REDUCING ENERGY USE IN FLORIDA BUILDINGS

Richard A. Raustad
Senior Research Engineer

Mangesh Basarkar
Research Analyst

Robin K. Vieira
Director, Buildings Research Division

Florida Solar Energy Center
Cocoa, Florida

ABSTRACT

The 2007 Florida Building Code (ICC, 2008) requires building designers and architects to achieve a minimum energy efficiency rating for commercial buildings located throughout Florida. Although the Florida Building Code is strict in the minimum requirements for new construction, several aspects of building construction can be further improved through careful thought and design. This report outlines several energy saving features that can be used to ensure that new buildings meet a new target goal of 85% energy use compared to the 2007 energy code in order to achieve Governor Crist's executive order to improve the energy code by 15%.

To determine if a target goal of 85% building energy use is attainable, a computer simulation study was performed to determine the energy saving features available which are, in most cases, stricter than the current Florida Building Code. The energy savings features include improvements to building envelop, fenestration, lighting and equipment, and HVAC efficiency. The impacts of reducing outside air requirements and employing solar water heating were also investigated. The purpose of the energy saving features described in this document is intended to provide a simple, prescriptive method for reducing energy consumption using the methodology outlined in ASHRAE Standard 90.1 (ASHRAE, 2007).

There are two difficulties in trying to achieve savings in non-residential structures. First, there is significant energy use caused by internal loads for people and equipment and it is difficult to use the energy code to achieve savings in this area relative to a baseline. Secondly, the ASHRAE methodology uses some of the same features that are proposed for the new building, so it may be difficult to claim savings for some strategies that will produce savings such as improved ventilation controls, reduced window area, or reduced plug loads simply because the methodology applies those features to the comparison reference building.

Several measures to improve the building envelope characteristics were simulated. Simply using the selected envelope measures resulted in savings of less than 10% for all building types. However, if such measures are combined with aggressive lighting reductions and improved efficiency HVAC equipment and controls, a target savings of 15% is easily attainable.

INTRODUCTION

The State of Florida first mandated a statewide building code during the 1970's to require municipalities and counties to adopt and enforce one of the four state minimum building codes. Over the years, the state minimum building code evolved into a single state building code that is enforced by local governments. As of March 1, 2002, the Florida Building Code supersedes all local building codes. These codes were developed and are maintained by the Florida Building Commission.

The Florida Building Code is based on national model building codes and national consensus standards which are amended when necessary for Florida's specific needs. This report describes methods by which the construction and design community could increase building energy efficiency by 15% over the 2007 Florida Building Code.

To determine if a target goal of 85% building energy use is attainable, a computer simulation study was performed to determine the energy saving features which are, in most cases, stricter than the current Florida Building Code. The purpose of the energy saving features described in this document is intended to provide a simple, prescriptive method for reducing energy consumption using ASHRAE Standard 90.1.

Several building models were used to investigate the applicability of specific energy saving features based on building type. The energy saving features selected for study are based on the recommendations described in ASHRAE's Advanced Energy Design Guides. Additional energy saving features are included to investigate the impact of exterior wall treatments, equipment load control, use of high-efficiency AC systems, and reducing outside air requirements. The following sections describe the building models, energy saving features, and simulation results in greater detail.

BUILDING MODELS

Building simulation models were developed using the EnergyGuage® Summit Energy Analysis and Rating Software (Author, 2007). Each model uses the minimum requirements as specified by the 2007 Florida Building Code. Computer simulations were performed on several building types to represent a diverse building stock. All building simulations were performed using Orlando weather and some comparisons were made using Jacksonville and Miami weather. Current TMY3 weather data were used for all simulations.

Table 1 describes specific building details for each building type. The typical building is single-storey in most cases and includes a 2-storey school building and an 8-storey hotel. Lighting and equipment power densities and occupancy are based on the ASHRAE Standard 90.1 space-by-space method.

ADVANCED ENERGY DESIGN GUIDES

Advanced energy design guides (AEDG) (ASHRAE, 2006) are intended to provide contractors and designers a simple method for constructing energy efficient buildings. Strategic application of these guides are reported to provide a 30% energy savings when compared to the same building designed using the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999 (ASHARE, 1999). AEDG recommendations are not intended to represent a code minimum or standard and are to be used as supplements to existing codes and standards.

The AEDG recommendations were primarily developed through the ASHRAE Special Project 102 Committee (SP-102). Representatives from other organizations also provided a contributing effort to produce the design guide documents. These agencies include:

- United States Department of Energy (DOE)
- American National Standards Institute (ANSI)
- American Society of Heating, Refrigeration, Air-Conditioning Engineers (ASHRAE)
- Illuminating Engineering Society of North America (IESNA)
- American Institute of Architects (AIA)
- United States Green Building Council (USGBC)
- New Buildings Institute (NBI)

To date, guides have been developed for four (4) building types: Small Office Buildings, Small Retail Buildings, K-12 School Buildings, and Small Warehouses and Self-Storage Buildings. A 65% draft guide is currently under review for Highway Lodging.

These guides specify recommendations for the building envelope, fenestration, skylights, lighting, HVAC, and other building operational controls. The current project will investigate suitable options for increasing the energy efficiency of Florida commercial buildings by an additional 15% over the minimum specifications required by the 2007 Florida Building Code. Table 2 compares the minimum ASHRAE and AEDG recommendations for building envelope construction for a small office building located in Zone 2. Note that the 2007 Florida Building Code is primarily based on ASHRAE Standard 90.1-2004. Complete tables for all building types are included in a separate report (Raustad, et. al., 2008). These specifications are the basis for the energy saving features selected for this study.

Table 1. Base Case Building Model Characteristics

Building Type	Location	Floor Area (ft^2)	Stories	Base Lighting Power Density (W/ft^2)	Base Equipment Power Density (W/ft^2)	Maximum Number of Occupants
Office	Orlando	4,151	1	1.28	0.89	85
Retail		139,004	1	1.65	1.03	3742
School		22,068	2	1.26	0.92	714
Warehouse		1,344	1	0.81	0.20	4
Hotel		239,832	8	1.04	0.59	2344
Clinic		6,997	1	1.34	0.85	193
Supermarket		39,283	1	1.53	0.96	910

Table 2. Office Building Envelope Specifications for Zone 2

Item	Component	ASHRAE 90.1 2004		AEDG Recommendation	
		U-max	R-min		
Roof	Insulation entirely above deck	U-0.063	R-15 c.i.	R-15 c.i.	
	Metal building	U-0.065	R-19	R-19	
	Attic and other	U-0.034	R-30	R-38	
	Single rafter	U-0.034	R-30	R-38	
	Surface reflectance/emittance	No recommendation		0.65 initial/0.86	
Walls	Mass (HC>7 Btu/ft^2)	U-0.58	NR	R-7.6 c.i.	
	Metal building	U-0.113	R-13	R-13	
	Stell framed	U-0.124	R-13	R-13	
	Wood framed and other	U-0.089	R-13	R-13	
	Below-grade walls	C-1.40		Comply with Standard 90.1	
Floors	Mass	U-0.137	R-4.2 c.i.	R-6.3 c.i.	
	Steel framed	U-0.052	R-19	R-19	
	Wood framed and other	U-0.051	R-19	R-19	
Slabs	Unheated	F-0.73	NR	Comply with Standard 90.1	
	Heated	F-1.020	R-7.5 for 12 in.	R-7.5 for 12 in.	
Doors	Swinging	U-0.70	NR	U-0.70	
	Non-swinging	U-1.45	NR	U-1.45	
Vertical Glazing	Window to wall ratio (WWR)	50% maximum		20% - 40%	
	Thermal transmittance	Fixed	Operable	U-0.45	
		U-1.22	U-1.27		
	Solar heat gain coefficient (SHGC)	0-40%: 0.25 all / 0.61 North 40-50%: 0.17 all / 0.44 North		N, S, E, W – 0.31	N only - 0.44
	Window orientation	Directional		$(A_N*SHGC_N+A_S*SHGC_S)>(A_E*SHGC_E+A_W*SHGC_W)$	
	Exterior sun control (S, E, W only)	Based on PF		Projection factor (PF) 0.5	

ENERGY SAVING FEATURES

Several energy saving features were identified as feasible options based on ease of installation and applicability to most building types. Other features were included in this study to provide a "measure of opportunity" for additional energy savings. Selected features cover a range of categories: building envelope, lighting, HVAC, equipment, indoor air quality, and solar. Each of the features are described below in further detail. AEDG recommendations for building materials and equipment were used as a basis for energy saving feature selection.

Table 3. Energy Saving Features Selected for Study

Feature	Property	Option Description
Roof	Reflectance Emittance	Roof Only
Wall	Reflectance	Wall Only
Window	U-value Overhang	Window Only
Lighting	90% Power Density	Lighting Only
	75% Power Density	75% Lighting
HVAC	System Efficiency	AEDG HVAC
	Fan Efficiency	HiEff Fan
Equipment	90% Power Density	90% Equipment
Outside Air	85% Outside Air	85% Outside Air
Solar Hot Water	HW Heating Energy	Solar Hot Water only

Building Envelope

Building envelope recommendations include: 1) improved roof insulation for attic and single rafter construction with improved reflectance and emittance properties, 2) improved heat transfer characteristics for fenestration, and 3) the use of overhangs on windows facing South, East, and West.

As shown in Table 2, AEDG recommendations for walls and doors in Zone 2 did not change when compared to the minimum requirements specified by ASHRAE Standard 90.1. The recommendations for roofs are unchanged for office buildings, however, increased roof insulation is recommended for other building types. A recommendation for improved exterior wall reflectance is included in this study, however, AEDG recommendations for improved floor insulation (estimated to be a very minor effect for most Florida buildings) was not modeled. AEDG recommendations for window solar heat gain coefficient (SHGC) were sometimes less stringent than ASHRAE 90.1 and were not modeled.

Lighting

Recommendations are made for reducing the lighting power density by building type. The recommendations provided by the AEDG are applicable to the building area method described in ASHRAE 90.1. In most cases, the AEDG recommended a reduction of 10% for lighting power density. Lighting power density reductions for retail and warehouse are specified by AEDG as 86.7% and 75%, respectively. To apply this lighting reduction strategy to this study, the maximum lighting power density specified for the space type using the ASHRAE 90.1 space-by-space method was adjusted according to the recommended percentage reduction in lighting power. In the case of all building types except retail and warehouse, the lighting power density was reduced to 90 % of the maximum amount allowed for each space type defined in the model buildings.

Several studies have been performed to determine the minimum lighting requirements in buildings. One study (Newsham, et. al.) showed that up to a 30% reduction in lighting can be achieved before occupants detect a change in lighting output. For this reason, an additional simulation was performed to determine the impact of a 25% reduction in lighting power density when using the ASHRAE 90.1 space-by-space method.

HVAC System

Improving the efficiency of mechanical systems can dramatically reduce building energy consumption. In this study, the HVAC system efficiencies were increased to the AEDG recommendations for one simulation, and increased again to the current efficiency limit available in today's market place. The higher efficiency equipment described in this document refers to mechanical systems with 14 SEER for smaller systems and 11 EER for larger systems.

Improved fan efficiency was also selected as an energy saving measure. Fan efficiency was increased from 0.82 W/cfm to 0.75 W/cfm for constant volume systems and from 1.12 W/cfm to 1.02 W/cfm for variable-volume systems. This translates to an approximate 10% improvement in efficiency for air moving equipment.

Miscellaneous Electric Load

Equipment loads prove to be an ever increasing drain on the electrical energy consumption of buildings. Although manufacturers strive to make equipment as efficient as possible, several equipment models draw a significant amount of electricity even when in stand-by mode. In addition, equipment typically used is often on solely as a convenience instead of on an as-needed basis. For these reasons, the equipment loads were modified to reflect a reduction of 10% over the maximum equipment loads specified by ASHRAE Standard 90.1. These reductions are assumed possible through application of power strips to non-essential equipment that can be turned off when not needed. An alternate method would be to connect non-essential equipment to a dedicated electrical circuit which is controlled manually or scheduled through building automation systems.

Impact of Outside Air

ASHRAE Standard 62.1 specifies the minimum amount of outside air for commercial buildings. The minimum requirement is based on the amount of outside air required per person and/or per floor area. The amount of energy required to condition outdoor air can be significant. Although lowering the minimum amount of outside air may not be a high-priority feature when considering energy savings measures, the impact of reducing the minimum outside air requirements by 15% was investigated in this study to identify potential savings due to advanced ventilation control strategies.

Solar Water Heating

Water heating can also pose a high demand on building electrical consumption. The ASHRAE Handbook – HVAC Applications Chapter 49 (ASHRAE Handbook, 2003) provides a measure of average daily hot water demand which may be used to identify potential savings opportunities when solar water heating methods are employed.

Applying the hot water usage information to this study involved calculating the daily hot water energy requirements for each building type. The maximum number of occupants shown in Table 1 is used to determine the maximum daily hot water usage. Assumptions for food service include a service factor based on building type. The service hot water set point temperature is assumed to be 120ºF. Stand-by losses were not considered and are estimated to be less than 5% of the total water heating energy use. The following describes the type of water usage included in the average daily demand by building type.

Office Buildings – Includes hot-water requirements for cleaning and lavatory use by occupants and visitors.

Elementary Schools - Includes hot-water requirements for lavatories, cafeteria and kitchen use, dishwashers, and general cleaning purposes.

High Schools - Includes hot-water requirements for showers, lavatories, dishwashers, kitchens, and general cleaning.

Motels - Includes hot-water requirements for tubs and showers, lavatories, and general purpose cleaning.

Food Service - Includes hot-water requirements for dish washing, food preparation, cleaning pots and pans and floors, and hand-washing for employees and customers.

The final assumptions and calculations for annual hot water heating energy are shown in Table 5. A combination of hot water demand for building types shown in Table 4 was used to determine the estimated annual hot water energy use for all buildings modeled in this study. As shown in Table 5, the percent contribution of water heating to total building energy use ranges from 0.3% to 5.9%.

SIMULATION RESULTS

Each of the energy saving features described previously were applied to the base case building model. For each building type, computer simulations were performed for a total of 20 simulations. The first simulation provided a basis of comparison for all other computer simulations. Simulations 2 through 12 show the impact of each energy savings feature compared to the base case model. Simulation 13 shows the impact of building envelope and lighting improvements compared to the base case. Simulations 14 through 20 show cumulative energy savings as each additional option is included in the simulation.

The results of simulations 2 through 12 are shown in Figure 1. Simulation 9 was left out of this single feature analysis so that HVAC efficiency improvements would not be counted twice (savings of approximately 7% for schools and 2% for all other building types – see 16 vs 15 in Figure 2). Lighting, fan efficiency, and HVAC efficiency improvements provide the largest energy savings across all building types. The AEDG recommendation for warehouse building HVAC did not change the results (i.e., same HVAC efficiency). Other options provide energy savings specific to the building type and also vary based on individual building characteristics. It is no surprise that the optional solar water heater can have a large impact when hot water usage is a significant portion of the overall building energy use.

Table 4. Hot Water Use for Various Building Types

Type of Building	Average Daily Demand	Maximum Daily Hot Water Usage (kWh/day)
Office	1.0 gal./person	10
Elementary Schools	0.6 gal./student	50
Junior or Senior High School	1.8 gal./student	151
Motels, 100 or more rooms	10.0 gal./room	117 ^
Food service A – full meal restaurants	2.4 gal./avg. meal/day	132 *
Food service B – drive-ins, snack shops, etc.	0.7 gal./avg. meal/day	7 #

Notes - ^ assumes 100 rooms
* assumes 20% occupancy for hotel guests
# assumes 10% usage by supermarket shoppers

Table 5. Building Hot Water Usage Assumptions and Annual Energy Use

Building Type	Days/wk	Combination Used	Energy Use (kWh/day)	Annual Energy Use (kWh)	Percent of Base Building Energy Use (%)
Office	5	Office	10	2,600	1.9
Retail	6	Office	44	13,728	0.3
School	5	Average of School Types	100	26,000	5.9
Warehouse	6	Office	0.5	156	0.9
Hotel	7	Motel + Food Service A	149	54,385	1.5
Supermarket	7	Office + Food Service B	18	6,552	0.7
Clinic	5	Office	23	5,980	3.7

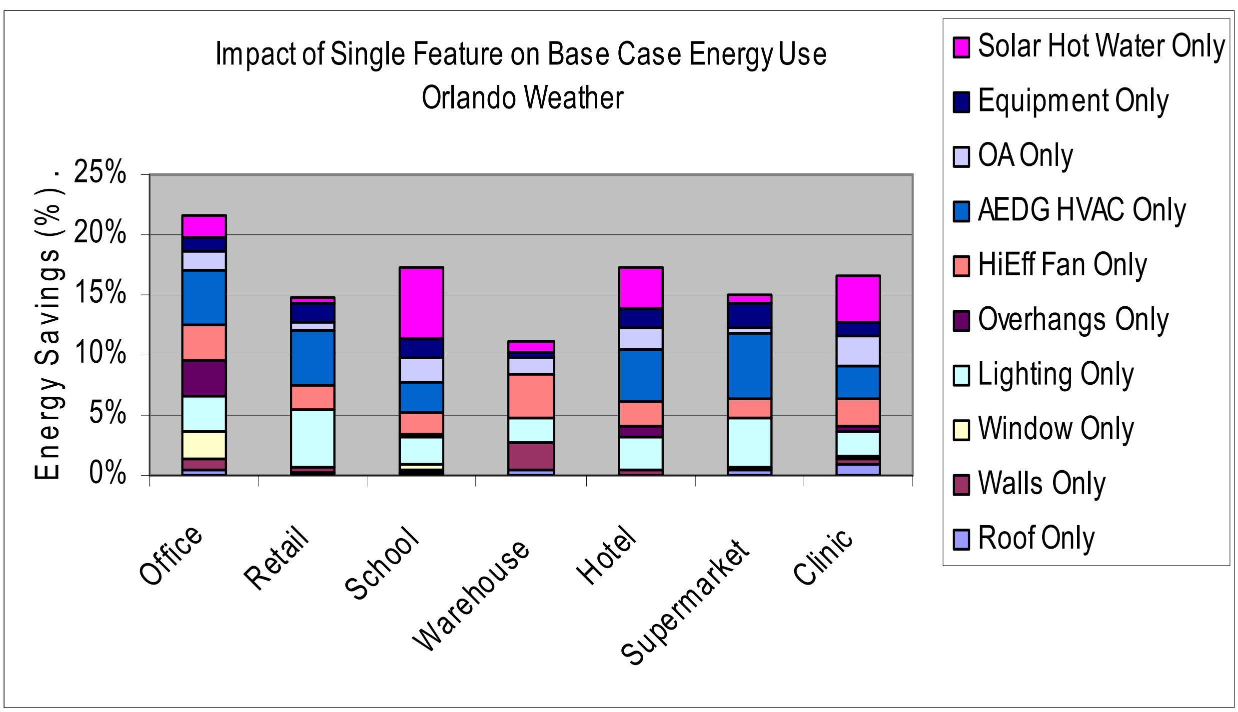

Figure 1. Energy Savings of Individual Features by Building Type

These results show that improvements to the building envelope are dependent on building type, and the amount of energy savings vary based on building architecture. For example, the option for improving roof insulation is only a cost effective measure when applied to buildings having large roof areas. Similarly, improving window heat transfer characteristics is only viable for large glazing areas. The usefulness of overhangs also depends on window orientation.

Although reducing the minimum amount of outside air is shown to provide approximately a 1% to 2% savings for several building types, application of this feature is likely to result in code violations without supporting evidence for using such a measure. For example, if building furnishings are shown to release minimal amounts of volatile organic compounds (VOC), the required amount of outside air may be reduced slightly. The use of demand controlled ventilation could also prove to be a significant energy saving feature.

Also of note is the fact that the combination of these energy saving features results in at least a 15% reduction in building energy use over the 2007 Florida Building Code for all building types except warehouse. Since analyzing individual features in this manner does not provide accurate results when investigating cumulative energy savings due to application of multiple energy savings features, additional computer simulations were performed to show the final results. Figure 2 shows the results for sequentially adding energy saving features to the base case building model.

Starting with the base case model, combining all AEDG building envelope and lighting recommendations results in an approximate 3% to 9% energy savings for the building types selected for study (e.g., Simulation ID 13 in Table 6). Adding in the AEDG recommendation for HVAC efficiency improvements yields an additional average improvement of 2.7% (ID 14). Similarly, incrementally adding the remaining features results in a total energy savings of over 15% for all building types studied. Office buildings were simulated for Miami and Jacksonville with very similar total savings numbers to the Orlando simulations.

SUMMARY OF ENERGY SAVING MEASURES

A summary of the energy saving features used in this study is shown in Table 7. Each energy savings feature specification shown here was used to modify the base case model to provide a single feature analysis compared to the base case model. The roof specifications were combined to show the results when the roof properties were adjusted according to the AEDG recommendations. Cumulative results also used these specifications as applicable. In most cases, the energy savings measures identified in Table 7 reflect the AEDG recommendation. In other cases, improvements beyond AEDG recommendations

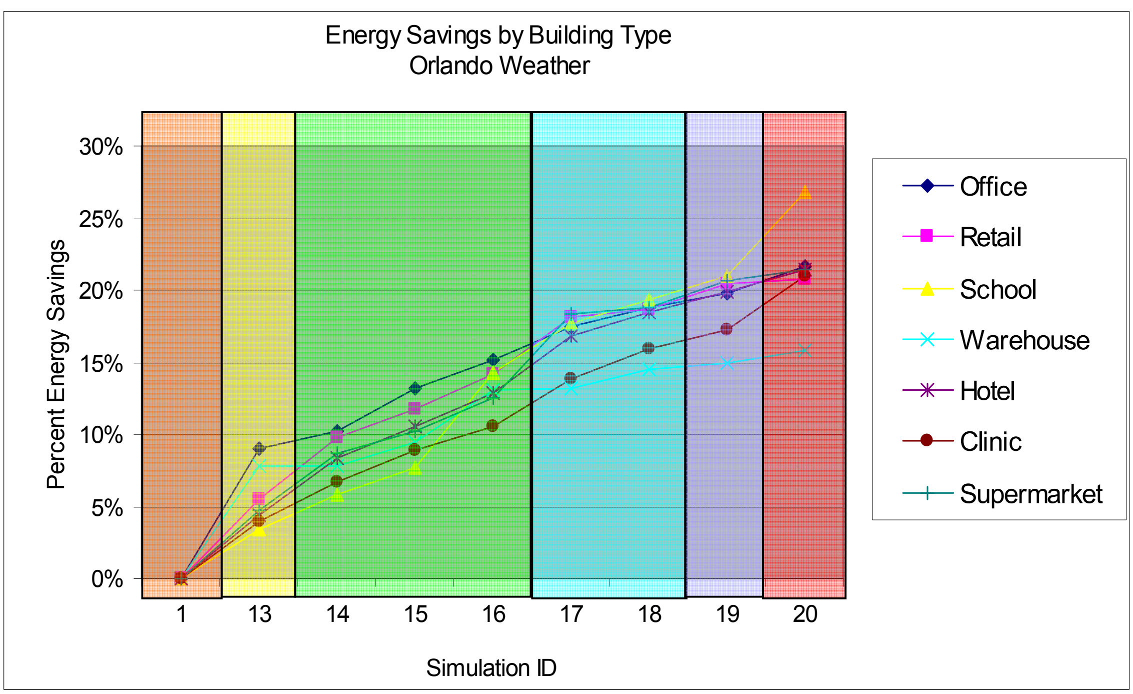

Figure 2. Cumulative Energy Savings by Building Type

Table 6. Energy Saving Feature Summary

Simulation ID	Description	Grouping
1	BaseCase (Florida Code 2007)	Florida Code 2007
2	Roof Only	Single Option
3	Walls Only	
4	Window Only	
5	Lighting Only	
6	Overhangs Only	
7	HiEff Fan Only	
8	AEDG HVAC Only	
9	HiEff HVAC Only	
10	OA Only	
11	Equipment Only	
12	Solar Hot Water Only	
13	All Options (building envelope + lighting)	Building Envelope
14	All Options + AEDG HVAC	HVAC Efficiency
15	All Options + AEDG HVAC + Hi Eff Fan	
16	All Options + Hi Eff HVAC + Hi Eff Fan	
17	Reduce Lighting to 75% of ASHRAE 90.1	Lighting
18	Reduce OA to 85% of ASHRAE 60.1	Indoor Air Quality
19	Reduce Equipment Loads	Equipment Control
20	Solar Hot Water	Solar Hot Water only

Table 7. Summary of Energy Saving Measures

Building Element	**Improved Building Specifications**						
	Office	**Retail**	**School**	**Warehouse**	**Hotel**	**Supermarket**	**Clinic**
Roof Absorptance	0.35	0.22					
Roof U-value	0.034	0.027					
Wall Absorptance	0.3						
Wall R-value	13 (no change)						
Floor Insulation R-value	19						
Window U-value	0.45	0.49	0.45				
Window SHGC 0-40% WW Ratio	0.61 North, 0.25 all other (no change)						
40-50% WW Ratio	0.44 North, 0.25 all other (no change)						
Overhang Projection Factor (PF)	0.5 (projection half the distance of window height)						
Lighting (% of base case Lighting)	90	86.7	90	75	90	90	90
Lighting (75% of base case Lighting)	75						
HVAC Fan Efficiency (W/cfm)	Constant Volume System 0.75 / Variable Volume System 1.02						
HVAC Cooling < 65,000 Btu/hr	13 SEER/7.7 HSPF						
HVAC Cooling ≥ 65,000 - 135,000 But/hr	10.6 EER / 11.0 IPLV / 3.2 COP						
HVAC Cooling ≥ 135,000 Btu/hr	10.1 EER / 11.5 IPLV / 3.1 COP						
High Efficiency HVAC	11 EER / 14 SEER						

show performance improvements based on reduced exterior wall absorptance, reduced lighting power density, and improved HVAC efficiency.

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