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Prepared for the U.S. Department of Energy
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Comparison of 2006 IECC and 2009 IECC Commercial Energy Code Requirements for Kansas City, MO

Y Huang
K Gowri

March 2011

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

This report summarizes code requirements and energy savings of commercial buildings in Climate Zone 4 built to the 2009 IECC when compared to the 2006 IECC.

In general, the 2009 IECC has higher insulation requirements for exterior walls, roof, and windows and has higher efficiency requirements for heating, ventilation and air-conditioning (HVAC) equipment. HVAC equipment efficiency requirements are governed by the National Appliance Energy Conservation Act of 1987 (NAECA), and are applicable irrespective of the IECC version adopted.

The energy analysis results show that residential and nonresidential commercial buildings meeting the 2009 IECC requirements save 9.0% and 6.1% site energy, and 7.7% and 6.4% energy cost when compared to the 2006 IECC. Analysis also shows that semiheated buildings have energy and cost savings of 3.9% and 2.5%.

Table of Contents

Tables

1. Background and Scope

Kansas City, MO is considering the adoption of the 2009 IECC and requested the assistance of DOE's Building Energy Codes Program to determine energy savings and environmental impact of adopting the 2009 IECC compared to the 2006 IECC. The analysis set the 2006 IECC as the baseline, because it is the currently enforced energy code in Missouri.

The following three building types were chosen for energy simulation and analysis:

1. Multifamily residential: Mid-rise apartment building
2. Nonresidential: Medium office building
3. Semi-heated: Industrial office/warehouse building

Department of Energy (DOE) Commercial Reference Building Models[a] for the above building types were adapted for the analysis. The analysis study was conducted by using the EnergyPlus simulation tool, and the original models were modified to meet the envelope, lighting and mechanical requirements of the 2006 IECC, and the 2009 IECC, correspondingly. Typical meteorological year 2 (TMY2) weather data for Kansas City was chosen to run the simulation.

This report focuses on the comparisons of code requirements and energy analysis results for the above building types in Climate Zone 4. 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 or payback for the additional cost of complying with the 2009 IECC.

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

2. Comparison of Code Requirements

The commercial code requirements in the 2006 IECC and the 2009 IECC for envelope, mechanical and lighting systems are listed in Tables 1 and 2. The envelope insulation and fenestration requirements for Kansas City, MO are specified in the 2009 IECC Tables 502.1.2, 502.2 and 502.3 for Climate Zone 4 (except Marine), representing the requirements for Jackson County (Climate Zone 4A). The scope of comparison is limited to building characteristics that can be modeled for detailed energy simulation and analysis. The 2009 IECC includes a number of significant changes to commercial building requirements in Chapter 5. The most important changes include the introduction of the envelope U-factor table, Group R specific envelope requirements, HVAC minimum efficiency requirements, economizer requirements, pipe insulation requirements and exterior lighting requirements. Appendix-A provides a detailed comparison of all the changes between the 2006 IECC and 2009 IECC Chapter 5.

A qualitative summary of the 2009 IECC changes are listed below:

- Alternative compliance using ASHRAE/IESNA 90.1 requires the use of 90.1-2007 (instead of 90.1-2004).
- More stringent envelope requirements are included for "Group R" buildings, in addition to more stringent opaque envelope requirements for all commercial buildings in all climate zones.
- The opaque requirements for roof, above-grade walls and floors are more stringent in the 2009 IECC, but the below grade wall assemblies and fenestration requirements remain the same as 2006 IECC.
- Metal building insulation requirements have been revised to be more stringent and require mandatory continuous insulation sheathing on metal building walls.
- Plastic skylights requirements are removed and all skylights are required to meet more stringent U-factor and solar heat gain coefficient (SHGC) requirements.
- All recessed lighting is required to be IC-rated and sealed.
- HVAC equipment efficiency requirements for unitary air conditioners, chilled water systems and boilers have been revised to be more stringent. The minimum efficiency requirements for unitary air-conditioners is seasonal energy efficiency rating (SEER) 13.0 for the 2009 IECC compared to SEER 10.0 in the 2006 IECC. (These are based on NAECA requirements and are applicable irrespective of the version of IECC adopted.)
- Piping insulation requirements have been revised and 1 ½ inch insulation is required for all pipes with nominal pipe diameter less than or equal to 1 ½ inch.
- A new fan power requirements section has been added and fan power limitations are included.
- Economizer requirements have been revised to require economizers when cooling capacity exceeds 54 kBtu/h in all climate zones except 1, 2A, 7 and 8.

- Heat rejection equipment requirements have been revised based on climate zone, and a new exception is provided if a heat pump is used to reject heat throughout the year.
- A new requirement has been added for supply-air temperature reset controls to reset the supply air temperature based on building loads or outdoor air temperature.
- Lighting exemption for dwelling units is provided if high-efficacy lamps are used in at least 50% of all the permanent fixtures.
- A new section has been added requiring manual daylight zone controls in zones adjacent to vertical fenestration and zones with skylights.
- The interior lighting power requirements exemption list has been revised and expanded to specify more detailed functions such as photographic process, lighting in refrigerator/ freezer cases, and furniture-mounted task lighting that is controlled by automatic shut off.
- Interior lighting power allowance adjustments have been revised for retail display based on the type of products on display.
- Lighting-zone-based power allowance requirements are specified for exterior lighting.

Table 1: Comparison of Envelope Requirements

Kansas City, MO [Climate Zone 4 (except Marine)]					Change captured in the model
Section	**Sub-category**	**2006 IECC**	**2009 IECC**		
502 Envelope					
502.2 Specific insulation requirements			**All other**	**Group R**	
Roofs	Insulation entirely above deck	U-0.063	U-0.048	U-0.048	Yes
	Metal	U-0.065	U-0.055	U-0.055	
	Attic and other	U-0.034	U-0.027	U-0.027	
Above-grade wall	Mass	U-0.151	U-0.104	U-0.09	Yes
	Metal building	U-0.124	U-0.084	U-0.084	
	Metal framed	U-0.124	U-0.064	U-0.064	
	Wood framed and other	U-0.124	U-0.089	U-0.064	
Below-grade wall	Below-grade wall	C-1.14	C-1.14	C-0.119	No
Floors	Mass	U-0.087	U-0.087	U-0.074	Yes
	Joist/framing steel/(wood)	U-0.052	U-0.033	U-0.033	
Slab-on-grid floors	Unheated slab	F-0.73	F-0.73	F-0.54	Yes
	Heated slab	F-1.02	F-0.68	F-0.86	
Opaque doors	Swinging	U-0.70	U-0.70	U-0.7	Yes
	Roll-up or sliding	U-1.45	U-0.50	U-0.5	
502.3 Fenestration					
Vertical fenestration (<40%)	Framing other than metal	U-0.4	U-0.4	-	Yes
	Metal framing - curtain Wall/storefront	U-0.50	U-0.50	-	
	Metal framing - entrance door	U-0.85	U-0.85	-	
	Metal framing - All other	U-0.55	U-0.55	-	
	PF<0.25	SHGC-0.4	SHGC-0.4	-	Yes
	0.25<=PF<0.5	SHGC-NR	SHGC-NR	-	
	PF>=0.5	SHGC-NR	SHGC-NR	-	
502.4 Air Leakage					
502.4.4 Hot gas bypass limitation	<=90 kBtu/h	NA	Max hot gas capacity: excepted		No
	> 90 kBtu/h and <= 240 kBtu/h	NA	Max hot gas capacity: 50%		
	>240 kBtu/h	NA	Max hot gas capacity: 25%		
502.4.7 Recessed luminaires		non-IC rated fixture allowed	All fixtures shall be IC-rated		No
502.5 Moisture control		vapor retarder required	NA		No

Table 2: Comparison of Mechanical and Lighting Requirements

Kansas City, MO [Climate Zone 4 (except Marine)]					Change captured in the model
Section	**Sub-category**	**2006 IECC**	**2009 IECC**		
503 Mechanical					
503.2.3 HVAC equipment performance requirements					
Unitary AC, electrical	<65 kBtu/h Single package	10.0 SEER	13.0 SEER	-	Yes
	<65 kBtu/h Split	9.7 SEER	13.0 SEER	-	
	>= 65 kBtu/h & < 135 kBtu/h	10.3 EER	11.2 EER	-	
	>= 135 kBtu/h & < 240 kBtu/h	9.7 EER	11.0 EER	-	
	>= 240 kBtu/h & < 760 kBtu/h	9.5 EER	10.0 EER	-	
	> 760 kBtu/h	9.2 EER	9.7 EER	-	
DCV	Space >500 sqft + 40person/1000sqft at average	NA	Required + 1 of 3 systems		No
ERV	Fan >=5000 cfm + 70% min fraction	ERV+exception	ERV+different exception		No
503.2.10 Air system design and control					
	Fan motor>5 hp	NA	CAV: hp<= cfm*0.0011 VAV: hp<= cfm*0.0015		No
505 Lighting					
505.5 Interior lighting power requirements					
	Lighting Power Density		Allows additional interior lighting power		No
505.6 Exterior lighting					
		1 bin	4 exterior lighting zones: Zone 3 used for non-residential	4 exterior lighting zones: Zone 4 used for residential	Yes

3. Energy Analysis

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

1. **Residential – Multifamily/Midrise 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 rook 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 33% window-wall ratio. This building is assumed to have steel frame walls, metal deck rook with insulation above deck and a slab-on-grade floor. The HVAC system is a multi-zone VAV system with electric reheat, and packaged air-conditioner with gas furnace. Service water heating is assumed to be 260-gallon gas water heating. Further details on the energy model are provided in Appendix-A, Table A-2.
3. **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 a 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 codes: the 2006 IECC and the 2009 IECC. 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 Kansas 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.ameren.com/sites/aue/MyHome/ResidentialRates/Pages/default.aspx
http://www.ameren.com/sites/aue/MyBusiness/BusinessRates/Pages/Businessrates.aspx

Table 3: Utility Tariffs used for Kansas City (2010-2011)

Utility Tarrif			
Residential	Energy Charge	**Electricity**	**Gas**
		Monthly Charge: $16.81/mo	Monthly charge: $15.00/mo <30 Therm: $0.7952/Therm >30 Therm: $0 /Therm
		Summer: On-peak: 14.06 cents/kWh Off-peak: 5.76 cents/kWh	
		Winter: On-peak: 8.3 cents/kWh Off-peak: 4.1 cents/kWh	
	Demand Charge	NA	NA
Commercial	Energy Charge	**Electricity**	**Gas**
		Monthly Charge: $96.23/mo	Monthly Charge: $28.83/mo
		Summer: <150 kWh: 8.89 cents/kWh next 200 kWh: 6.69 cents/kWh >350 kWh: 4.50 cents/kWh Summer Adjustment: On-peak: +1.05 cents/kWh Off-peak: -0.59 cents/kWh	<7000 Therm: $0.3089/Therm >7000 Therm: $0.2023/Therm
		Winter <150 kWh: 5.60 cents/kWh next 200 kWh: 4.15 cents/kWh >350 kWh: 3.26 cents/kWh Winter Adjustment: On-peak: +0.32 cents/kWh Off-peak: -0.18 cents/kWh	
	Demand Charge	Summer: $4.15/kW Winter: $1.54 / kW	NA

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 Missouri, CO_2 emission factors assumed are: 50.23 g/MJ for natural gas and 192.02 g/MJ for electricity.

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

Table 4: Energy Impact Summary

Energy Impact						
Building Prototype	**Energy Use Intensity (EUI)**					
	2006 IECC			**2009 IECC**		
	Electricity (kWh/sf/yr)	Natural Gas (kBtu/sf/yr)	EUI (kBtu/sf/yr)	Electricity (kWh/sf/yr)	Natural Gas (kBtu/sf/yr)	EUI (kBtu/sf/yr)
Residential	11.3	15.7	54.3	10.5	13.4	49.4
Nonresidential	8.8	6.29	36.3	8.1	6.31	34.1
Semiheated	4.11	18.54	32.5	4.05	17.48	31.3

Table 5: Utility Cost and Environmental Impact Summary

Cost and Environmental Impact								
Building Prototype	**Utility Cost ($/yr)**						**CO_2 Emission (kg/yr)**	
	2006 IECC			**2009 IECC**			**2006 IECC**	**2009 IECC**
	Electricity	**Gas**	**Total**	**Electricity**	**Gas**	**Total**		
Residential	28,532	2,727	31,259	26,485	2,357	28,842	294,162	271,982
Nonresidential	24,434	1,387	25,822	22,775	1,390	24,165	347,805	323,391
Semiheated	11,521	3,326	14,846	11,318	3,154	14,472	200,906	195,841

4. Conclusions

The current buildings in Kansas City, MO are complying with the 2006 IECC commercial building requirements. Table 6 shows the percentage savings of energy, cost and environmental impacts reductions if these are built to comply with the 2009 IECC.

Table 6: Energy, Utility Cost and Environmental Reduction (percentage)

Percentage Savings- 2006 IECC vs. 2009 IECC							
Building Prototype	**Energy Savings**			**Utility Cost Savings**			**CO_2 Emission Savings**
	Electricity Savings (%)	Natural Gas Savings (%)	Total Energy Savings (%)	Electricity Cost Savings (%)	Natural Gas Cost Savings (%)	Total Utility Cost Savings (%)	
Residential	7.1%	18.8%	9.0%	7.2%	13.6%	7.7%	7.54%
Nonresidential	7.4%	-0.3%	6.1%	6.8%	-0.2%	6.4%	7.02%
Semiheated	1.4%	5.8%	3.9%	1.8%	5.2%	2.5%	2.52%

Based on the analysis, it can be observed that:

- Multifamily residential buildings built to the 2009 IECC would save 9% energy and save 7.7% energy cost compared to the 2006 IECC; and reduce CO_2 emissions by 7.54%.
- Nonresidential buildings built to the 2009 IECC save 6.1% energy, reduce 6.4% in energy cost, and 7.02% in CO_2 emissions.
- The IECC does not have a separate set of envelope requirements for semiheated spaces and hence the nonresidential requirements are used in the analysis. Semiheated warehouse buildings have significantly different building occupancy and operational characteristics compared to other nonresidential buildings, and the analysis shows energy savings of 3.9% and cost savings of 2.5%, with CO_2 emission reduction of 2.52%.

Appendix A
Detailed Comparison of Code Requirements

Appendix A – Detailed Comparison of Code Requirements

Table A.1: Comparison of Code Requirements

Climate Zone 4		
Topic	**2006 IECC**	**2009 IECC**
Design by acceptable practice for commercial buildings	Code requirements for commercial buildings contained in Chapter 5 resulting from the replacement of Chapters 4, 5 and 6 with Chapter 4 and the elimination of Chapter 7 from the IECC.	Requires that the code user must demonstrate compliance with Chapter 5, of the IECC in its entirety or ASHRAE 90.1-2007 but cannot mix compliance approaches on the same project. Added a comparable assembly U-factor table to correspond to the R-value requirements in Table 502.2(1).
ASHRAE/IESNA reference	References ASHRAE/IESNA 90.1-2004	References ASHRAE 90.1-2007
Opaque and fenestration requirements	Allows buildings up to 40% of the window area to gross above-grade wall area. Buildings that exceed this level are to use 90.1-2004 or Section 506.	Expands Table 502.2(1) to include a separate category for high-rise residential and commercial occupancies. Increases the insulation requirements for both high-rise residential and commercial in several climate zones.
Moisture control	Requires vapor retarders to be installed in unvented framed cavities in climate zones greater than 3.	Defines a vapor retarder based on Class (Type 1-3) and allows for the use of latex paint as a vapor retarder based on siding type and climate zone.
Metal building walls	Provides a description for meeting the metal building wall requirements	Adds additional descriptions for metal building walls
Roof assembly	2006 IECC prohibits counting insulation placed on a suspended ceiling and counting it toward compliance with the roof R-value requirement.	Adds additional assembly descriptions for metal roof systems
Skylights	Skylight U-factor based on climate zone and material (either glass or plastic). Maximum SHGC also required for skylights. Skylight percentage limited to 3% of gross roof area.	Consolidated the U-factor and SHGC requirements for skylights into one skylight category. Reduced (made more stringent) the U-factor and SHGC requirements.
HVAC equipment performance requirements	Air conditioners, air cooled < 65,000 Btu/h required SEER 13.0 for split systems.	Allows for alternative for water-cooled centrifugal water-chilling package efficiency. Revises equipment efficiency tables for water-chilling packages.
Snow melt controls	None	Requires snow melt controls on all snow melt equipment installed as part of a commercial project.
Demand control ventilation	None	Requires demand control ventilation for spaces larger than 500 ft^2 with an average occupant load of 40 people per 1000 ft^2.

Table A.1: Comparison of Code Requirements (continued)

Climate Zone 4		
Topic	**2006 IECC**	**2009 IECC**
Energy recovery ventilation	Requires an energy recovery ventilation system for systems of 5,000 cfm or greater and a minimum outside air supply of 70% or greater of the design supply air quantity. Several exceptions.	Removed the exception for laboratory fume hood systems with a total exhaust rate of 15,000 cfm or less.
Duct and plenum insulation and sealing	Requires minimum duct insulation R-value of 5 for ducts in unconditioned space and R-8 outside the building. Requires approved sealing for low, medium or high pressure duct systems. Specifies UL 181 labeling for specific duct connections. Requires maximum duct leakage rate of 6.0 for high pressure duct systems	References the 2009 International Mechanical Code for air sealing requirements.
HVAC piping insulation	Requires piping used to convey "conditioned" fluids to be insulated. Includes some exceptions.	Adds an exception for factory-installed piping within room fan-coils and unit ventilators. Increase piping insulation thickness by ½ inch for piping ≤ 1.5 inch.
Simple system economizers	Requires economizers for all cooling systems for systems ≥ 54,000 Btu/h. No exceptions for economizers in Climate Zones 5b and 6b.	Requires systems greater than 54,000 Btu/h in hot humid climates (Zone A) to meet the economizer requirements for Climate Zone 3 and above. Eliminates the category for systems ≥ 135,000 Btu/h and sets the threshold for requiring an economizer to 54,000 Btu/h for all systems.
Fan power limitations	None	Requires HVAC fan systems greater than 5 hp to meet maximum fan power horsepower requirements.
Hydronic (water loop) heat pump systems.	Provides requirements for the use of heat injection and heat rejection into the heat pump loop. Places requirements for bypassing the cooling tower when it is not needed.	Reorganizes the code provision to make it more understandable. Splits the requirements for bypassing the cooling tower when no heat rejection is needed based on climate zone.
Supply air temperature reset controls	None	Requires controls to be placed on systems serving multiple zones to be able to reset the supply air temperature by 25% based on the supply air temperature and the room temperature.
Efficient lighting in dwelling units	None	Requires at least 50% of the permanently connected lighting in dwelling units to be fitted with high efficacy lamps.
Daylight zone control	None	Requires that connected lighting that is installed in daylight zones be separately switched from other lighting in the space. Daylight zones are defined for spaces with vertical fenestration and also for skylights.
Exterior lighting controls	Specifies the type of controls that can be used to control exterior lighting not intended for 24 hour operation. This includes: • Lighting not designated for dusk-to-dawn operation – astronomical time switch • Lighting designated for dawn-to-dusk • Operation – astronomical time switch or photosensor.	Allows for the use of a photocell in tandem with a time clock or an astronomical time clock for exterior lighting systems that are not designed to stay on from dusk to dawn. Eliminates the lighting control exemption for lights that need to remain on for reasons that pertain to safety, security or eye adaptation.

Table A.1: Comparison of Code Requirements (continued)

Climate Zone 4		
Topic	**2006 IECC**	**2009 IECC**
	Astronomical time switches are required to have 10 hour battery back-up. Exempts lighting for covered vehicle entrances or exits from buildings, or parking structures where required by safety, security or eye adaptation.	
Total connected interior lighting power.	Provides five exemptions for lighting used for specialized lighting and associated with life/safety including: • Specialized lighting for medical and dental • Professional sports arena playing field lighting. • Display lighting for exhibits in galleries, museums and monuments. • Sleeping unit lighting in hotels, motels, boarding houses or similar buildings. • Emergency lighting automatically off during normal building operation.	Adds exempted lighting that does not need to be considered when calculating the Total Connected Interior Lighting Power including: • Lighting in spaces specifically designated for use by occupants with special lighting needs including the visually impaired and other medical and age related issues. • Lighting in interior spaces that has been specifically designated as a registered interior historic landmark. • Casino gaming areas. • Task lighting for plant growth or maintenance. • Advertising signage or directional signage. • In restaurant buildings and areas, lighting for food warming or integral to food preparation equipment. • Lighting equipment that is for sale. • Lighting demonstration equipment in lighting education facilities. • Lighting approved because of safety or emergency considerations, inclusive of exit lights. • Lighting integral to both open and glass-enclosed refrigerator and freezer cases. • Lighting in retail display windows, provided the display area is enclosed by ceiling height partitions. Furniture mounted supplemental task lighting that is controlled by automatic shutoff.
Line-voltage lighting track and plug-in busway	Requires the code user to use either the actual wattage of the fixtures connected to the track lighting or 30 watts/linear feet, whichever is greater, to document the wattage of track lighting.	Adds two additional options for documenting the wattage or line-voltage lighting, track and plug-in busway lighting that include: • The wattage limit of the system's circuit breaker, or • The wattage limit of other permanent current limiting device(s) on the

Table A.1: Comparison of Code Requirements (continued)

Climate Zone 4		
Topic	**2006 IECC**	**2009 IECC**
		system.
Interior lighting power.	Provides a signal column of lighting power densities for all occupancy types that can be used for either a whole building or tenant area or portion of building approach. Reduces the lighting power densities for a portion of the occupancies, e.g., Office (1.0 W/ft^2) and Retail (1.5 W/ft.^{2}) Eliminates the increased lighting allowances for visual display terminals, decorative lighting and emergency, recovery, medical supply and pharmacy space. Provides an additional 1.6 W/ft^2 for general merchandise display lighting for up to 50% of the resale floor area and 3.9 W/ft^2 for the actual shelf or case area for displaying jewelry, china and silver.	Revises the display lighting allowances to the following: Calculate the additional lighting power as follows: • Additional Interior Lighting Power Allowance = 1000 watts + (Retail Area 1 x 0.6 W/ft^2) + (Retail Area 2 x 0.6 W/ft^2) + (Retail Area 3 x 1.4 W/ft^2) + (Retail Area 4 x 2.5 W/ft^2), Where: • Retail Area 1 = the floor area for all products not listed in retail area 2, 3 or 4. • Retail Area 2 = the floor area used for the sale of vehicles, sporting goods and small electronics. • Retail Area 3 = the floor area used for the sale of furniture, clothing, cosmetics and artwork. • Retail Area 4 = the floor area used for the sale of jewelry, crystal, and china.
Exterior lighting	Requires all exterior lighting greater than 100 watts to have a minimum efficacy of 60 lumens per watt unless that lighting is controlled by a motion sensor or is exempted. Requires lighting budgets for all exterior lighting. Includes categories for "tradable surfaces" and "nontradable" surfaces. Limits the total wattage that can be installed on the exterior of commercial buildings.	Creates exterior lighting zones for exterior lighting based on lighting need. Exterior lighting allowances are defined by the following lighting zones with the highest lighting levels allowed in Zone 4: Zone 1: Developed areas of National Parks, State Parks, Forest Land, and Rural areas Zone 2: Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas Zone 3: All other areas Zone 4: High activity commercial districts in major metropolitan areas as designated by the local land use planning authority. A base lighting allowance is allowed for each lighting zone - from 500 watts to 1,300 watts – for Zones 1 to 4, respectively.

Appendix B

Prototype Building Descriptions

Appendix B – Prototype Building Descriptions

Table B.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 25ft x 38ft (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 in. concrete slab-on-grade floors (unheated)
Interior Partitions	2 x 4 uninsulated stud wall
Internal Mass	6 in. 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 B.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°F, Minimum 52°F
	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 in. 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°F
Misc.		
	Exterior Lighting	2075 W

Table B.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 in. 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)	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 B.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°F, Minimum 52°F
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 in.-6.3 in. water
Service Water Heating	
SWH Type	Storage tank
Fuel Type	Natural gas
Thermal Efficiency (%)	80%
Tank Volume (gal)	260
Water Temperature Setpoint	120°F
Misc.	
Exterior Lighting	
Peak Power	2730 W

Table B.3: Semiheated Prototype Building Characteristics

Large Warehouse Building Characteristics	
General	
Building Type (Principal Building Function)	Non-refrigerated warehouse
Total Floor Area	52,045 ft^2
Building Shape	Rectangle
Aspect Ratio	2.2
Number of Floors	1
Window Fraction	Storage Area: No windows; Office Area: 12% veiw 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)	14 ft (for the office area only)
Glazing Sill Height	3 ft (top of the window is 8-ft high)
Exterior Walls	Metal Building
Roof	Metal Building
Foundation	6 in. concrete slab-on-grade
Interior Partitions	Double layer of gypsum board with an exterior layer of stucco
Internal Mass	Defined as material with properties: density: 12.5 lb/ ft^2 thickness: 8 ft 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: 0.75 W/ ft^2 Bulk storage: 0.24 W/ ft^2
Occupancy	5 (in the office)

Table B.3: Semi-heated 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°F, Minimum 55°F
	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 in. water Fine storage: 2.5 in. water Bulk storage: 0.2 in. water
	Service Water Heating	
	SWH Type	Electric storage water heater
	Fuel Type	Electricity
	Thermal Efficiency (%)	100%
	Tank Volume (gal)	20
	Water Temperature Setpoint	120°F
Misc.		
	Exterior Lighting Peak Power	4800 watts

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