (16.6 lb/ft²)
	Infiltration	Peak: 0.2016 cfm/sf of above grade exterior wall surface area (when fans turn off) Off Peak: 25% of peak infiltration rate (when fans turn on)
Internal Loads & Schedules		
	Lighting power density (W/ft^2)	Apartment units: 0.36 W/ft² Corridor: 0.5 W/ft² Office: 1.1 W/ft²
	Plug load power density (W/ft^2)	Building average, 0.62 W/ft²
	Occupancy	78 Total (2.5 person per apartment unit)

Table A-1: Residential Prototype Building Characteristics (continued)

HVAC		
	System Type	
	Heating type	Gas furnace inside the packaged air conditioning unit
	Cooling type	Split DX System
	Distribution and terminal units	Constant volume
	HVAC Control	
	Thermostat setpoint	75 °F Cooling/70 °F Heating
	Thermostat setback	No setback
	Supply air temperature	Maximum 110 ºF, Minimum 52 ºF
	Ventilation	20 cfm/person
	Demand control ventilation	No
	Energy recovery	No
	Supply Fan	
	Fan type	Constant air volume
	Supply fan total efficiency (%)	70 %
	Supply fan pressure drop	0.2 inch water
	Service Water Heating	
	SWH type	Storage tank
	Fuel type	Electricity
	Thermal efficiency (%)	100%
	Tank volume (gal)	20 (one per unit)
	Water temperature setpoint	120 ºF
Misc.		
	Exterior Lighting	Not modeled

Table A-2: Nonresidential Prototype Building Characteristics

Medium Office Building Characteristics	
General	
Building prototype	Medium Office
Total floor area	53,600 sf
Building shape	Rectangle (163.8 ft x 109.2 ft)
Aspect ratio	1.5
Number of floors	3
Window fraction	33%
Shading geometry	None
Thermal zoning	Perimeter zone depth: 15 ft Each floor has four perimeter zones and one core zone. Percentages of floor area: Perimeter 40%, Core 60%
Floor to floor height (feet)	13 ft
Floor to ceiling height (feet)	9 ft, (4 ft above-ceiling plenum)
Glazing sill height (feet)	3.35 ft (top of the window is 7.64 ft high with 4.29 ft high glass)
Exterior walls	Steel-framed wall
Roof	Insulation entirely above deck, metal deck roof
Foundation	8 inch concrete slab-on-grade floors (unheated)
Interior partitions	2 x 4 uninsulated stud wall
Internal mass	6 inches standard wood (16.6 lb/ft^2)
Infiltration	Peak: 0.2016 cfm/sf of above grade exterior wall surface area (when fans turn off) Off Peak: 25% of peak infiltration rate (when fans turn on)
Internal Loads & Schedules	
Lighting power density (W/ft^2)	Building average, 1.00
Plug load power density (W/ft^2)	Building average, all zones 0.75
Occupancy	268 Total (5 persons/1000 sf)

Table A-2: Nonresidential Prototype Building Characteristics (continued)

HVAC		
	System Type	
	Heating type	Gas furnace inside the packaged air conditioning unit
	Cooling type	Packaged air conditioning unit
	Distribution and terminal units	VAV terminal box with damper and electric reheating coil Zone control type: minimum supply air at 30% of the zone design peak supply air.
	HVAC Control	
	Thermostat setpoint	75 °F Cooling/70 °F Heating
	Thermostat setback	80 °F Cooling/60 °F Heating
	Supply air temperature	Maximum 110 ºF, Minimum 52 ºF
	Ventilation	20 cfm/person
	Demand control ventilation	No
	Energy recovery	No
	Supply Fan	
	Fan type	Variable air volume
	Supply fan total efficiency (%)	57% to 60% depending on the fan motor size
	Supply fan pressure drop	4”-6.3” water
	Service Water Heating	
	SWH type	Storage tank
	Fuel type	Natural gas
	Thermal efficiency (%)	80%
	Tank volume (gal)	260
	Water temperature setpoint	120 ºF
Misc.		
	Exterior Lighting	
	Peak power	2730 W

Table A-3: Small Retail Prototype Building Characteristics

Small Retail Building Characteristics	
General	
Building prototype	Small retail
Total floor area	22,500 ft^2 (10 stores, including 2 large stores of 3750 sqft, and 8 small stores of 1875 sqft)
Building shape	Rectangle
Aspect ratio	4 (0.33 for small stores and 0.67 for large stores)
Number of floors	1
Window fraction	10.5%
Shading geometry	none
Thermal zoning	One zone per store
Floor to floor height (feet)	17 ft
Floor to ceiling height (feet)	17 ft
Glazing sill height (feet)	3.00 ft (top of the window is 8 ft high)
Exterior walls	Steel-framed wall
Roof	Insulation entirely above deck, metal deck roof
Foundation	6 inch concrete slab-on-grade floors (unheated)
Interior partitions	2x4 steel-frame with gypsum board
Internal mass	6 inch wood total mass area: 45,000 (ft^2) includes 2 large stores (7500 ft^2 each) and 8 small stores (3750 ft^2 each)
Infiltration	Peak: 0.2016 cfm/sf of above grade exterior wall surface area (when fans turn off) Off Peak: 25% of peak infiltration rate (when fans turn on)
Internal Loads & Schedules	
Lighting power density (W/ft^2)	1.5 W/ft^2
Plug load power density (W/ft^2)	Building average, all zones 0.4 W/ft^2
Occupancy	30 in each large store, and 15 in each small store

Table A-3: Small Retail Prototype Building Characteristics (continued)

HVAC		
	System Type	
	Heating type	Gas furnace inside the packaged air conditioning unit
	Cooling type	Packaged air conditioning unit
	Distribution and terminal units	10 single-zone rooftop units with constant air volume system. One unit serving one store.
	HVAC Control	
	Thermostat setpoint	75 °F Cooling/70 °F Heating
	Thermostat setback	85 °F Cooling/60 °F Heating
	Supply air temperature	Maximum 104 ºF, Minimum 55 ºF
	Ventilation	20 cfm/person
	Demand control ventilation	No
	Energy recovery	No
	Supply Fan	
	Fan Type	Constant air volume
	Supply fan total efficiency (%)	60% to 62% depending on the fan motor size
	Supply fan pressure drop	Various depending on the fan supply air cfm
	Service Water Heating	
	SWH type	Storage tank
	Fuel type	Natural gas
	Thermal efficiency (%)	78.40%
	Tank volume (gal)	6
	Water temperature setpoint	120 ºF
Misc.		
	Exterior Lighting	
	Peak power	See Table.2

Table A-4: Semiheated Prototype Building Characteristics

Large Warehouse Building Characteristics	
General	
Building type	Non-refrigerated warehouse
Total floor area	52,045 sqft
Building shape	Rectangle
Aspect ratio	2.2
Number of floors	1
Window fraction	Storage Area: No Windows; Office Area: 12% View windows; Overall: 0.71%; North: 0.76%; East: 0.0%; South: 0.0%; West: 2.86%
Shading geometry	None
Thermal zoning	Office: 2549.76 ft^2 Fine Storage: 14,998.54 ft^2 Bulk Storage: 34496.61 ft^2 (semi-heated)
Floor to floor height	28 ft
Floor to ceiling height (feet)	14ft (for the office area only)
Glazing sill height	3 ft (top of the window is 8 ft high)
Exterior walls	MetalBuilding
Roof	MetalBuilding
Foundation	6" concrete slab-on-Grade
Interior partitions	double layer of sypsum board with an exterior layer of stucco
Internal mass	defined as material with properties: density: 12.5 lb/sf thickness: 8ft Internal mass surface area: 64889.66 ft^2
Infiltration	Office: 0.078cfm/ft^2 Fine storage: 0.080 cfm/ft^2 Bulk storage: 4793.56 cfm
Internal Loads & Schedules	
Lighting	
Average power density (W/ft^2)	Fine and bulk area: 0.80 w//ft^2 Office area: 1.00 w//ft^2
Daylighting controls	Daylight control: bulk storage area
Occupancy sensors	No
Plug Load power density (W/ft^2)	Office: 0.75w//ft^2 Bulk storage: 0.24 w//ft^2
Occupancy	5 (in the office)

Table A-4: Semiheated Prototype Building Characteristics (continued)

HVAC		
	System Type	
	Heating type	Gas-fired furnace
	Cooling type	DX cooling coil
	Distribution and terminal units	Direct uncontrolled air
	HVAC Control	
	Thermostat setpoint	Fine storage: 80 °F Cooling/ 60 °F Heating; Office Area: 75 °F Cooling/ 70 °F Heating; Bulk Storage: 50 °F Heating;
	Thermostat setback	Office Area: 85 °F Cooling/60 °F Heating
	Supply air temperature	Maximum 110 ºF, Minimum 55 ºF
	Ventilation	bulk storage: 80009 cfm (exhaust); 2000 cfm (natural) Office: 0.085 cfm/ft^2 Storage: 0.06 cfm/ft^2
	Demand control ventilation	No
	Energy recovery	No
	Supply Fan	
	Fan type	Constant air volume
	Supply fan total efficiency (%)	Office Area: fan efficiency 54.6%, motor efficiency 84%; fine storage: fan efficiency 56.875%, motor efficiency 87.5; bulk storage unit heater: fan efficiency 53.6%, motor efficiency 82.5%
	Supply fan pressure drop	Office Area: 2.5” Water Fine storage: 2.5” water Bulk storage: 0.2” water
	Service Water Heating	
	SWH type	Electric storage water heater
	Fuel type	Electricity
	Thermal efficiency (%)	100%
	Tank volume (gal)	20
	Water temperature setpoint	120 ºF
Misc.		
	Exterior lighting peak power	4800 watts

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