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Creating Energy Independence

QUANTITATIVE and ECONOMIC ANALYSIS of THE 7th Edition (2020) FLORIDA BUILDING ENERGY CODE

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Final Report

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Executive Summary

This project was initiated because of the state of Florida desire to review provisions of its proposed 7th Edition (2020) Florida Energy Code (FEC) for commercial buildings in order to make a determination if it meets or performs better than ASHRAE 90.1-2016 code. For this purpose the proposed code modifications were reviewed and quantitatively analyzed. Two scenarios of the IECC-2018 based 2020 Florida Energy Code were investigated: *approved-I* and *approved-II* code modifications. The *approved-I* 2020 FEC code modifications that have energy impact approved by Florida Building Commission as of October 31, 2018 for addition to the 2020 FEC are summarized in Appendix-A. And additional code modifications that have energy impact approved by Florida Building Commission since November 1, 2018 and as of March 31, 2019 for addition to the 2020 FEC are summarized in Appendix-B. The *approved-II* 2020 FEC includes all code amendments that has energy impact approved by Florida Building Energy Commission as of March 31, 2019. The *approved-I* 2020 FEC scenario quantitative analysis included twenty-one code amendments. The *approved-II* 2020 FEC scenario quantitative analysis included twenty-six code amendments, i.e., including the twenty-one code modification under approved-I scenario and five-more code amendments approved since November 1, 2018. The quantitative analysis was performed for *approved-I* and *approved-II* code modification scenarios for Florida Climate Zone 1A and 2A. EnergyPlus, whole building simulation program was used for the analysis.

The 2020 FEC performance was investigated using sixteen prototype commercial building energy models. Two sets of the 2020 FEC prototype building energy models were created: one set of models for the *approved-I* 2020 FEC, and another set for the *approved-II* 2020 FEC. The *approved-I* 2020 FEC prototype building energy models were created by incorporating the twenty-one code amendments approved as of October 31, 2018 to the 6th Edition FEC prototype building energy models. And the *approved-II* 2020 FEC prototype building energy models were created by incorporating the twenty-six code amendments approved as of March 31, 2019 to the 6th Edition FEC prototype building energy models. The analysis compared annual site energy use and energy cost performance of the two scenarios of the 2020 FEC prototype building energy models against that of the 2016 ASHRAE 90.1 code energy models. The 2016 ASHRAE 90.1 code prototype buildings energy models were used as reference. Energy models of the two scenarios of the 2020 FEC and ASHRAE 90.1-2016 code prototype buildings were simulated for Miami and Orlando, Florida site locations representing climate zones 1A and 2A, respectively. The building energy simulation results were processed to determine site energy use intensity (EUI) and Energy Cost Index (ECI) values for each of the prototype buildings energy models weighted by commercial buildings stock tool floor area distributions in climate zones 1A and 2A of the state.

Results of Approved-I 2020 FEC Quantitative Analysis: The quantitative analysis of the 2020 FEC under approved-I scenario is summarized as follows:

- The quantitative analysis result show that the *approved-I* 2020 FEC prototype buildings slightly underperformed that of ASHRAE 90.1-2016 code. Figure I shows EUIs of the *approved-I* 2020 FEC and ASHRAE 90.1-2016 code of the sixteen prototype buildings.

- The weighted Florida average site EUI was 46.64 kBtu/ft^2-Yr and 46.50 kBtu/ft^2-Yr for the *approved-I* 2020 FEC and the 2016 ASHRAE 90.1 code, respectively. The quantitative analysis conducted for *approved-I* 2020 FEC code demonstrates that the 2020 FEC underperforms energy efficiency of ASHRAE 90.1-2016 code by about 0.29 percent.

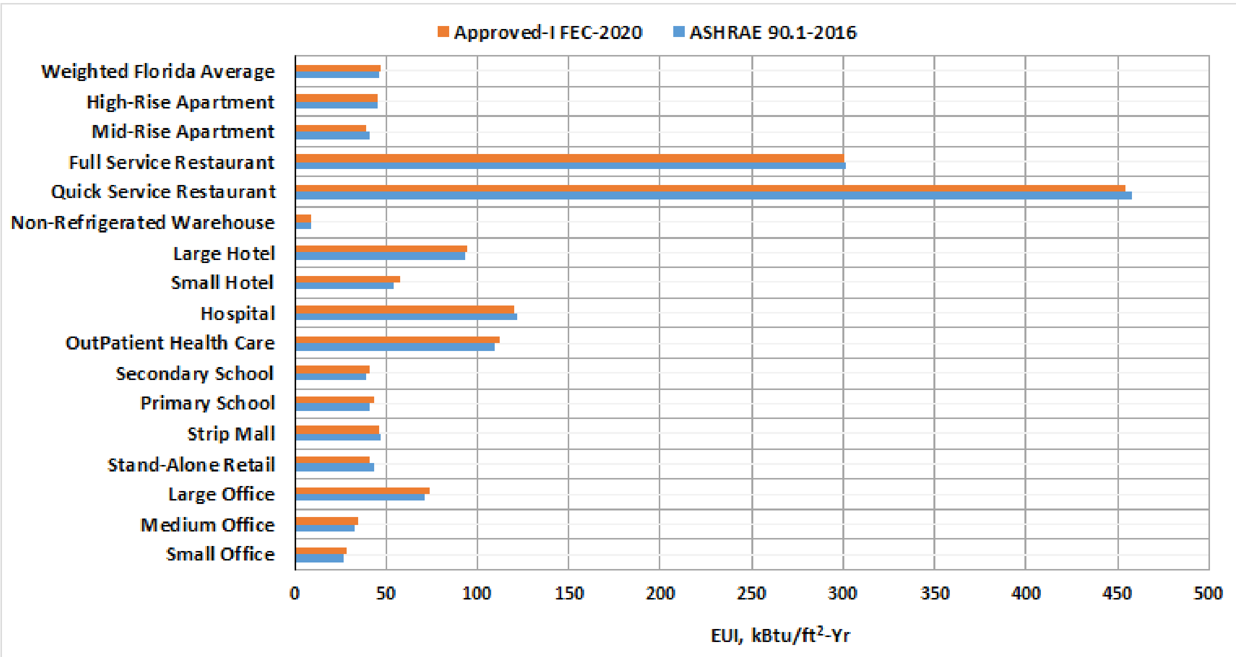

Figure I Annual Energy Use Intensity of the *Approved-I* 2020 FEC by Prototype Building

Results of Approved-II 2020 FEC Quantitative Analysis: The quantitative analysis of the 2020 FEC under approved-II scenario is summarized as follows:

- The Florida Building Commission subsequently approved five-more commercial code amendments listed in Appendix-B for addition to the 2020 FEC on March 26, 2019 meeting. The *approved-II* 2020 FEC scenario analysis included the twenty-six code changes with energy impact approved as of March 31, 2019.

- The quantitative analysis demonstrated that the weighted Florida average annual site energy use and operating total energy cost of the *approved-II* 2020 FEC scenario was less than ASHRAE 90.1-2016 code. Figure II shows that the EUIs of the *approved-II* 2020 FEC scenario and ASHRAE 90.1-2016 code by prototype buildings. The weighted Florida average site EUI was determined to be 45.75 kBtu/ft^2-Yr and 46.50 kBtu/ft^2-Yr for the *approved-II* 2020 FEC and the 2016 ASHRAE 90.1 code, respectively. This *approved-II* 2020 FEC scenario performed better by about 1.61 percent compared to ASHRAE 90.1-2016 code in terms of energy use.

- Figure III shows the annual operating total energy cost index by prototype building. The weighted Florida average annual total energy cost index of *approved-II* 2020 FEC scenario is lower than that of the 2016 ASHAE 90.1 code building by 1.75 percent.

- The quantitative analysis demonstrated that energy efficiency of commercial buildings constructed in accordance with the *approved-II* 2020 FEC is better than that of ASHRAE 90.1-2016 code. The study concluded that the approved-II 2020 FEC scenario approved by Florida Building Commission as of March 31, 2019 for addition to the 2020 FEC performs better than the 2016 ASHRAE 90.1 code.

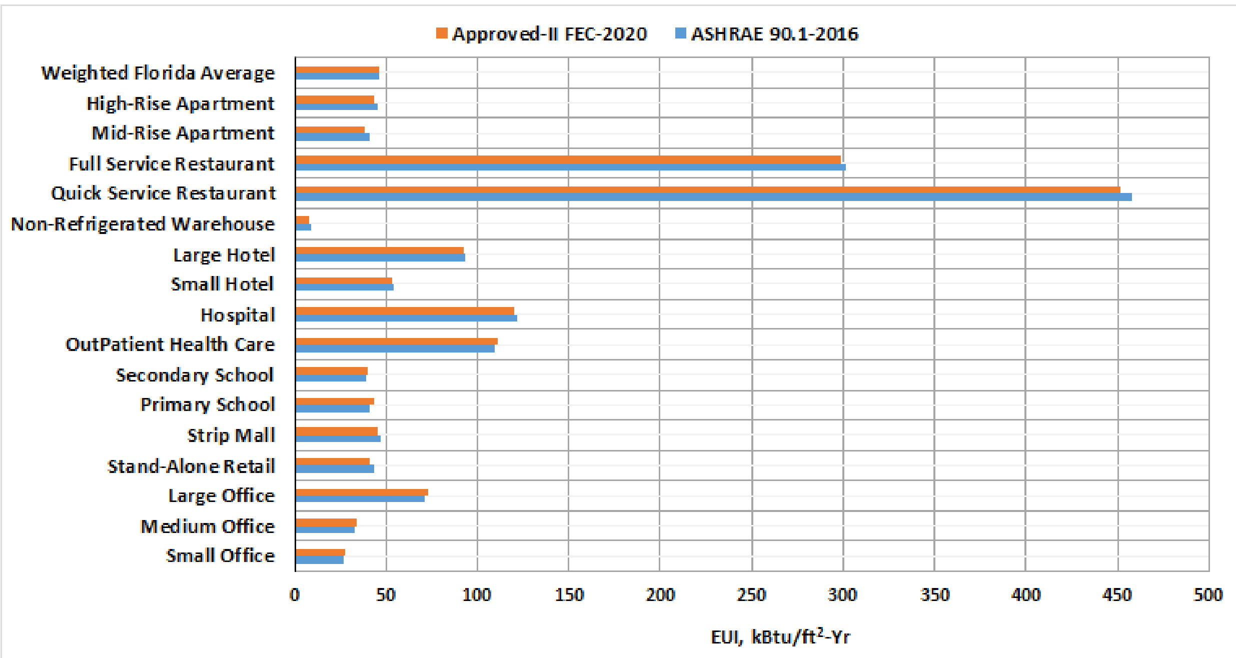

Figure II Annual Energy Use Intensity of the Approved-II 2020 FEC by Prototype Building

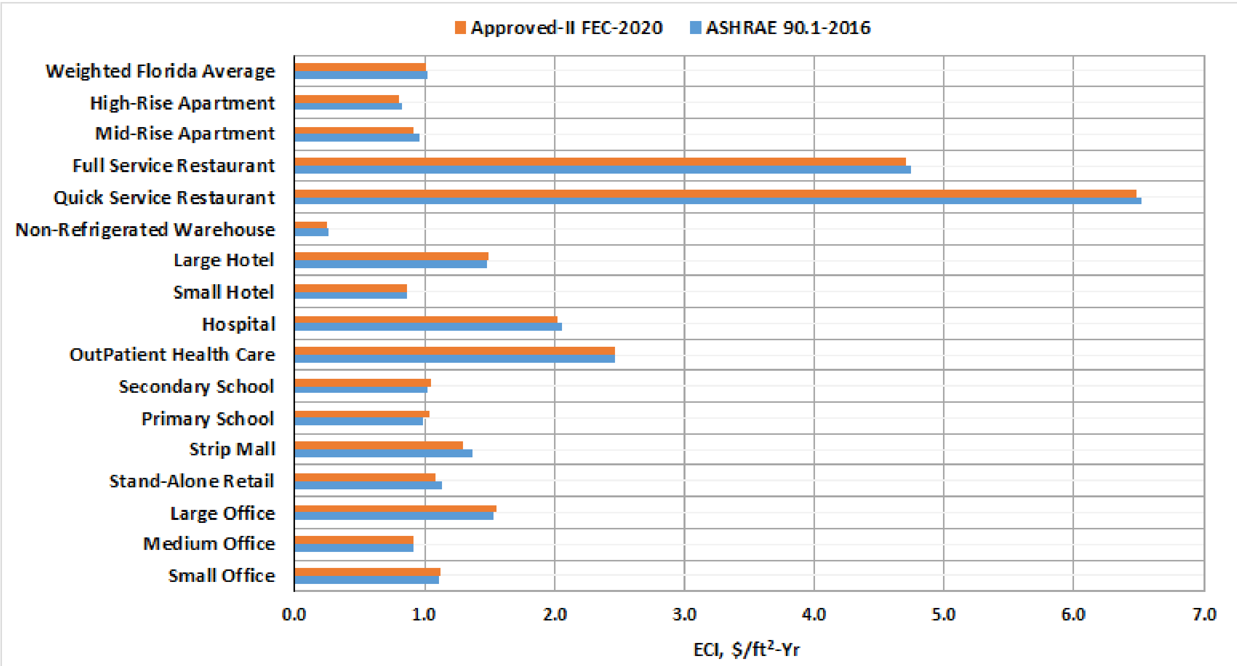

Figure III Annual Total Energy Cost Index of the *Approved-II* 2020 FEC by Prototype Building

Results of ASHRAE 90.1-2020 FEC Quantitative Analysis: The quantitative analysis of the 2016 ASHARE 90.1 code alternative compliance option of the 2020 FEC is summarized as follows:

- Florida Building Code, Energy Conservation, 7th Edition (2020) also allows amended version of ANSI/ASHRAE/IESNA 90.1-2016 standard as an alternative compliance option. Performance of the amended ASHRAE 90.1-2016 code per code modification EN8045 approved by Florida Building Commission for addition to the 2020 FEC was quantified and compared against that of the original 2016 ASHRAE 90.1 code. Code modification EN8045 excludes interior lighting control of section 9.4.1.1(g) and the automatic receptacle control section 8.4.1 of ASHRAE 90.1-2016 code.

- Figure IV shows annual site energy use intensity of the amended and original version of the 2016 ASHRAE 90.1 code by prototype building. Prototype building of the amended ASHRAE 90.1-2016 code used as an alternative compliance option for Florida code is labeled as ASHRAE 90.1-2020 FEC. Annual site energy use intensities of ASHRAE 90.1-2020 FEC were somewhat higher than that of the 2016 ASHRAE 90.1 code for all the sixteen prototype buildings. The weighted Florida average annual site energy use of ASHRAE 90.1-2020 FEC code was higher by about 2.20% compared to the original 2016 ASHRAE 90.1 code. The annual site energy use intensities of ASHRAE 90.1-2020 FEC and ASHRAE 90.1-2016 were determined to be 47.53 kBtu/ft^2-Yr and 46.50 kBtu/ft^2-Yr, respectively.

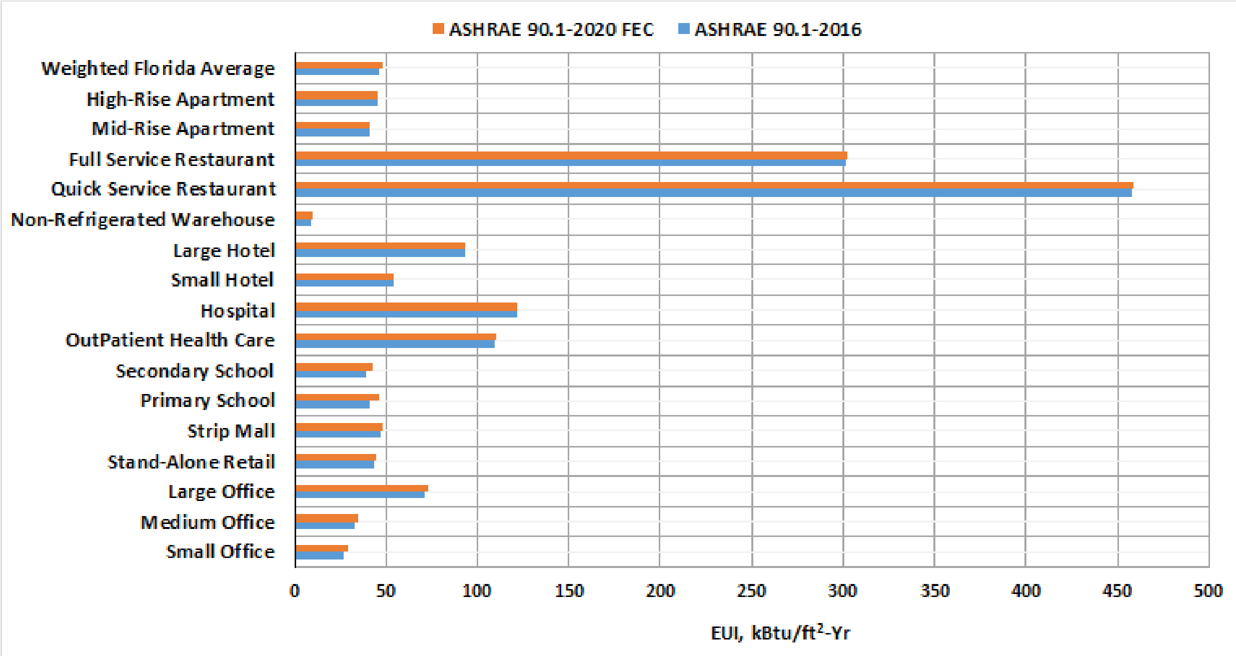

Figure IV Annual Site Energy Use Intensity of the ASHRAE 90.1-2020 FEC by Prototype Building

Results of Cost-Benefit Analysis: Cost benefit analysis of selected approved code amendments was performed and summarized as follows:

- Cost benefit analysis was performed for a selected code amendments submitted after October 31, 2018 and are summarized in Appendix-B. The selection excluded code modifications whose energy impact cannot be analyzed quantitatively, code modifications with no or negligible net first cost, federal minimum code modifications, and those code changes that has already been approved.
- Savings to investment ratio, which is one of the commonly used metric for cost benefit determination, was computed. Only five out of nine code amendments investigated were found cost effective. Cost benefit analysis results were summarized and recommendation were provided in Section 5.0 of this report.

Conclusion: The 7th Edition (2020) FEC provides two performance compliance options – one IECC 2018 based and other ASHRAE 90.1-2016 based. The study demonstrates that the deviations of the 2020 FEC from the ASHRAE 90.1-2016 Standard are quite small and can be considered within the margin of error – either favorable or otherwise. In terms of annual energy use the IECC based option is somewhat better performing by about 1.61% while the amended ASHRAE option is somewhat worse by about 2.20%. In terms of annual energy cost the IECC based option is better performing by about 1.75% while the amended ASHRAE option is worse by about 1.48%. The 2020 FEC performance when the two performance compliance options aggregated using equal weights is within ±0.30% and ±0.15% in terms of annual energy use and energy cost, respectively. Hence the 2020 FEC overall, for all practical purposes, may be considered equivalent to the original ASHRAE 90.1-2016.

Acknowledgments

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Acronyms and Abbreviations

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
DOE	U.S. Department of Energy
ECI	Annual Energy Cost Index, $/(ft^2-yr)
EUI	Annual Energy use intensity, kBtu/(ft^2-yr)
FEC	Florida Commercial Energy Code
FEC-2020	2020 Florida Energy Code
FSEC	Florida Solar Energy Center
HVAC	Heating, ventilation, and air-conditioning
IES	Illuminating Engineering Society of North America
IECC	International Energy Conservation Code
PNNL	Pacific Northwest National Laboratory
X	The EUI or ECI value of a prototype building

Simulation Prototype Terminology

***Approved-I* 2020 FEC** A building input designed to simulate the baseline and changes approved by the Florida Building Commission as of October 31, 2018 for the 2020 (7th Edition) Florida Building Code, Energy Conservation.

***Approved-II* 2020 FEC** A building input designed to simulate the baseline and changes approved by the Florida Building Commission as of March 31, 2019 for the 2020 (7th Edition) Florida Building Code, Energy Conservation.

ASHRAE 90.1-2020 FEC A building input designed to simulate the ASHRAE 90.1-2016 standard and the amendments approved by the Florida Building Commission as of March 31, 2019 for the 2020 (7th Edition) Florida Building Code, Energy Conservation.

ASHRAE 90.1-2016 A building input designed to simulate the ASHRAE 90.1-2016 standard.

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1. Introduction

The state of Florida desires to review provisions of its proposed 2020 (7th Edition) commercial buildings energy code in order to make a determination if it meets or performs better than the 2016 ASHRAE 90.1 code. This report summarizes analysis performed and evaluation carried out to make determination whether the 2020 Florida Energy Code (FEC) meets or performs better than ASHRAE 90.1-2016 code. Summary of the tasks performed include:

- Reviewed all approved and proposed code modifications as of March 31, 2019 to Florida base energy code and evaluated the modified code against provisions of the 6th Edition FEC to make assessment for quantitative analysis.

- Reviewed the 2015 IECC sixteen prototype commercial building energy models originally created by PNNL (DOE, 2018) and subsequently modified by FSEC for the 6th Edition (2017) FEC.

- Starting with these prototype building energy models FSEC updated input assumptions and created the 2020 FEC equivalent prototype building energy models for climate zones 1A and 2A. Two sets of the IECC-2018 based 2020 FEC prototype building energy model scenarios were created: one based on the *approved-I* code changes, which includes code modification approved by Florida Building Commission for addition to the 2020 FEC as of October 31, 2018; and another based on the *approved-II* code changes, which includes code modification approved by Florida Building Commission for addition to the 2020 FEC as of March 31, 2019. The code modifications analysis covered: Building Envelope, Building Mechanical Systems, Service Water Heating, and Electric Power and Lighting sections of the Florida commercial energy code. The analysis effort requires identifying how best to represent the code modification in the prototype building models, perform sizing calculations, and identifying and updating the various minimum efficiency requirements. This step was repeated for each of the two approved code amendment scenarios, the sixteen prototype buildings and the two climate zones.

- Obtained the latest DOE ASHRAE 90.1-2016 sixteen reference prototype buildings energy models for climate zones 1A and 2A (DOE, 2018). Modified the climate zone 2A building energy models site location to Orlando, Florida and updated climate and location dependent model parameters. The ASHRAE 90.1-2016 and the 2020 FEC prototype buildings energy models were transitioned to EnergyPlus version 8.6 and simulated.

- Processed the EnergyPlus program output and determined site Energy Use Intensity (EUI) and Energy Cost Index (ECI) for each of the prototype buildings, the two climate zones, and for the two 2020 FEC scenarios. The EUIs and ECIs of the prototype buildings were weighed by Florida climate zones floor area weighting factors and aggregated across the sixteen commercial buildings to determine weighted Florida average site EUI for the commercial sector. Made determination whether the performance of the 2020 FEC code meets or performs better than ASHRAE 90.1-2016 code by comparing the EUIs and ECIs of the prototype building models. Provided summary of the results and recommendation based on the two approved IECC-2018 based 2020 FEC scenarios. The *approved-I* 2020 FEC scenario analysis is presented in Section 4.2 and *approved-II* 2020 FEC scenario analysis is presented in Section 4.4.

- Furthermore, amended version of the 2016 ASHRAE 90.1 code for Florida Energy Code was quantitatively investigated and compared against the original ASHRAE 90.1-2016 code. An amended version of the 2016 ASHRAE 90.1 code is an alternative compliance option for Florida. The amended 2016 ASHRAE 90.1 designated here as ASHRAE 90.1-2020 FEC excludes interior lighting control section 9.4.1.1(g) and the automatic receptacle control section 8.4.1 from the 2016 ASHRAE 90.1 code. These two code amendments were approved under code modification EN8045. The prototype buildings model of ASHRAE 90.1-2020 FEC buildings were created by removing the interior lighting control of section 9.4.1.1(g) and the automatic receptacle control section 8.4.1 from the 2016 ASHRAE 90.1 reference prototype building models. Finally performance of the ASHRAE 90.1-2020 FEC and the 2016 ASHRAE 90.1 code prototype building energy models was quantitatively analyzed. Analysis of ASHRAE 90.1-2020 FEC is covered in Section 4.6.

- Conducted preliminary assessment of the proposed commercial code modifications for cost benefit analysis and performed cost benefit analysis of selected code modifications summarized in Appendix-B. Savings to investment ratio, which is one of the metrics commonly used for cost benefit determination, was computed for those selected code changes. Finally the cost benefit analysis results were summarized and recommendation provided. The cost beneft analysis is covered in Section 5.

2. The 2020 Florida Energy Code Modification

The approved and proposed 2020 Florida Energy Code modifications to the base code, which is the 6th Edition (2017) Florida Energy Code, were reviewed. The list of approved and proposed 2020 FEC code modifications with energy impact along with brief description of the code modifications are provided in Appendix-A and Appendix-B. Total code modifications count for the 2020 FEC with energy impact for the commercial building energy code are summarized in Table 1. Out of the thirty-two code modifications with energy impact, twenty-eight were quantitative analyzed using the sixteen commercial prototype building energy models. Building mechanical system and electric power and lighting sections of code modifications cover 90.6% of the 2020 FEC total code changes investigated while the remaining 9.4% represent building envelope and service water heating. Two scenarios of code modifications were investigated: *approved-I* 2020 FEC commercial code modification approved by Florida Building Commission for addition to the 2020 FEC as of October 31, 2018; and *approved-II* 2020 FEC commercial code modification approved by Florida Building Commission for addition to the 2020 FEC as of March 31, 2019. *Approved-I* 2020 FEC scenario investigated twenty-one code modifications whereas *approved-II* 2020 FEC scenario investigated twenty-six code modifications.

Table 1 Number of Code Modifications with Energy Impact in the Proposed 2020 FEC

Commercial Code Section	Code Changes Count	Code Changes Percent, %
Section C402 Building Envelope	2	6.25
Section C403 Building Mechanical Systems	12	37.50
Section C404 Service Water Heating	1	3.12
Section C405 Electric Power and Lighting	17	53.13
Total	32	100

3. Florida Climate Zones

Based on DOE's climate zones classification the state of Florida is categorized into two climate zones: very hot and humid (1A), and hot and humid (2A). Representative site locations for climate zones 1A and 2A selected for the quantitative analysis were Miami, Florida (1A, very hot, humid) and Orlando, Florida (2A, hot, humid). Orlando was selected as a representative site location for climate zone 2A mainly because it is the geographic center for major cities in climate zone 2A region of the State. Miami is the largest city in climate zone 1A, so it was selected as a representative site location. Representative commercial building stock floor area weighing factors by climate zones and building types and the procedure used to estimate the factors is provided in Appendix-D.

4. Quantitative Analysis of the 2020 Florida Energy Code Performance

The quantitative analysis determined and compared annual site energy use intensity (EUI) and annual Energy Cost Index (ECI) by prototype building and weighted Florida average. Sixteen commercial prototype buildings type were used to represent the Florida commercial buildings total floor area stock. The annual site energy use and energy cost comparison was made between prototype buildings energy model designed with the *approved-I* and *approved-II* 2020 FEC against the 2016 ASHRAE 90.1 code energy models. The *approved-I* 2020 FEC prototype building energy models were created from the 6th Edition (2017) FEC prototype energy models and the twenty-one code amendments approved by Florida Building Commission for addition to the 2020 FEC as of October 31, 2018. The *approved-II* 2020 FEC prototype building energy models were created from the 6th Edition (2017) FEC prototype energy models and the twenty-six code modifications approved by Florida Building Commission for addition to the 2020 FEC as of March 31, 2019. The 2016 ASHRAE 90.1 code prototype building energy models were DOE reference prototype building energy models published by Pacific Northwest National Laboratory (PNNL) (DOE, 2018). The DOE reference prototype building energy models were also modified for this study to account for site location and site location dependent parameters such as site water mains temperature, and ground temperature. The sixteen prototype commercial buildings energy models of the 2020 FEC and the 2016 ASHRAE 90.1 code were simulated for Miami and Orlando site locations. Finally, EUI and ECI of the prototype building energy models designed with the 2020 FEC and ASHRAE 90.1-2016 code were determined and evaluated. The EUI and ECI percent difference between the 2020 FEC and ASHRAE 90.1-2016 code were calculated as follows:

$$\Delta X = 100 \cdot \frac{X_{\mathrm{ASHRAE90.1-2016}} - X_{\mathrm{FLORIDA-2020}}}{X_{\mathrm{ASHRAE90.1-2016}}}$$

Where X, represents the EUI or ECI value of a prototype building or an aggregate of the sixteen prototype buildings. The EUI for each prototype building was determined by dividing the annual total energy use of a building by its total floor area. The ECI for each prototype building was obtained by dividing the operating annual total energy cost of a building by its total floor area. The operating total energy cost includes annual electric energy cost, demand changes and natural gas energy cost. The rates for electric energy, demand charges and natural gas used in this analysis are provided in Appendix-C. The weighted Florida average site EUI and ECI were determined from the sixteen commercial prototype buildings using weighting factors that account for the prototypes floor area distribution by climate zones and building type. The commercial buildings total floor area stock distribution by climate zone and building type for Florida is summarized next.

4.1 Prototype Buildings and Floor Area Distribution

Quantitative analysis of the Florida commercial building energy code performance was investigated using the sixteen prototype buildings energy models representing climate zones 1A and 2A. Figure 1 shows the commercial buildings total floor area weighting factors used for Florida by prototype buildings. The eight building types and sixteen prototype energy models shown in Table 2 represent the commercial buildings stock floor area and floor area distribution by prototype building in the State of Florida.

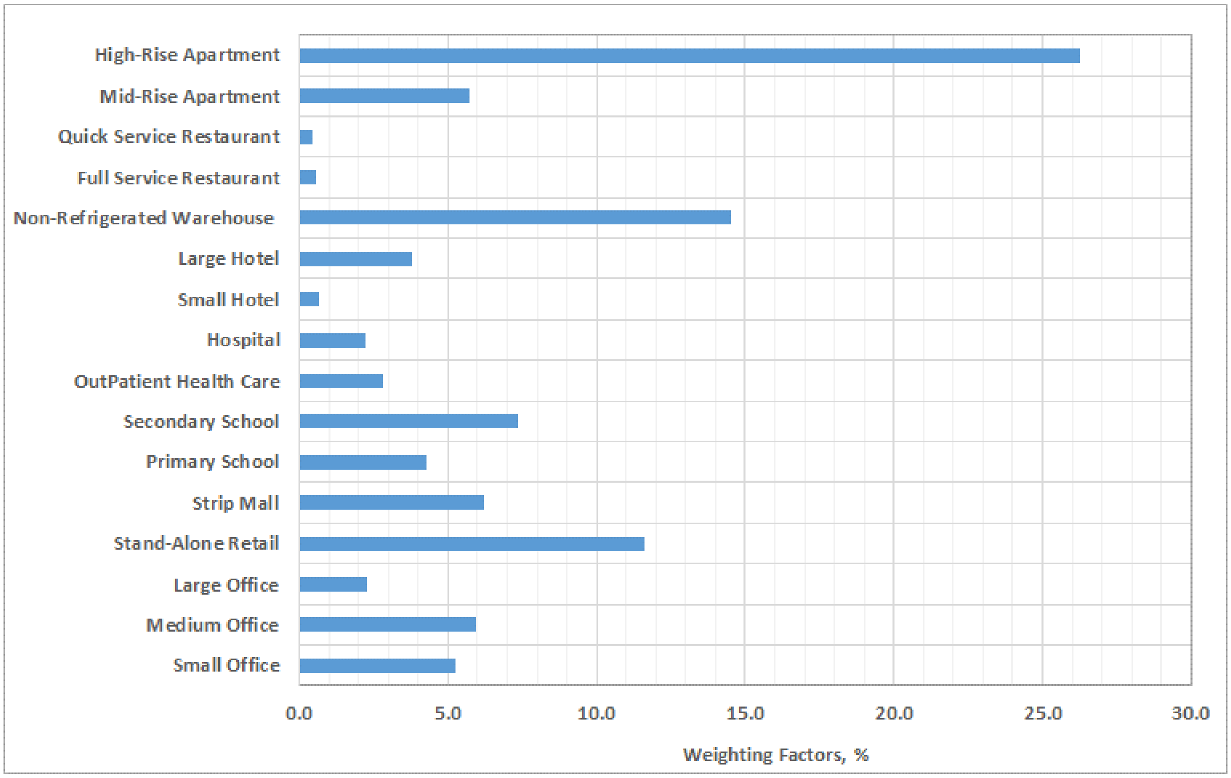

Figure 1 Commercial Prototype Buildings Type and Floor Area Distribution in Florida

The DOE uses the same prototype buildings to represent the US national commercial building stock for building energy use quantitative analysis and they claim that these building types represent 80% of the US national commercial building floor area stock (DOE, 2018). The prototype building floor area weighting factors presented here are specific for the State of Florida and were determined as described in Appendix-D.

Table 2 Commercial Prototype Buildings Type and Floor Area Distribution in Florida

Building Type	Prototype Building	Prototype Building Floor Area, ft^2	Total Building Floor Area, 1000 ft^2	Floor Area Weighting Factors, %
Office	Small Office	5,502	37,889	5.27
	Medium Office	53,628	42,765	5.94
	Large Office	498,588	16,558	2.30
Retail	Stand-Alone Retail	24,692	83,481	11.60
	Strip Mall	22,500	44,652	6.21
Education	Primary School	73,959	30,815	4.28
	Secondary School	210,887	52,709	7.33
HealthCare	Outpatient Health Care	40,946	20,381	2.83
	Hospital	241,501	16,210	2.25
Lodging	Small Hotel	43,202	4,682	0.65
	Large Hotel	122,120	27,389	3.81
Warehouse	Non-Refrigerated Warehouse	52,045	104,327	14.50
Food Service	Full Service Restaurant	2,501	4,003	0.56
	Quick Service Restaurant	5,502	3,296	0.46
Apartment	Mid-Rise Apartment	33,741	41,402	5.75
	High-Rise Apartment	84,360	188,913	26.25
Total		1,515,674	719,472	100.00

4.2 Annual Energy Use of Approved-I 2020 Florida Energy Code

The *approved-I* 2020 FEC scenario represents twenty-one code modifications approved and added to the base code, which is the 6th Edition (2017) FEC. The *approved-I* 2020 FEC code modifications that were quantitatively investigated are summarized in Appendix-A. The building energy use performance of the *approved-I* 2020 FEC were determined by comparing the site annual Energy Use Intensity (EUI) against that of ASHRAE 90.1-2016 code by prototype building. The site annual energy use intensity (EUI) of each of the prototype buildings type were aggregated by Florida climate zone floor area weighing factors to determine the EUI by prototype building type for the *approved-I* 2020 FEC scenario. Figure 2 shows the EUIs of the commercial prototype buildings designed with the *approved-I* 2020 FEC and ASHRAE 90.1-2016 code in the State of Florida. The weighted Florida average site annual EUI for the commercial sector was determined to be 46.64 kBtu/ft2-Yr and 46.50 kBtu/ft2-Yr for the *approved-I* 2020 FEC and the 2016 ASHRAE 90.1 code, respectively.

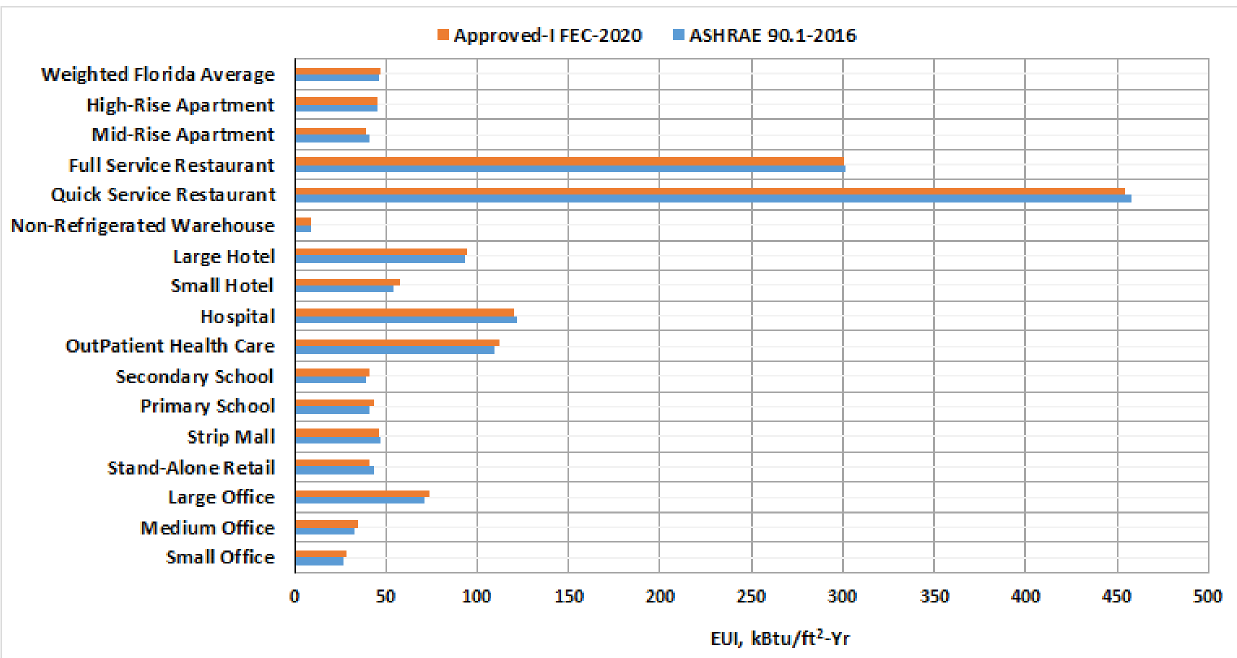

Figure 2 Annual Site Energy Use Intensity for the Approved-I 2020 FEC by Prototype Building

Figure 3 shows the site annual EUI difference between the *approved-I* 2020 FEC and ASHRAE 90.1-2016 code by the prototype buildings. Also Table 3 summarizes the EUIs of the *approved-I* 2020 FEC and the 2016 ASHRAE 90.1 code by prototype buildings and the weighted Florida average value. Seven out of the sixteen prototype buildings energy models designed with the *approved-I* 2020 FEC had site annual EUIs less than that of ASHRAE 90.1-2016 code whereas the remaining nine prototype buildings energy models had higher EUI values. Based on the Florida weighed average annual site EUI value the *approved-I* 2020 FEC underperforms the 2016 ASHRAE 90.1 code by about 0.29%.

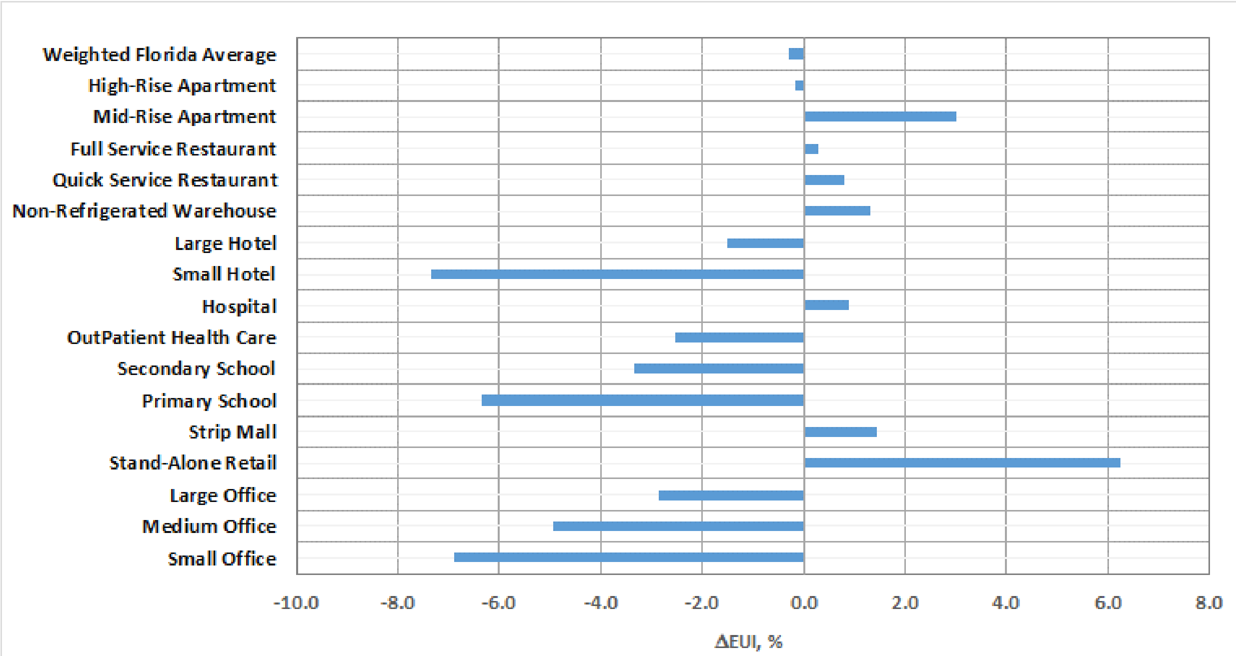

Figure 3 Annual Site Energy Use Intensity Difference by Prototype Building of the Approved-I 2020 FEC

Table 3 Annual Site Energy Use Intensity for the Approved-I 2020 FEC by Prototype Building

Building Type	Weighting Factors, %	ASHRAE 90.1-2016 EUI, kBtu/ft^2-yr	Approved-I FEC-2020 EUI, kBtu/ft^2-yr	ΔEUI, %
Small Office	5.27	26.44	28.27	-6.90
Medium Office	5.94	32.91	34.54	-4.94
Large Office	2.30	71.31	73.35	-2.86
Stand-Alone Retail	11.60	43.64	40.91	6.26
Strip Mall	6.21	47.23	46.55	1.44
Primary School	4.28	41.18	43.79	-6.34
Secondary School	7.33	39.13	40.45	-3.35
Outpatient Health Care	2.83	109.47	112.25	-2.54
Hospital	2.25	121.33	120.24	0.90
Small Hotel	0.65	53.77	57.71	-7.33
Large Hotel	3.81	93.03	94.42	-1.50
Non-Refrigerated Warehouse	14.50	8.93	8.81	1.32
Full Service Restaurant	0.56	457.87	454.20	0.80
Quick Service Restaurant	0.46	301.52	300.72	0.27
Mid-Rise Apartment	5.75	40.43	39.21	3.01
High-Rise Apartment	26.25	44.81	44.88	-0.17
Weighted Florida Average	100.00	46.50	46.64	**-0.29**

The weighted Florida average annual energy use performance determined based on the *approved-I* 2020 FEC scenario indicates that additional code modifications are required to make the 2020 FEC perform better than that of the 2016 ASHRAE 90.1 code. In this regard, the additional code amendments with energy impact were approved by the Florida Building Commission for addition to the 2020 FEC as of March 31, 2019 and were investigated quantitatively as described in Section 4.4.

4.3 Energy Cost Index of the Approved-I 2020 Florida Energy Code

In addition to energy use performance comparison, the total annual Energy Cost Index (ECI) of the *approved-I* 2020 FEC scenario was determined and compared against that of ASHRAE 90.1-2016 code by prototype building. The Energy Cost Indices (ECIs) of each of the prototype buildings were weighed by Florida climate zones weighting factors to determine the ECI by a prototype building. Figure 4 shows the ECI for commercial prototype buildings designed with the *approved-I* 2020 FEC and ASHRAE 90.1-2016 code in the State of Florida.

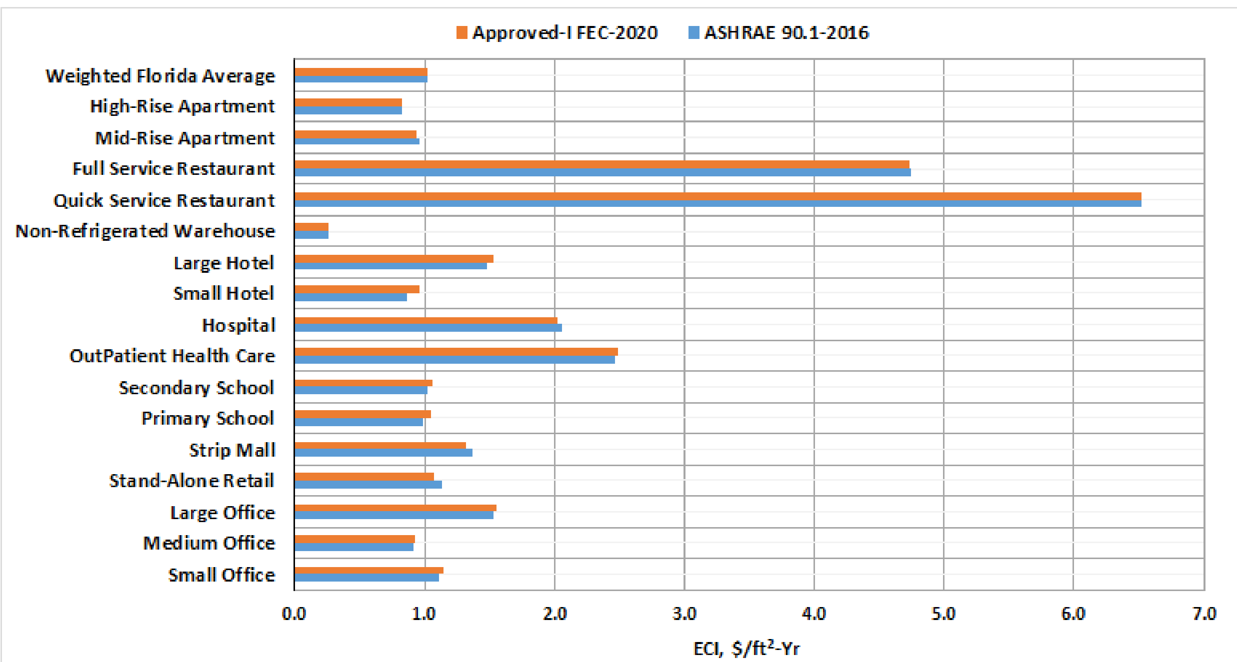

Figure 4 Energy Cost Index for the Approved-I 2020 FEC by Prototype Building

The weighted Florida average ECI for the commercial sector was estimated to be 1.024 $\$/ft^2$-Yr and 1.027 $\$/ft^2$-Yr for the *approved-I* 2020 FEC and the 2016 ASHRAE 90.1 code, respectively. Table 4 summarizes the annual ECI's of the *approved-I* 2020 FEC and the 2016 ASHRAE 90.1 prototype building models including the percent differences. The *approved-I* 2020 FEC weighted Florida average annual operating total energy cost index (ECI) is lower by about 0.24%. That is the weighted Florida average energy cost performance for the commercial sector slightly surpasses that of the 2016 ASHRAE 90.1 code, by about 0.24%. The *approved-I* 2020 FEC total energy cost shows slightly better performance than that of total annual energy use is in part due to difference in energy rates by fuel type as well as total energy cost which includes demand charge for this analysis. Nevertheless, the energy and energy cost differences determined between the *approved-I* 2020 FEC scenario and the 2016 ASHRAE 90.1 code were within the margin of error of prototype building model assumption. Additional code amendments investigation is warranted to demonstrate a clear performance difference between the 2020 FEC and the 2016 ASHRAE 90.1 code.

Table 4 Energy Cost Index for the Approved-I 2020 FEC by Prototype Building

Building Type	Weighting Factors, %	ASHRAE 90.1-2016 ECI, $/ft^2-yr	Approved-II FEC-2020 ECI, $/ft^2-yr	∆ECI, %
Small Office	5.27	1.112	1.145	-2.90
Medium Office	5.94	0.909	0.922	-1.44
Large Office	2.30	1.524	1.555	-2.05
Stand-Alone Retail	11.60	1.140	1.074	5.79
Strip Mall	6.21	1.371	1.317	3.90
Primary School	4.28	0.981	1.051	-7.13
Secondary School	7.33	1.021	1.056	-3.52
Outpatient Health Care	2.83	2.459	2.487	-1.13
Hospital	2.25	2.064	2.025	1.88
Small Hotel	0.65	0.868	0.958	-10.37
Large Hotel	3.81	1.483	1.528	-3.06
Non-Refrigerated Warehouse	14.50	0.264	0.254	3.79
Full Service Restaurant	0.56	6.514	6.514	0.00
Quick Service Restaurant	0.46	4.745	4.732	0.27
Mid-Rise Apartment	5.75	0.957	0.935	2.30
High-Rise Apartment	26.25	0.827	0.828	-0.12
Weighted Florida Average	100.00	1.027	1.024	0.24

Section 4.4 of this report describes annual site energy use and total energy cost impact under *approved-II* 2020 FEC scenario which investigated twenty-six code modifications approved by Florida Building Commission for addition to the 2020 FEC as of March 31, 2019.

4.4 Annual Energy Use of the Approved-II 2020 Florida Energy Code

The *approved-II* 2020 FEC investigated represents twenty-one code modifications that were approved by Florida Building Commission as of October 31, 2018 and five-more code modifications approved by Florida Building Commission as of March 31, 2019 for addition to the 2020 FEC. The twenty-one code modifications approved for addition to the 2020 FEC are summarized in Appendix-A and the five code modification approved for addition to the 2020 FEC are summarized in Appendix-B. The building energy use performance of the *approved-II* 2020 FEC were determined by comparing the site annual Energy Use Intensity (EUI) against that of ASHRAE 90.1-2016 code by prototype building. The EUI of each of the prototype buildings for each climate zones were aggregated by Florida climate zone floor area weighing factors to determine the EUI by prototype building. Figure 5 shows the site annual EUIs for the commercial prototype buildings designed with the *approved-II* 2020 FEC and ASHRAE 90.1-2016 code in the State of Florida. Weighted Florida average annual site EUI for the commercial sector was determined to be 45.75 kBtu/ft^2-Yr and 46.50 kBtu/ft^2-Yr for the *approved-II* 2020 FEC and the 2016 ASHRAE 90.1 code, respectively. The weighted Florida average annual energy use performance of the *approved-II* 2020 FEC surpasses that of the 2016 ASHRAE 90.1 code by about 1.61%. The weighted Florida average annual site EUI was determined from the sixteen commercial prototype buildings EUIs using weighting factors that account for the commercial buildings total floor area distribution by climate zones and building type.

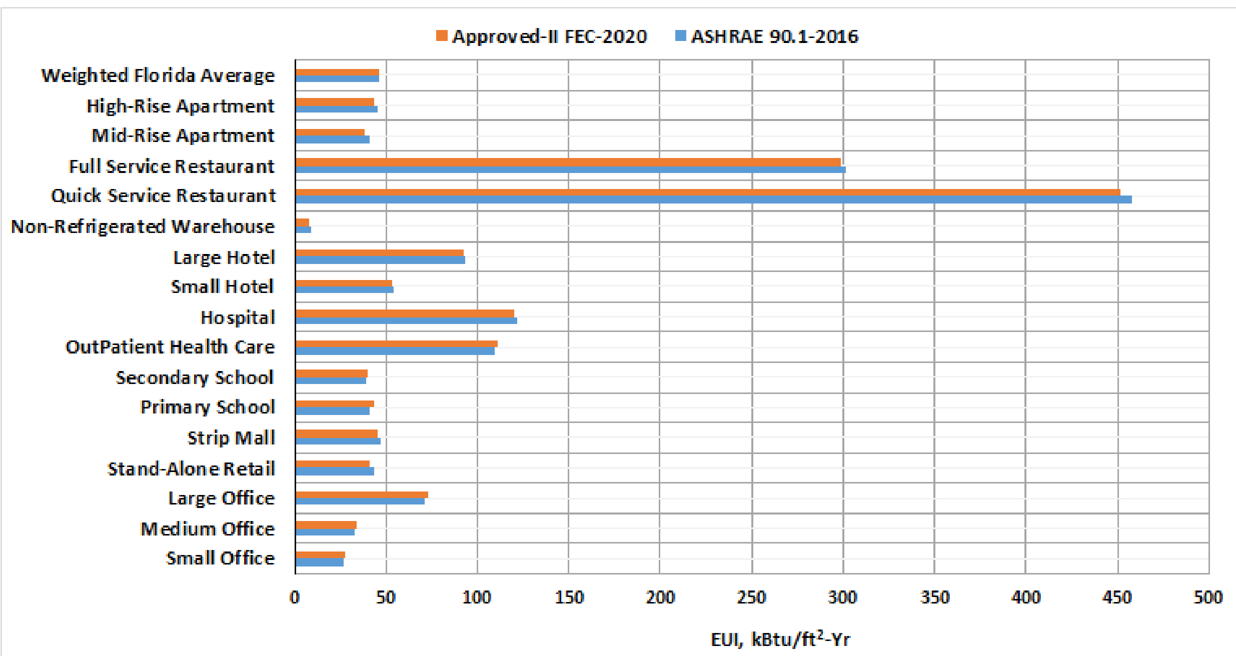

Figure 5 Annual Site Energy Use Intensity for the Approved-II 2020 FEC by Prototype Building

Figure 6 shows the site annual EUI difference between the *approved-II* 2020 FEC scenario and ASHRAE 90.1-2016 code by prototype buildings. Also Table 5 summarizes the site annual EUIs of the *approved-II* 2020 FEC and the 2016 ASHRAE 90.1 code by prototype buildings.

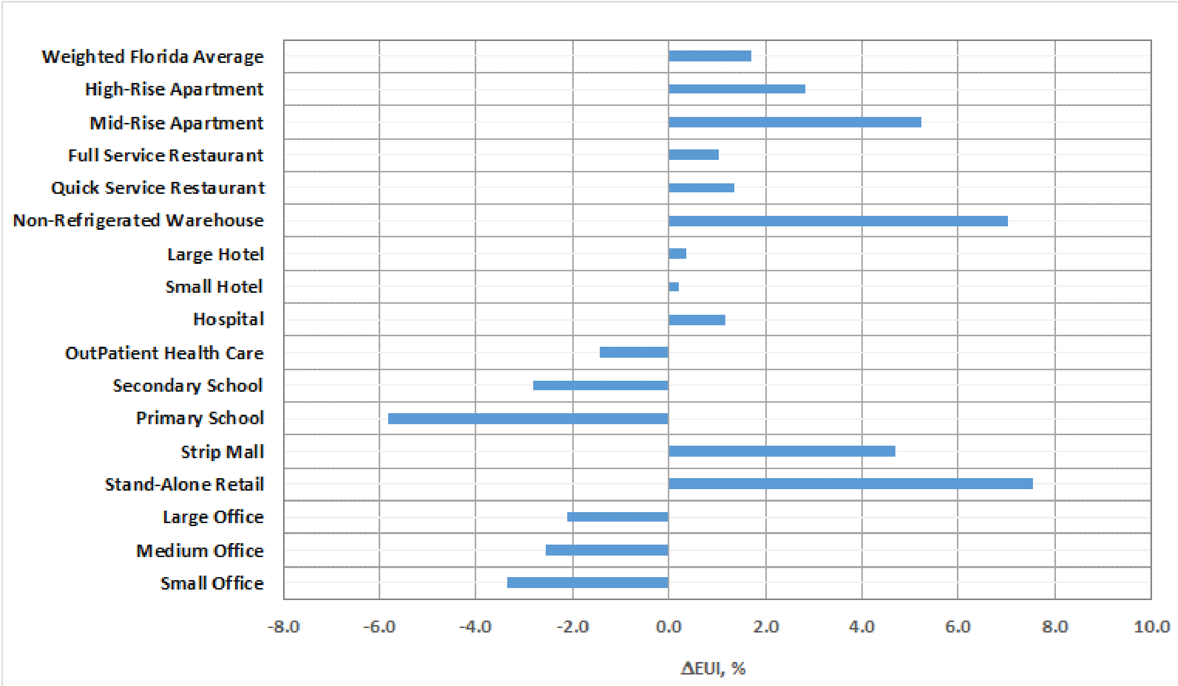

Figure 6 Annual Site Energy Use Intensity Difference by Prototype Building of the Approved-II 2020 FEC

Table 5 Annual Site Energy Use Intensity for the Approved-II 2020 FEC by Prototype Building

Building Type	Weighting Factors, %	ASHRAE 90.1-2016 EUI, kBtu/ft^2-yr	Approved-II FEC-2020 EUI, kBtu/ft^2-yr	ΔEUI, %
Small Office	5.27	26.44	27.33	-3.35
Medium Office	5.94	32.91	33.75	-2.54
Large Office	2.30	71.31	72.8	-2.1
Stand-Alone Retail	11.60	43.64	40.81	6.49
Strip Mall	6.21	47.23	45.02	4.68
Primary School	4.28	41.18	43.57	-5.82
Secondary School	7.33	39.13	40.24	-2.82
Outpatient Health Care	2.83	109.47	111.04	-1.43
Hospital	2.25	121.33	119.94	1.15
Small Hotel	0.65	53.77	53.65	0.21
Large Hotel	3.81	93.03	92.68	0.37
Non-Refrigerated Warehouse	14.50	8.93	8.31	6.91
Full Service Restaurant	0.56	457.87	451.76	1.34
Quick Service Restaurant	0.46	301.52	298.35	1.05
Mid-Rise Apartment	5.75	40.43	38.17	5.58
High-Rise Apartment	26.25	44.81	43.54	2.82
Weighted Florida Average	100.00	46.50	45.75	1.61

Ten out of the sixteen prototype buildings energy models designed with the *approved-II* 2020 Florida code had EUIs less than that of ASHRAE 90.1-2016 code buildings. But the other six prototype buildings slightly underperformed the 2016 ASHRAE 90.1 code. Table 6 summarizes the six *approved-II* 2020 FEC prototype buildings energy models underperformed the 2016 ASHRAE 90.1 code. These six prototype buildings underperformed primarily due to absence of one or two of advanced control function in the 2020 FEC. The advanced control functions that are required in ASHRAE 90.1-2016 code but not in the IECC-2018 based 2020 FEC were: (1) Automatic Receptacle Control (ASHRAE 90.1-2016, Section 8.4.2), and (2) Secondary Sidelight Area Control (ASHRAE 90.1-2016, Section 9.4.1.1(e)). One or both advanced control functions were applied to the six ASHRAE 90.1-2016 prototype buildings but were not applicable to the 2020 FEC prototype building energy models.

Table 6 Underperformed Prototype Buildings of Approved-II 2020 FEC Scenario

Building Type	Weighting Factors, %	ASHRAE 90.1-2016 EUI, kBtu/ft^2-yr	Approved-II FEC-2020 EUI, kBtu/ft^2-yr	∆EUI, %
Small Office	5.27	26.44	27.33	-3.35
Medium Office	5.94	32.91	33.75	-2.54
Large Office	2.30	71.31	72.8	-2.10
Primary School	4.28	41.18	43.57	-5.82
Secondary School	7.33	39.13	40.24	-2.82
Outpatient Health Care	2.83	109.47	111.04	-1.43

ASHRAE 90.1-2016 code requires automatic receptacle control in spaces types such as private offices, conference rooms, printing and copying rooms, classrooms, break rooms, and private work station (ASHRAE, 2016). The Large Hotel, Small Hotel, Hospital, Medium Office, Large Office, Small Office, Standalone Retail, Full-service Restaurant, Primary School, Secondary School, Outpatient Healthcare, and Warehouse prototype buildings for ASHRAE 90.1-2016 code have automatic receptacle control. Automatic receptacle control in ASHRAE 90.1-2016 code buildings energy models were accounted for using reduced plug load schedules (U.S. DOE, 2018). In addition to the automatic receptacle control, ASHRAE 90.1-2016 Section 9.4.1.1 allows secondary sidelight area control, which is not a requirement in the 2020 FEC. However, the *approved-II* 2020 FEC scenario prototype building energy models weighted Florida average EUI, which is an aggregate across the sixteen commercial buildings and the two Florida climate zones, is lower than that of ASHRAE 90.1-2016 code by about 1.61%. Implying the *approved-II* 2020 FEC scenario performs slightly better than the 2016 ASHRAE 90.1 code.

4.5 Energy Cost Index of the Approved-II 2020 Florida Energy Code

In addition to energy use performance comparison, the total annual Energy Cost Index (ECI) of the *approved-II* 2020 FEC prototype building energy models were compared against that of ASHRAE 90.1-2016 code. The Energy Cost Indices (ECIs) of each of the prototype buildings were weighed by Florida climate zones weighting factors to determine the ECI by prototype building. Figure 7 shows the ECI for commercial prototype buildings designed with the approved-II 2020 FEC scenario and ASHRAE 90.1-2016 code in the State of Florida. Weighted Florida average ECI was determined by aggregating the sixteen commercial prototype buildings ECI using weighting factors that account for the state's commercial building floor area distribution by the two climate zones and prototype buildings. The weighted Florida average ECI for the commercial sector was estimated to be 1.009 $/ft^2-Yr and 1.027 $/ft^2-Yr for the *approved-II* 2020 FEC scenario and the 2016 ASHRAE 90.1 code, respectively.

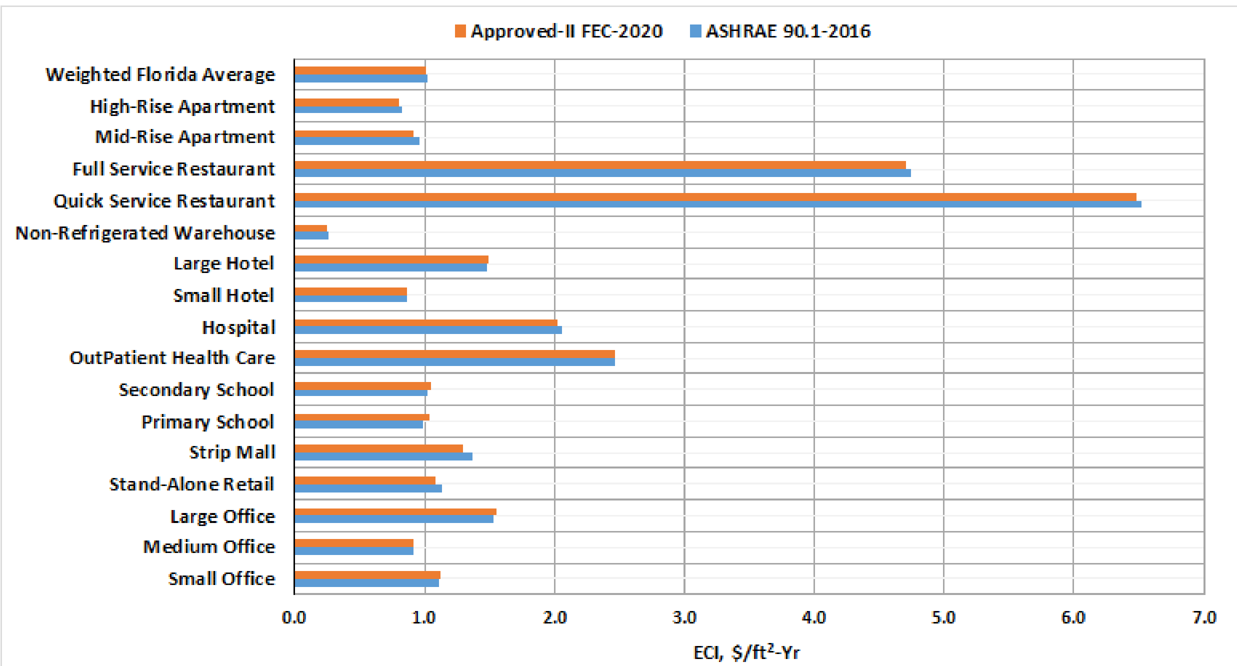

Figure 7 Energy Cost Index for the Approved-II 2020 FEC by Prototype Building

Table 7 summarizes the annual Energy Cost Index (ECI) of the *approved-II* 2020 FEC and the 2016 ASHRAE 90.1 prototype building models including the percent differences. The *approved-II* 2020 FEC weighted Florida average annual operating ECI, which is an aggregate of the sixteen commercial prototype buildings for the state of Florida, is lower by about 1.75%.

Table 7 Energy Cost Index for the Approved-II 2020 FEC by Prototype Building

Building Type	Weighting Factors, %	ASHRAE 90.1-2016 ECI, $/ft^2-yr	Approved-II FEC-2020 ECI, $/ft^2-yr	ΔECI, %
Small Office	5.27	1.112	1.127	-1.30
Medium Office	5.94	0.909	0.912	-0.34
Large Office	2.30	1.524	1.551	-1.80
Stand-Alone Retail	11.60	1.140	1.082	5.05
Strip Mall	6.21	1.371	1.297	5.36
Primary School	4.28	0.981	1.041	-6.11
Secondary School	7.33	1.021	1.051	-2.94
Outpatient Health Care	2.83	2.459	2.469	-0.41
Hospital	2.25	2.064	2.015	2.37
Small Hotel	0.65	0.868	0.858	1.15
Large Hotel	3.81	1.483	1.488	-0.36
Non-Refrigerated Warehouse	14.50	0.264	0.250	5.22
Full Service Restaurant	0.56	6.514	6.484	0.46
Quick Service Restaurant	0.46	4.745	4.702	0.90
Mid-Rise Apartment	5.75	0.957	0.915	4.39
High-Rise Apartment	26.25	0.827	0.798	3.51
Weighted Florida Average	100.00	1.027	1.009	1.75

4.6 Energy Use of the ASHARE 90.1-2020 Florida Energy Code

Florida Building Code, Energy Conservation, 7th Edition (2020) also allows ANSI/ASHRAE/IESNA 90.1-2016 standard as an alternative compliance option. This section investigated performance of the modified ASHRAE Standard 90.1 code per code modification EN8045 approved by Florida Building Commission for addition to the 2020 FEC. The approved code modification EN8045 excludes sections 9.4.1.1(g) and 8.4.2 of ASHRAE 90.1-2016 code. The quantitative analysis compared the amended ASHRAE Standard 90.1 code against the 2016 ASHRAE 90.1 Standard. The prototype building energy models representing the modified ASHRAE 90.1-2016 code as an alternative compliance option for Florida is labeled as ASHRAE 90.1-2020 FEC. The prototype buildings model of ASHRAE 90.1-2020 FEC buildings were created by removing the interior lighting control of section 9.4.1.1(g) and the automatic receptacle control section 8.4.1 from the 2016 ASHRAE 90.1 prototype building models. The interior lighting control code section impacts Medium Office, Large Office, Small Office, Standalone Retail, Strip Mall, Primary School, Secondary School, Quick-Service Restaurant, Full-Service Restaurant, and Warehouse prototype buildings. Whereas the automatic receptacle control code section impacts all the sixteen prototype buildings. Annual site energy use intensities of the prototype buildings weighted by Florida climate zones and commercial buildings floor area stock of the state are summarized in Table 8. All the sixteen prototype buildings of the modified ASHRE 90.1 code, which is labeled as ASHRAE 90.1-2020 FEC, show higher annual energy use.

Table 8 Annual Site Energy Use Intensity for the ASHRAE 90.1-2020 FEC by Prototype Building

Building Type	Weighting Factors, %	ASHRAE 90.1-2016 kBtu/ft^2-yr	ASHRAE 90.1-2020 FEC, kBtu/ft^2-yr	ΔEUI, %
Small Office	5.27	26.44	29.24	-10.57
Medium Office	5.94	32.91	34.37	-4.42
Large Office	2.30	71.31	72.87	-2.18
Stand-Alone Retail	11.60	43.64	44.37	-1.68
Strip Mall	6.21	47.23	48.02	-1.68
Primary School	4.28	41.18	46.12	-12.00
Secondary School	7.33	39.13	42.96	-9.76
Outpatient Health Care	2.83	109.47	109.79	-0.29
Hospital	2.25	121.33	122.03	-0.58
Small Hotel	0.65	53.77	53.86	-0.17
Large Hotel	3.81	93.03	93.09	-0.06
Non-Refrigerated Warehouse	14.50	8.93	9.47	-6.03
Full Service Restaurant	0.56	457.87	458.51	-0.14
Quick Service Restaurant	0.46	301.52	302.17	-0.21
Mid-Rise Apartment	5.75	40.43	40.50	-0.17
High-Rise Apartment	26.25	44.81	44.85	-0.09
Weighted Florida Average	100.00	46.50	47.53	-2.20

Figure 8 shows annual site energy use intensities of ASHRAE 90.1-2020 FEC and ASHRE 90.1-2016 code prototype buildings. The ASHRAE 90.1-2020 FEC prototype building energy models use slightly higher annual total energy due to removal of the interior lighting control and automatic receptacle control. The weighted Florida average annual site energy use for ASHRAE 90.1-2020 FEC was higher by about 2.20% compared to the original ASHRAE 90.1-2016 code.

The Energy Cost Indices (ECIs) of each of the prototype buildings for ASHRAE 90.1-2020 FEC and the original ASHRAE 90.1-2016 code were also determined. Figure 9 shows the ECI for commercial prototype buildings designed with ASHRAE 90.1-2020 FEC and the original ASHRAE 90.1-2016 code. The weighted Florida average ECI was determined to be 1.042 \$/ft^2-Yr and 1.027 \$/ft^2-Yr for the ASHRAE 90.1-2020 FEC and the 2016 ASHRAE 90.1 code, respectively. The ASHRAE 90.1-2020 FEC ECI was higher by about 1.48% compared to the original ASHRAE 90.1-2016 code.

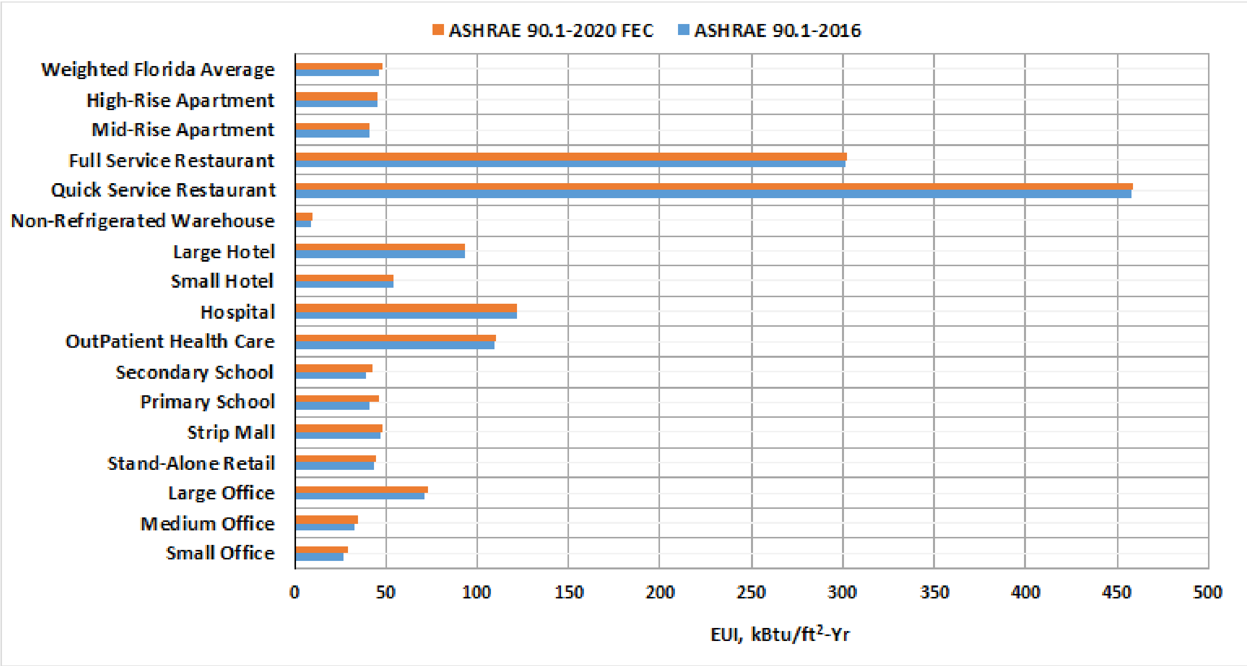

Figure 8 Annual Site Energy Use Intensity for the ASHRAE 90.1-2020 FEC by Prototype Building

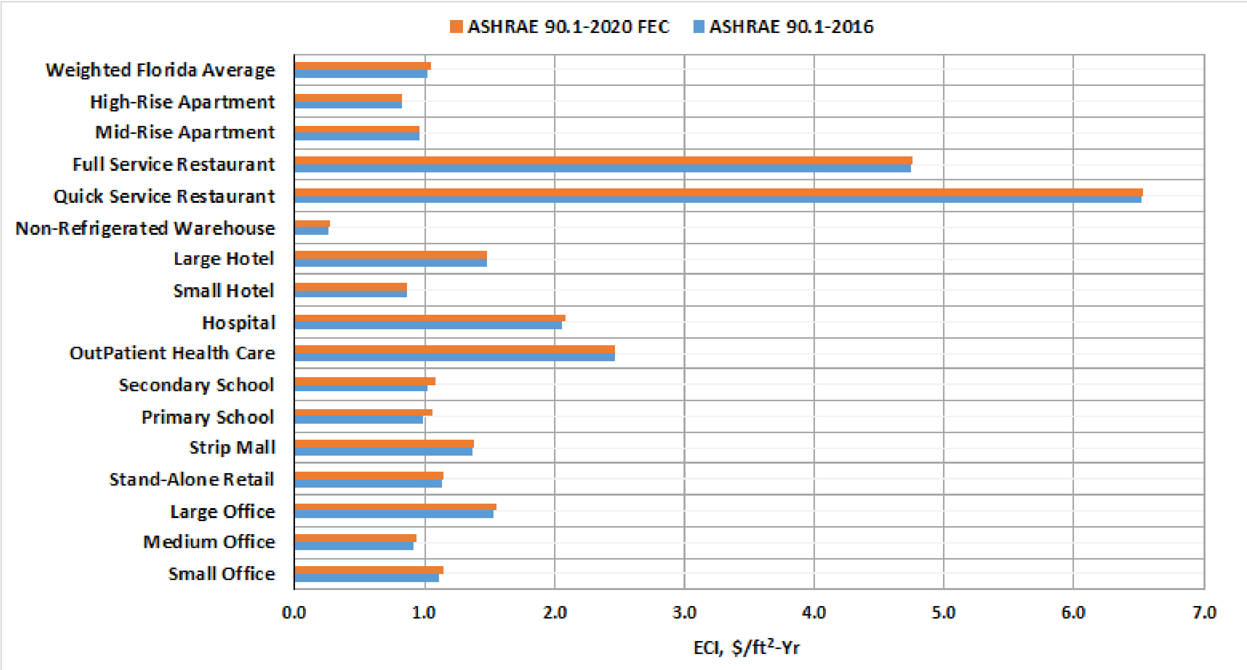

Figure 9 Energy Cost Index for the ASHRAE 90.1-2020 FEC by Prototype Building

4.7 Summary of the 2020 Florida Energy Code Scenarios

This section summarizes energy use performance of the 2020 FEC and the 2016 ASHRAE 90.1 code. The 2020 FEC has three scenarios: the *approved-I* 2020 FEC, *approved-II* 2020 FEC and modified ASHRAE 90.1-2020 FEC. The *approved-I* and *approved-II* 2020 FEC are the 7th Edition based Florida Energy Code with twenty-one and twenty-six code amendments included, respectively. The modified ASHRAE 90.1-2020 FEC is the 2016 ASHRAE 90.1 code excluding interior lighting control section 9.4.1.1(g) and automatic receptacle control section 8.4.2.

Table 9 and Figure 10 show annual site energy use intensities of the three 2020 Florida Energy Code scenarios. Annual site energy use performance of the three 2020 FEC scenarios was compared against that of ASHRAE 90.1-2016 code. Weighted Florida average annual energy use of ASHRAE 90.1-2020 FEC, which is a modified version of the ASHREA 90.1-2016 code, is higher by about 2.20% compared to the 2016 ASHRAE 90.1 code. Whereas the *approved-II* 2020 FEC annual energy use performance exceeds that of the 2016 ASHRAE 90.1 by about 1.61%. Annual site energy use performance of IEEC-2018 based and ASHRAE based 2020 FEC combined using equal weights was higher by about 0.30% compared to ASHRAE 90.1-2016 code building.

Table 10 and Figure 11 show annual energy cost index of the three 2020 Florida Energy Code scenarios. Annual energy cost index performance of the three 2020 FEC scenarios was compared against that of ASHRAE 90.1-2016 code. Weighted Florida average annual energy cost of ASHRAE 90.1-2020 FEC was higher by about 1.48% compared to the 2016 ASHRAE 90.1 code while the *approved-II* 2020 FEC was lower by about 1.75% compared to the 2016 ASHRAE 90.1 code building. Annual energy cost index performance of IEEC-2018 based and ASHRAE based 2020 FEC combined using equal weights was lower by about 0.15% compared to ASHRAE 90.1-2016 code building. Weighted Florida average annual site energy use intensities and annual energy cost indices of commercial buildings in the state of Florida for the three FEC scenarios and the 2016 ASHRAE 90.1 code are shown in Figure 12 and Figure 13, respectively.

Table 9 Annual Site Energy Use Intensity for the 2020 FEC Scenarios by Prototype Building

Building Type	ASHRAE 90.1-2016, kBtu/ft^2-yr	Approved-I FEC-2020, kBtu/ft^2-yr	Approved-II FEC-2020, kBtu/ft^2-yr	ASHRAE 90.1-2020 FEC, kBtu/ft^2-yr
Small Office	26.44	28.27	27.33	29.24
Medium Office	32.91	34.54	33.75	34.37
Large Office	71.31	73.35	72.80	72.87
Stand-Alone Retail	43.64	40.91	40.35	44.37
Strip Mall	47.23	46.55	45.02	48.02
Primary School	41.18	43.79	43.57	46.12
Secondary School	39.13	40.45	40.24	42.96
Outpatient Health Care	109.47	112.25	111.04	109.79
Hospital	121.33	120.24	119.94	122.03
Small Hotel	53.77	57.71	53.65	53.86
Large Hotel	93.03	94.42	92.68	93.09
Non-Refrigerated Warehouse	8.93	8.81	8.30	9.47
Full Service Restaurant	457.87	454.20	451.76	458.51
Quick Service Restaurant	301.52	300.72	298.35	302.17
Mid-Rise Apartment	40.43	39.21	38.17	40.50
High-Rise Apartment	44.81	44.88	43.54	44.85
Weighted Florida Average	46.50	46.64	45.75	47.53

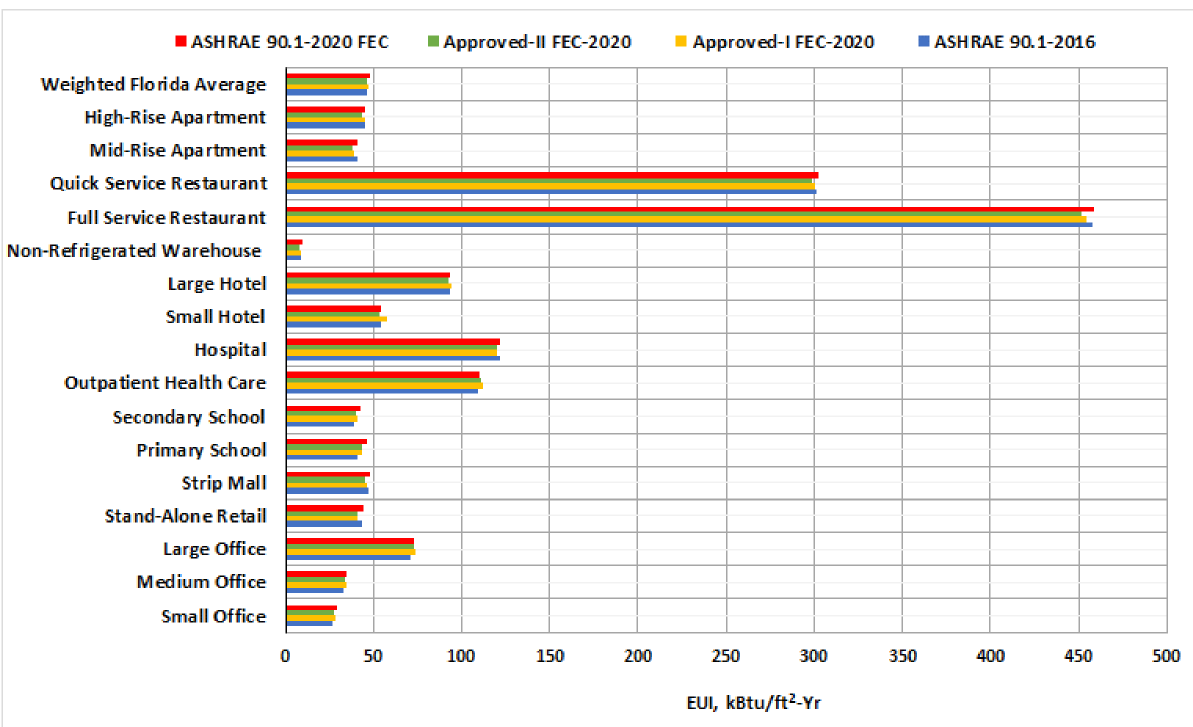

Figure 10 Annual Site Energy Use Intensity for the 2020 FEC Scenarios by Prototype Building

Table 10 Energy Cost Index for the 2020 FEC Scenarios by Prototype Building

Building Type	ASHRAE 90.1-2016, ECI, $/ft²-yr	Approved-I FEC-2020, ECI, $/ft²-yr	Approved-II FEC-2020, ECI, $/ft²-yr	ASHRAE 90.1-2020 FEC, ECI, $/ft²-yr
Small Office	1.112	1.145	1.127	1.145
Medium Office	0.909	0.922	0.912	0.932
Large Office	1.524	1.555	1.551	1.548
Stand-Alone Retail	1.14	1.074	1.082	1.15
Strip Mall	1.371	1.317	1.297	1.381
Primary School	0.981	1.051	1.041	1.061
Secondary School	1.021	1.056	1.051	1.085
Outpatient Health Care	2.459	2.487	2.469	2.469
Hospital	2.064	2.025	2.015	2.076
Small Hotel	0.868	0.958	0.858	0.868
Large Hotel	1.483	1.528	1.488	1.483
Non-Refrigerated Warehouse	0.264	0.254	0.25	0.27
Full Service Restaurant	6.514	6.514	6.484	6.524
Quick Service Restaurant	4.745	4.732	4.702	4.752
Mid-Rise Apartment	0.957	0.935	0.915	0.959
High-Rise Apartment	0.827	0.828	0.798	0.827
Weighted Florida Average	1.027	1.024	1.009	1.042

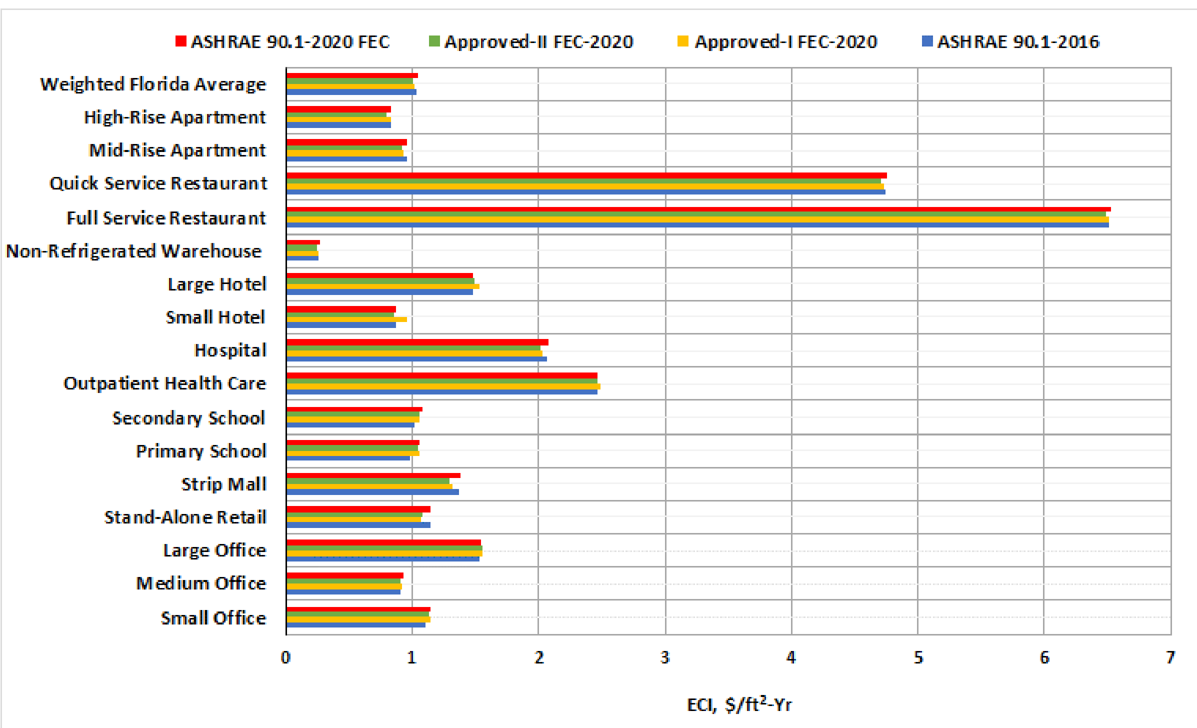

Figure 11 Energy Cost Index for the 2020 FEC Scenarios by Prototype Building

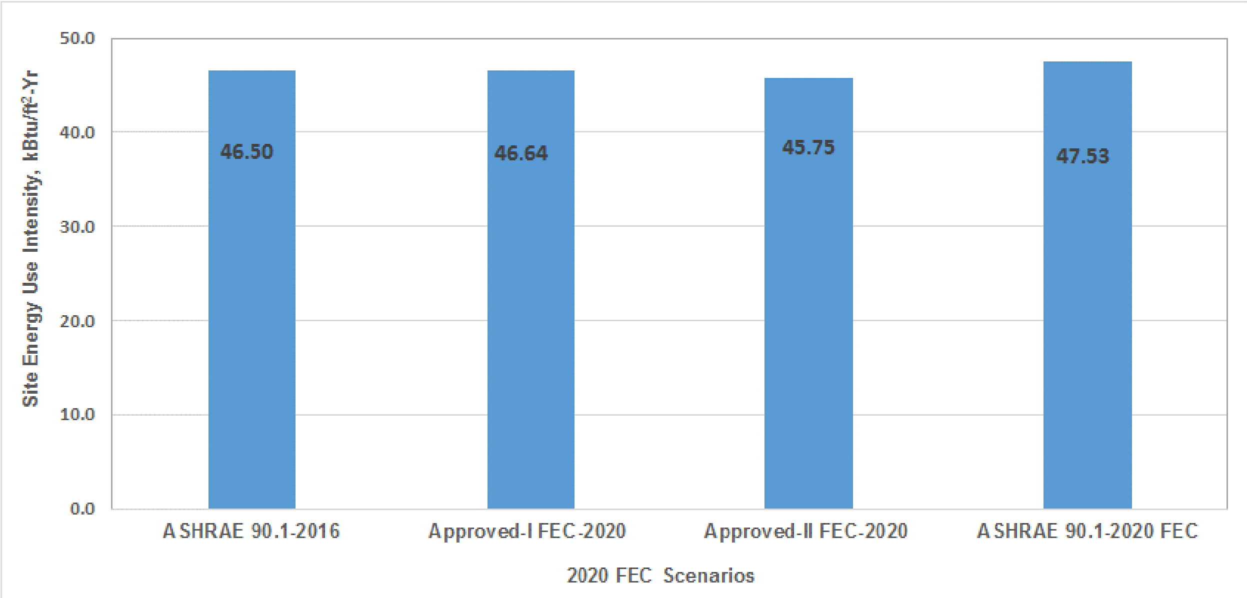

Figure 12 Weighted Florida Average Annual Site Energy Use Intensity for the 2020 FEC Scenarios

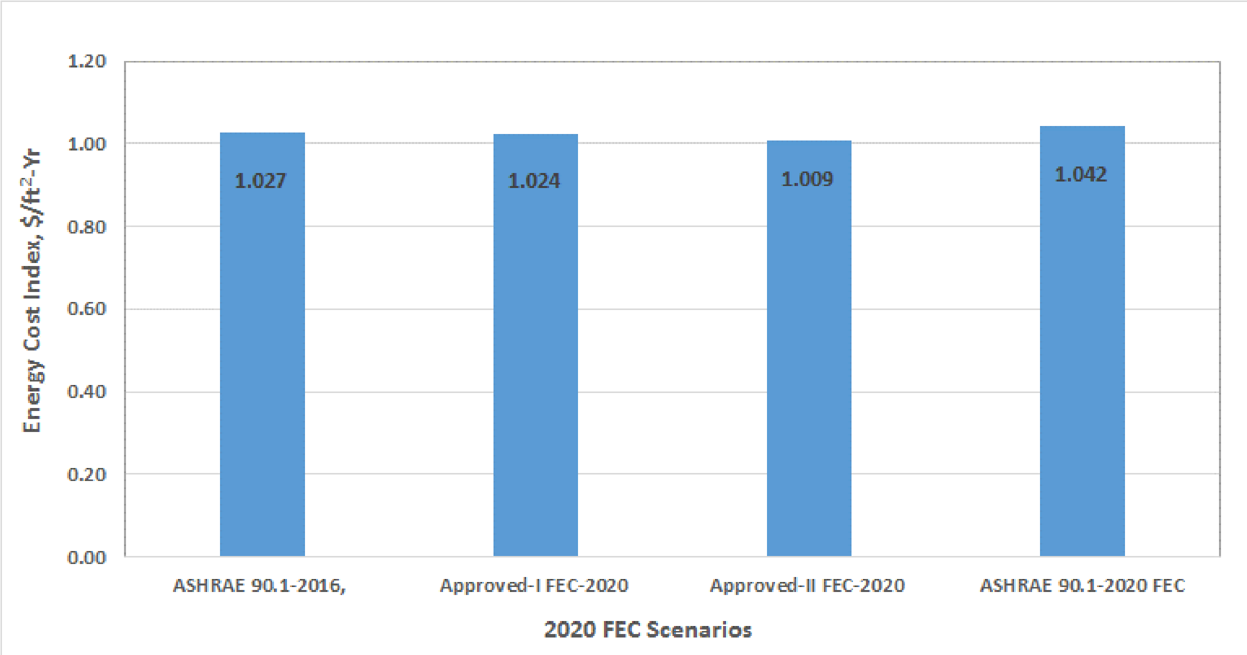

Figure 13 Weighted Florida Average Energy Cost Index for the 2020 FEC Scenarios

5. Economic Analysis of the 2020 Florida Energy Code

Economic analysis quantifies cost effectiveness of code amendments between the 7th Edition (2020) and the 6th Edition (2017) Commercial Florida Energy Code. The cost effectiveness analysis used the annual energy savings determined between the base case, which is the 6th Edition (2017) Florida Energy Code, and the upgrade, which is the 7th edition (2020) Commercial Florida Energy Code. This requires to create a separate baseline and upgrade code prototype building energy model for each code amendment or new code addition. Florida energy rates for electricity and natural gas and energy price escalation rates summarized in Appendix-C were used to compute annual total energy and life cycle energy costs. Summary of code modifications amenable for cost benefit analysis has been selected and provided in Appendix-A and Appendix-B. The selection excludes code modifications whose energy impact cannot be analyzed quantitatively, code modifications with no or negligible net first cost, federal minimum code modifications, and those code changes that has already been approved. Thus, the cost-benefit analysis will focus only on the code modifications that are submitted after October 31, 2018 and has energy impact and are summarized in Appendix-B.

5.1 Life-Cycle Cost Analysis of Code Modifications

Cost benefit analysis of a selected proposed code modifications was performed by calculating savings to investment ratio (SIR). SIR is ratio of net present value of the energy savings over a life time to net present value of life cycle cost of an investment. The net energy cost savings and net investment cost were determined from the difference between the upgrade (the 7th Edition FEC) and baseline (6th Edition FEC) models. In this analyses a constant dollar approach with real discount rate of 5.0% was assumed for both the baseline and upgrade life cycle cost calculation. The net present value of energy cost and net present value of the investment cost were determined using EnergyPlus, Whole Building Simulation Software. Table 11 summarizes cost benefit analysis results for each of the nine code modifications investigated. SIR value less than 1.0 means the net life cycle investment cost exceeds the net life cycle energy savings cost of the code modification or upgrade; hence, it is considered not economical. Out of the nine code modifications investigated five of them (EN7318, EN7326, EN7503, EN7523, and EN7536/EN8142) had SIR value greater than 1.0; hence they are considered economically feasible and are recommended for addition to the 2020 Florida Energy Code. Whereas the other three code modifications (EN7499, EN7515, and EN7558) had SIR value less than 1.0; hence they are not cost effective. However, code modification EN7533 need special consideration as its energy impact have not been captured in the simplified representation.

Table 11 Life Cycle Cost Analysis Summary

Code Mod #	Code Section # and Brief Description of Proposed Code Modifications	Savings to Investment Ratio (SIR)
EN7318	C405.2.4 Specific Application Control	+∝
EN7326	Tables C405.4.2(2) and C405.4.2 (3) Exterior Lighting Power Allowance	6.6
EN7503	C405.2.5.3 Exterior Lighting Setback	+∝
EN7523	C403.4.1.4 Heated or Cooled Vestibules	9.0
EN7536 /EN8142	C403.7.6 Automatic Control of HVAC Systems Serving Guest Rooms	1.2
EN7533	C403.2.4.2.3 Automatic And Optimum Start Capability of HVAC System	-
EN7515	C402.5.6 Loading Dock Weatherseals	<1.0
EN7499	C402.4.1.2 Increasing Skylight Area with Daylighting Control	-∝
EN7558	C403.7.7 Shutoff Dampers	0.30

The next section discusses the details assumptions and the cost effectiveness calculations for the nine code amendments.

Specific Application Control: EN7318

Modified Section C405.2.4. Permanently installed luminaires within dwelling units shall be provided with controls complying with Section C405.2.1.1 or C405.2.2.2. Thus, luminaires in dwelling/sleeping units must have occupancy sensor that turns off the lights within 20 minutes of all occupants have left the space. The code modifications did not change the technology, instead reduced the occupancy sensor cut-off time for interior lights control from 30 minutes to 20 minutes. We do not anticipate any first cost change for this code modification. This amendments impacts the two apartment prototype buildings.

Annual energy use and energy cost savings were estimated for the medium and high rise apartment prototype buildings. The interior lighting use schedule of the upgrade was decreased to account for the occupancy sensor based interior lights control cut-off time reduction. The analysis demonstrated that reducing cut-off time of occupancy sensor based interior lights control have impacts on annual energy use intensity and annual energy cost savings potential as shown in Table 12 and Table 13, respectively.

Cost-benefit analysis was performed assuming 10 years' service life but the code modification does not incur any additional first cost hence its net life cycle investment cost is zero. As the result, SIR value is large positive number as shown in Table 14. Therefore, code modification EN7318 is strongly recommended for approval by Florida Building Commission for addition to the 2020 FEC.

Table 12 Annual Energy Use Intensity Due to Specific Application Control

Prototype Building	Energy Use Intensity [kBtu/ft^2]		
	2017 FEC	2020 FEC	Difference
Mid Rise Apartment	39.22	38.52	0.70
High Rise Apartment	44.58	43.88	0.70

Table 13 Annual Total Energy Costs Due to Specific Application Control

Prototype Building	2017 FEC Annual Total Energy Cost, $	2020 FEC Annual Total Energy Cost, $	Energy Cost Savings, $
Mid Rise Apartment	29,720.98	29,160.81	560.2
High Rise Apartment	66,490.02	64,955.40	1534.62

Table 14 Life Cycle Cost Benefit Analysis of Specific Application Control

Prototype Building	Net Present Value of Investment Cost, $	Net Present Value of Energy Cost Savings, $	Savings to Investment Ratio (SIR)
Mid Rise Apartment	0.0	3,941.75	$\propto$
High Rise Apartment	0.0	10,812.24	$\propto$
Weighted Average	0.0	9,577.18	$\propto$

Exterior Lighting Power Allowance: EN7326

Modified Table C405.5.2 (2) Lighting Power Allowance for Building Exteriors. Reduced the exterior lighting power allowance values for tradable exterior building surface. Code change between the 6th edition (2017) FEC and the proposed 7th Edition (2020) FEC reduces the exterior lighting base allowance, tradeable surfaces lighting allowance. This change impacted the 16 reference prototype buildings parking lot and building entrance lighting allowance.

Modified Table C405.5.2 (3) Individual Lighting Power Allowance for Building Exteriors. Reduced the exterior lighting power allowance values for non-tradable exterior building surfaces. Code change between the 6th Edition (2017) FEC and the proposed 7th Edition (2020) FEC reduces the exterior non-tradeable surfaces lighting allowance.

Cost benefit analysis of the parking lot lighting upgrade was performed for all sixteen prototype buildings. The parking lot lights allowance for baseline and upgrade models were reviewed and modified. The exterior lighting zone assumptions may vary by prototype building (Thornton *et al.*, 2011). The life-cycle net investment cost and life-cycle net energy cost savings determined using EnergyPlus simulation were used to estimate the SIR value for each of the 16 prototype buildings. Table 15 summarized lamp type and efficacy assumptions for the baseline (2017 FEC) and the upgrade (2020 FEC). The baseline model assumes high intensity discharge (HID) fixtures and the upgrade assumes LED fixture. The lamp cost, ballast cost, installation and replacement cost, lamp life span, and fixture life span assumptions used in the analysis are summarized in Table E-1 through Table E-16 in Appendix-E for each of the prototype buildings.

Table 15 Lamp Type and Efficacy Assumptions for Parking Lot Lighting Upgrade

Prototype Building	Lamp Type	Watts Per Lamp	Lumens per Lamp	Lumens Per Watt	Life of Lamps, Hours
2017 FEC					
Small Office	HID	400	44000	110	20000
All Prototype Buildings Except Small Office Building	HID	1000	100000	100	10000
2020 FEC					
All Prototype Buildings	LED	300	40000	133.33	100000

Table 16 summarized the annual total energy cost for the baseline and upgrade, and the annual energy savings potential by prototype buildings. The savings to investment ratio (SIR) for each of the sixteen prototype buildings was found to be greater than 1.0 as shown in Table 17. Note that LED lamp have much longer life span compared to the HID lamps but for this analysis, 12-years life span was used as the life cycle based on HID lamp ballast service life as a common denominator. The SIR values calculated would have been much higher had we used the life span of LED lamp. Therefore, code modification EN7326 is strongly recommended for addition to the 2020 FEC.

Table 16 Annual Total Energy Costs Due to Parking Lot Lighting Upgrade

Prototype Building	2017 FEC Annual Total Energy Cost, $	2020 FEC Annual Total Energy Cost, $	Annual Energy Cost Savings, $
Small Office	6281.7	6232.5	49.3
Medium Office	49366.4	48926.3	440.1
Large Office	771099.3	768351.2	2748.2
Stand-Alone Retail	26410	26223.3	186.8
Strip Mall	29547.7	29333.1	214.5
Primary School	77467.7	77418.1	49.6
Secondary School	222092.7	221792.5	300.3
Outpatient Health Care	102475.2	102034.4	440.8
Hospital	478507.5	477831.8	675.7
Small Hotel	37481.3	37124.2	357.1
Large Hotel	182967.6	181685.6	1282
Non-Refrigerated Warehouse	13289.6	13188	101.6
Quick Service Restaurant	16323.6	16259.4	64.1
Full Service Restaurant	26053.1	25911	142.1
Mid-Rise Apartment	30969.5	30766.5	203
High-Rise Apartment	69318.6	68283.8	1034.9
Weighted Florida Average	88520.5	87991.4	529.2

Table 17 Life Cycle Cost Benefit Analysis of Parking Lot Lighting Upgrade

Prototype Building	Net Present Value of Investment Cost, $	Net Present Value of Energy Cost Savings, $	Savings to Investment Ratio (SIR)
Small Office	37	433	11.7
Medium Office	915	3867	4.2
Large Office	3658	24144	6.6
Stand-Alone Retail	457	1641	3.6
Strip Mall	457	1885	4.1
Primary School	-120	436	∝
Secondary School	1000	2638	2.6
Outpatient Health Care	915	3872	4.2
Hospital	741	5937	8.0
Small Hotel	74	3137	42.5
Large Hotel	915	11263	12.3
Non-Refrigerated Warehouse	457	892	2.0
Quick Service Restaurant	-120	564	∝
Full Service Restaurant	457	1248	2.7
Mid-Rise Apartment	457	1783	3.9
High-Rise Apartment	915	9092	9.9
Weighted Florida Average	702	4649	6.6

Cost benefit analysis for building facade lighting upgrade was demonstrated using the medium office building. The building facade lighting power density allowance for the medium office baseline and upgrade prototype building energy models were updated based on the 6th Edition FEC and the proposed 7th Edition FEC. The life-cycle net investment cost and life-cycle net energy cost savings determined using EnergyPlus simulations were used to calculate the saving to investment ratio. Table 18 summarized lamp type and efficacy assumptions for the baseline (2017 FEC) and the upgrade (2020 FEC). The baseline model assumes linear compact fluorescent lamps with dimming ballast and the upgrade assumes LED fixture. The lamp cost, ballast cost, installation and replacement cost, lamp life span, and fixture life span assumptions used in the analysis are summarized in Table E-17 in Appendix-E.

Table 18 Lamp Type and Efficacy Assumptions for Building Facade Lighting Upgrade

Prototype Building	Lamp Type	Watts Per Lamp	Lumens per Lamp	Lumens Per Watt	Life of Lamps, Hours
2017 FEC					
Medium Office	HID	119	10000	84.0	30000
2020 FEC					
Medium Office	LED	100	11000	110.0	50000

Table 19 summarized the annual total energy cost for the baseline and upgrade, and the annual energy savings potential for the medium office prototype building. The savings to investment ratio (SIR) for each of the medium office prototype buildings was found to be about 6.0 as shown in Table 20. Therefore, code modification building facade lighting power density upgrade is strongly recommended for addition to the 2020 FEC.

Table 19 Annual Total Energy Costs Due to Exterior Facade Lighting Upgrade

Prototype Building	2017 FEC Annual Total Energy Cost, $	2020 FEC Annual Total Energy Cost, $	Annual Energy Cost Savings, $
Medium Office	49366.4	49352.1	14.28

Table 20 Life Cycle Cost Benefit Analysis of Exterior Facade Lighting Upgrade

Prototype Building	Net Present Value of Investment Cost, $	Net Present Value of Energy Cost Savings, $	Savings to Investment Ratio (SIR)
Medium Office	20.6	125.5	6.09

Increased Skylight Area with Daylight Responsive Controls: EN7499

Modified code section C402.4.1.2 by increasing the skylights area fraction limit allowed when daylight response control is used from 5% to 6%. Impacts of the skylight area fraction limit increase was investigated using the warehouse, primary school and secondary school prototype buildings. For each of the three prototype buildings two building energy models were created with 5% and 6% skylight area fraction representing the 6^{th} Edition (2017) FEC and the 7^{th} Edition (2020) FEC, respectively. The baseline and the upgrade models were created for climate zones 1A and 2A, and the predicted annual total energy use and cost were weighted by climate zones 1A and 2A. The difference in annual energy use intensity and annual total energy cost between the upgrade and the baseline were determined. Contrary to our expectation the annual energy use and annual total energy cost slightly increased for the 6% skylight area fraction as shown in Table 21 and Table 22, respectively. Looking deeper the analysis demonstrated that the interior lighting energy use decreased because of the daylighting zone area increase for the 2020 FEC (6% skylight area) compared to the 2017 FEC (5% skylight area) scenario but the lighting energy savings were offset by increased HVAC energy use.

Table 21 Annual Energy Use Intensity Due to Skylight Area Fraction Increase

Prototype Building	Energy Use Intensity [kBtu/ft^2]		
	2017 FEC	2020 FEC	Difference
Primary School	43.47	43.51	-0.04
Secondary School	40.23	40.33	-0.10
Non-Refrigerated Warehouse	8.73	8.76	-0.03

Table 22 Annual Total Energy Costs Due to Skylight Area Fraction Increase

Prototype Building	2017 FEC Annual Total Energy Cost, $	2020 FEC Annual Total Energy Cost, $	Energy Cost Savings, $
Primary School	73,992.8	74,079.55	-86.74
Secondary School	21,7086.1	217,732.08	-646.03
Non-Refrigerated Warehouse	11,224.65	11,257.07	-32.42

Annual energy use and annual total energy cost difference between the upgrade and the baseline were negative indicating that the energy use bumped up with the skylight area fraction increase to 6.0%. Therefore, for zero net life cycle investment cost and increased annual energy use due to the upgrade results in large negative SIR value as shown in Table 23. This implies increasing the skylight area fraction limit from 5.0% to 6.0% cannot be justified economically in the three prototype buildings investigated primarily due to prevailing small interior lighting density (LPD).

Table 23 Life Cycle Cost Benefit Analysis of Skylight Area Fraction Increase

Prototype Building	Net Present Value of Investment Cost, $	Net Present Value of Energy Cost Savings, $	Savings to Investment Ratio (SIR[1])
Primary School	0.0	-1211.2	-∝
Secondary School	0.0	-8906.5	-∝
Non-Refrigerated Warehouse	0.0	-459.9	-∝

The estimated energy use differences could be different for prototype buildings with higher interior LPD allowance. The analysis conducted by PNNL to justify the sky lighting area fraction limit to increase to 6.0% was done based on the 2010 ASHRAE 90.1 code analysis (Athalye et al., 2013). Since then the interior lighting power density (LPD) has come down significantly; there is less interior lighting energy savings potential for this upgrade when analyzed using the proposed 2020 FEC, which is based on the 2018 IECC. Since the energy use has increased, the SIR value is very large negative, which implies increasing skylight area fraction to 6.0% is not

[1] SIR value of negative large number occurs when the life cycle net investment cost is less than or equal to zero, and the upgrade results net increase in annual energy use.

cost effective based three building types investigated. This proposed code change may be economically feasible if we use more stringent skylight U-value. Perhaps testing in other prototype building with higher interior LPD allowance may be also helpful. We suggest keeping the skylight area fraction limit at 5.0% and recommend further investigation for range of skylight u-value and interior lighting power density (LDP) before approval for addition to the 7th edition Florida Energy Code.

Lighting setback: EN7503

Modify the new code section C405.2.5.3. Lighting setback requirement for exterior lighting. Currently parking lot and entrance door exterior lighting is setback to 70% of the full LDP during building off hours (Mid night to 6 AM). The 2016 ASHRAE 90.1 code uses 50% reduction. Code modification EN7503 was submitted to increase the dimming capability from 30% to 50%. Buildings that could be occupied or operated 24/7 such as Large Hotel, Small Hotel, Hospital, High-Rise and Mid-rise Apartments are exempted from this requirement.

The approved code medication section C405.2.5.3 Lighting setback as of October 31, 2018 already requires 30% exterior lighting dimming capability from midnight to 6 am. The current exterior lighting power dimming capability approved for the 2020 FEC (adopted from IECC-2018) were primarily based on LED lighting technologies. The LED exterior lighting products for outdoor application analyzed under code modification EN7326 already have dimming capability that range from 25% to 75%. Therefore we do not anticipate any first cost increase by increasing the dimming capability of LED fixtures from 30% to 50%. Annual energy use and annual energy cost determined using simulation for the baseline (with 30% dimming capability) and the upgrade (with 50% dimming capability) are summarized in Table 24, respectively. Annual energy cost savings are demonstrated for eleven of the prototype buildings.

Table 24 Annual Total Energy Cost Due to Code Modification EN7503

Prototype Building	2017 FEC Annual Total Energy Cost, $	2020 FEC Annual Total Energy Cost, $	Total Annual Energy Cost Savings, $
Small Office	6224.3	6213.1	11.2
Medium Office	48969.5	48884.8	84.7
Large Office	773653.6	773188.7	464.9
Stand-Alone Retail	26150.4	26115.2	35.2
Strip Mall	29370.4	29279.8	90.6
Primary School	77438.3	77371.2	67.1
Secondary School	222219.4	222065.5	153.9
Outpatient Health Care	101315.0	101199.5	115.5
Non-Refrigerated Warehouse	13101.6	12946.4	155.2
Quick Service Restaurant	16219.5	16210.5	9.0
Full Service Restaurant	25885.3	25865.1	20.2

Table 25 Life Cycle Cost Benefit Analysis of Increasing Lighting Setback Upgrade

Prototype Building	Net Present Value of Investment Cost, $	Net Present Value of Energy Cost Savings, $	Savings to Investment Ratio (SIR)[2]
Small Office	0.0	116.25	∝
Medium Office	0.0	879.16	∝
Large Office	0.0	4825.5	∝
Stand-Alone Retail	0.0	365.36	∝
Strip Mall	0.0	940.40	∝
Primary School	0.0	696.48	∝
Secondary School	0.0	1597.43	∝
Outpatient Health Care	0.0	1198.85	∝
Non-Refrigerated Warehouse	0.0	1610.92	∝
Quick Service Restaurant	0.0	93.42	∝
Full Service Restaurant	0.0	209.67	∝

Since net first cost increase is not anticipated for this upgrade, cost benefit analysis is not required. Nevertheless, the SIR value for estimated net present value of energy cost savings over fifteen years life span and zero net investment cost is large positive number as shown in Table 25. Therefore, the proposed code modifications EN7503 is strongly recommended for addition to the 7th Edition (2020) Florida Energy Code.

Loading Dock Weatherseals: EN7515

Modified code section C402.5.6. Door openings shall be equipped with weatherseals to restrict infiltration and provide direct contact along the top and sides of vehicles when parked in the doorway. The EN7515 code modification applies to warehouse prototype building only.

The warehouse prototype building has 15 overhead doors and assumes 21.3% of the doors are in open position at a time and the peak design infiltration rate through the loading dock in open position was assumed to be 873.0 cfm (U.S. DOE, 2017). Impact of outside air infiltration rate reduction on the building load due to loading dock weatherseals was determined by assuming a 50% peak infiltration rate cut from the baseline when the docking doors are in open position. The baseline and upgrade annual energy use intensities and annual total energy cost due to code modification EN7515 are summarized in Table 26 and Table 27, respectively. The annual energy use and annual energy cost savings potential for the loading dock weatherseals were found out to be very small.

[2] SIR value of positive infinity occurs when the life cycle net investment cost is less than or equal to zero, and there is energy savings. This implies the upgrade cost is less than that of the baseline over the service life of study.

Table 26 Annual Total Energy Use Intensity Savings Due to Loading Dock Weatherseals

Prototype Building	2017 FEC Energy Use Intensity, $kBtu/ft^2$	2020 FEC Energy Use Intensity, $kBtu/ft^2$	Energy Use Intensity Savings, $kBtu/ft^2$
Non-Refrigerated Warehouse	8.547	8.543	0.004

Table 27 Annual Total Energy Cost Savings Due to Loading Dock Weatherseals

Prototype Building	2017 FEC Annual Total Energy Cost, $	2020 FEC Annual Total Energy Cost, $	Total Annual Energy Cost Savings, $
Non-Refrigerated Warehouse	13,105.1	13,097.3	7.84

Table 28 Life Cycle Cost Benefit Analysis of Loading Dock Weatherseals

Prototype Building	Net Present Value of Investment Cost, $	Net Present Value of Energy Cost Savings, $	Savings to Investment Ratio (SIR)
Non-Refrigerated Warehouse	1428.57	106.89	0.07

Net investment cost and net present value of the energy savings over twenty-five-year service life of the upgrade are shown in Table 28. It was difficult to estimate the first and operating costs of this upgrade; however, a conservative incremental first cost of $100.0 per door and zero maintenance cost were assumed. The incremental first cost for this upgrade can be much higher hence, this cost benefit analysis should be taken as demonstration only. A conservative estimate of the SIR value for this upgrade is less than 1.0 and can be concluded the upgrade is not economical for such small annual energy savings estimate. Therefore, loading dock weatherseals upgrade is not justified until reliable infiltration reduction rate and upgrade cost estimate is available but can be considered as good practice for addition to the 7th Edition (2020) Florida Energy Code.

Heated or Cooled Vestibules: EN7523

Added new code section C403.4.1.4. Defines heating and cooling temperature limits for heated or cooled vestibules and air curtain.

Added an EMS control for heating and cooling setpoint temperature control for heated and cooled vestibules and turns off the heating system when the outdoor air temperature is greater than 7°C (45°F). Only stand-alone retail prototype building has vestibules. Heated vestibule advanced control were added to the stand-alone retail prototype building energy model. The annual total energy cost for the baseline and upgrade standalone-retail prototype building due to proposed code modification are summarized in Table 29. Life cycle net investment cost, life time net energy cost savings, and the estimated SIR value are summarized in Table 30. The SIR value this code modification is about 9.0, implies the code change is economically feasible and is recommended for addition to the 7th Edition (2020) Florida Energy Code. The incremental first cost and recurring maintenance cost assumptions used for life cycle cost analysis are summarized in Table E-18 in Appendix-E.

Table 29 Annual Total Energy Cost Savings Due to Code Modification EN7523

Prototype Building	2017 FEC Annual Total Energy Cost, $	2020 FEC Annual Total Energy Cost, $	Total Annual Energy Cost Savings, $
Stand-Alone Retail	26175.87	26099.17	76.70

Table 30 Life cycle cost analysis Due to Code Modification EN7523

Prototype Building	Net Present Value of Investment Cost, $	Net Present Value of Energy Cost Savings, $	Savings to Investment Ratio (SIR)
Stand-alone Retail	66.67	601.32	9.02

Automatic and Optimum Start Capability: EN7533

Modifies Section C403.2.4.2.3 Automatic start capability. Individual heating and cooling systems with setback controls and direct digital control shall have optimum start controls. The control algorithm shall, as a minimum, be a function of the difference between space temperature and occupied set point, the outdoor temperature, and the amount of time prior to scheduled occupancy. This code modification impacts prototype buildings that are not constantly occupied such as medium and large office, outpatient healthcare, standalone-retail, primary and secondary school buildings.

Optimum start control capability was added to the upgrade prototype building energy models using an EMS program. The program uses a fixed starting time and outdoor air temperature sensor. The baseline model had optimum start control based on a fixed thermostat schedule without outside air temperature sensor per the 6th Edition Florida Energy Code Section C403.2.4.2.3 Automatic start capabilities. Simulation results of the proposed upgrade and baseline did not produce significant energy savings potential as shown in Table 31. Note that the EMS based optimum start control is an approximation of the real building operation, which requires learning the building response time for a combination of thermostat setpoint, outside air condition and actual controlled space temperature. Building response time is dependent on the building thermal mass.

Table 31 Annual Total Energy Use Intensity Due to Code Modification EN7533

Prototype Building	2017 FEC Energy Use Intensity, kBtu/ft^2	2020 FEC Energy Use Intensity, kBtu/ft^2	Energy Use Intensity Savings, kBtu/ft^2
Medium Office	33.739	33.739	0.001
Large Office	72.066	72.042	0.024
Standalone Retail	40.119	40.119	0.0
Primary School	43.434	43.434	0.0
Secondary School	40.188	40.188	0.0
Outpatient Health Care	117.911	117.745	0.166

Even though simulation results of code modification EN7533 did not produce significant energy savings potential we don't want to discourage from adopting this code modification simply because a simplified EMS model added did not capture the saving potential anticipated. But it is good practice to have an optimum start capability instead of relying on scheduled based start control. Cost benefit analysis of this upgrade was not performed due small energy savings realized compared to fixed scheduled start control.

Automatic control of HVAC Systems Serving Guest Rooms: EN7536/EN8042

Added new code section C403.7.6. Control requirement for each guest room in buildings containing over 50 guest rooms. Increases first cost but the amendment is cost effective.

Temperature setpoint controls: Added new code section C403.7.6.1. Add set point temperature setback or setup control requirement when each guest room is not occupied. Increases first cost but cost effective.

Ventilation controls: Added new code section C403.7.6.2. Controls shall be provided on each HVAC system that can automatically turn off the ventilation and exhaust fans 30 minutes after the occupant leaves the guest room.

This new code impacts the small and large hotel prototype buildings. The proposed code change includes reducing the heating thermostat setpoint temperature to 60 °F and increasing the cooling thermostat setpoint temperature to 80 °F, when the guest rooms are not occupied. Vacant guest room thermostat temperature setpoint is reduced to 60 °F and raised to 80 °F for heating and cooling, respectively. Ventilation and exhaust air fans are turned off 30 minutes after the occupant leaves the guest room or the rooms are unoccupied for extended period. Vacant guest rooms were purged once a day for one hours. These code changes were incorporated into the upgrade prototype building energy models using an EMS program. The baseline and upgrade annual total energy cost for small and large hotel buildings for the proposed code modifications EN7536/EN8142 were determined using simulation and are summarized in Table 32.

Table 32 Annual Total Energy Cost for Code Modification EN7536

Prototype Building	2017 FEC Annual Total Energy Cost, $	2020 FEC Annual Total Energy Cost, $	Total Annual Energy Cost Savings, $
Small Hotel	41164.36	37481.31	3683.05
Large Hotel	186742.43	182967.57	3774.86
Weighted Average Hotel	165490.16	161728.70	3761.46

Cost benefit analysis of this code amendment was investigated using two different incremental first cost scenarios. Incremental first and annual maintenance cost assumptions used for life cycle cost analysis are provided in Table E-19 in Appendix-E. The analysis assumes Guest Room HVAC system controller upgrade incremental first cost of $150.0 and $200.0 for Scenario I and Scenario II, respectively. Guest room HVAC controls can use either *Occupancy Sensor* or *Card-Key* based controllers. The guest room controllers installed cost[3] vary from 50.0 – 450.0 per guest room depending on technology and additional features integrated to the controller. The high end controller besides the HVAC control, may have integrated additional control features that can be used for interior lighting, plug load, and blind control. The incremental first cost estimate used in this analysis anticipates that a single occupancy sensor or card-key technology can be used across all control features such as interior lighting, plug loads, blind, HVAC, and ventilation controllers.

Life cycle cost analysis results for code modification EN7536/EN8142 are summarized in Table 33. For both scenarios, the saving to investment ratio is greater than 1.0 implying that code modification EN7536/EN8142 is cost effective and recommended for addition to the 7th Edition (2020) Florida Energy Code. Note that occupant sensor control is already a requirement in Section C405.2.1 of the 6th and 7th Editions Florida Energy Code; hence, occupant sensor control cost was not included in estimating the incremental installed cost for this upgrade.

Table 33 Life Cycle Cost Analysis for Code Modification EN7536

Prototype Building	Net Present Value of Energy Cost Savings, $	Net Present Value of Investment Cost, $	Savings to Investment Ratio (SIR)
Scenario I			
Small Hotel	32,358.36	11000.0	2.94
Large Hotel	33,184.76	25,571.43	1.30
Weighted Average Hotel	33,064.12	23,444.21	1.54
Scenario II			
Small Hotel	32,358.36	14,666.67	2.21
Large Hotel	33,184.76	33,333.33	1.00
Weighted Average Hotel	33,064.12	30,608.27	1.17

[3] Card-Key Based Guestroom Controls Evaluation Report. https://www.etcc-ca.com/sites/default/files/OLD/images/stories/etcc_projectdoc_15.pdf

Shutoff Dampers: EN7558

Modified code section C403.2.4.3. Restricts gravity dampers use for “exhaust and relief” system only. This change is restrictive and if adopted requires motorized dampers for outdoor air intake. Outside air may leak into the outside air intake system through the shutoff damper due to negative pressure when the system is *turned-on* and the building served by the system is not occupied (e.g. during warmup hours before the building is occupied and night time cycling operations). The leakage amount depends on the shutoff damper type – gravity (non-motorized shutoff dampers) allow higher leakage rates than motorized dampers. Impact of replacing gravity dampers with motorized dampers in outside air intake system was investigated using large and medium office prototype building models. An EMS program was added to account for air leakage by detecting the status of the night-cycle manager and the supply fan schedule. Outside air leakage rate is set depending the damper type. The fractions used for the two scenarios were estimated from the system design flow rates, and the leakage limits allowed for the gravity and motorized dampers. A 2.5 % of the system air flow rate was assumed as air leakage rate for gravity damper and 0.25% was assumed for motorized damper. Note that outside air system with motorized damper sees slightly higher static pressure than a fan used for with gravity damper, but this effect was not considered in the analysis. Results summarized in Table 34 and Table 35 show the annual energy use and the annual total energy cost, respectively, weighted by climate zones 1A and 2A in medium and large office prototype buildings. The cool outside air leaked during early morning hours and late night hours sometimes acts as free cooling and other times it may increase the building load. On annual basis impact of leaked air on the system load somehow offset each other. As the results, the annual energy and cost savings predicted to be very small.

Life cycle cost analysis was conducted for replacement of gravity dampers with motorized dampers in outdoor air intake system. Saving to investment ratio (SIR) of a motorized damper upgrade estimated in medium and large office prototype buildings are summarized in Table 35. Installed first cost assumptions used for life cycle cost analysis are summarized in Table E-20 in Appendix-E. The SIR value for both prototype buildings were determined to be less than 1.0. Therefore, based on results of the two prototype energy models, it is not economical to require motorized damper for outside air intake system in Florida climate. However, since air-economizer is mostly required in climate zone 2A, motorized damper is already a necessity in outside air intake system for proper control of air-economizer operation. Thus, this code change if enforced has implication on climate zone 1A only.

Table 34 Annual Energy Use Intensity Due to Shutoff Dampers Upgrade

Prototype Building	Energy Use Intensity [kBtu/ft^2]		
	2017 FEC	2020 FEC	Difference
Medium Office	33.49	33.49	0.00
Large Office	71.84	71.86	-0.02

Table 35 Annual Total Energy Costs Due to Shutoff Dampers Upgrade

Prototype Building	2017 FEC Annual Total Energy Cost, $	2020 FEC Annual Total Energy Cost, $	Energy Cost Savings, $
Medium Office	47,224.14	47,223.64	0.5
Large Office	775,440.02	775,375.04	64.98

Table 36 Life Cycle Cost Benefit Analysis of Shutoff Dampers Upgrade

Prototype Building	Net Present Value of Investment Cost, $	Net Present Value of Energy Cost Savings, $	Savings to Investment Ratio (SIR)
Medium Office	243.81	5.68	0.02
Large Office	1514.29	691.28	0.46
Weighted Average	598.43	197.05	0.33

6. Results Summary

The *approved-I*, *approved-II* and amended ASHRAE 90.1-2016 code scenarios of the 2020 Florida Energy Code performance were investigated quantitatively using prototype buildings energy models and compared against the original 2016 ASHRAE 90.1 code performance. The *approved-I* 2020 Florida Energy Code scenario include twenty-one code modifications with energy impact approved by Florida Building Commission as of October 31, 2018. And the *approved-II* 2020 FEC scenario include twenty-six code modifications with energy impact approved by Florida Building Commission as of March 31, 2019. The *approved-I* 2020 Florida Energy Code prototype building energy models were created by modifying the 6th Edition Florida Energy Code (2017) prototype building models that include the twenty-one approved code modifications for addition to the 2020 Florida Energy Code. And the *approved-II* 2020 Florida Energy Code prototype building energy models were created by modifying the 6th Edition Florida Energy Code (2017) prototype building models that include the twenty-six approved code modifications for addition to the 2020 Florida Energy Code. The 2016 ASHRAE 90.1 code reference prototype buildings energy models published by PNNL (U.S. DOE, 2018) were obtained and modified for Florida climate zones 1A and 2A. The prototype buildings energy models were simulated using EnergyPlus, whole building simulation program.

The *approved-I* 2020 FEC scenario quantitative analysis determined that seven out of the sixteen prototype buildings site annual Energy Use Intensity (EUI) were lower than that of ASHRAE 90.1-2016 code whereas the remaining nine prototype buildings underperformed the 2016 ASHRAE 90.1. Aggregated across the sixteen prototype buildings the weighted Florida average annual energy use performance of the *approved-I* 2020 FEC scenario slightly underperformed the 2016 ASHRAE 90.1 code.

The *approved-II* 2020 FEC scenario quantitative analysis determined that ten out of the sixteen prototype buildings energy models site annual Energy Use Intensity (EUI) were lower than that of ASHRAE 90.1-2016 code building models. Averaging across all the sixteen commercial prototype building energy models, the *approved-II* 2020 Florida Energy Code scenario performed better than that of the 2016 ASHRAE 90.1 code building. Weighted Florida averaged annual site EUI aggregated across the sixteen prototype buildings for the *approved-II* 2020 FEC scenario was lower than ASHRAE 90.1-2016 code buildings by about 1.61%. This implies a commercial building designed with the *approved-II* 2020 FEC in Florida consumes about 1.61% less energy compared to a building designed with the 2016 ASHRAE 90.1 code building.

Performance of the amended ASHRAE 90.1-2016 code, which is an alternative compliance option in Florida Commercial Energy Code, was also investigated. The 2020 FEC excludes interior lighting control section 9.4.1.1(g) and automatic receptacle control section 8.4.2 from the 2016 ASHRAE 90.1 code. Performance of the amended ASHRAE 90.1-2016 code, which is labeled as ASHRAE 90.1-2020 FEC in this report, and the original ASHRAE 90.1-2016 code prototype buildings were investigated using EnergyPlus. The quantitative analysis determined that annual site energy use of ASHRAE 90.1-2020 FEC was higher that of ASHRAE 90.1-2016 code building by about 2.20%. Annual site energy use performance of IEEC-2018 based (*approved-II* 2020 FEC) and ASHRAE based (ASHRAE 90.1-2020 FEC) 2020 FEC combined using equal weights was worse by about 0.30% compared to ASHRAE 90.1-2016. The weighted Florida average Energy Cost Index (ECI) for the commercial sector was estimated to be 1.009 $/ft2-Yr and 1.027 $/ft2-Yr for the *approved-II* 2020 FEC scenario and the 2016 ASHRAE 90.1 code, respectively. The *approved-II* 2020 FEC ECI was lower by about 1.75%. The weighted Florida average ECI for ASHRAE 90.1-2020 FEC was about 1.042 $/ft2-Yr and was higher than that of the 2016 ASHRAE 90.1 code by about 1.48%. Energy cost index performance of IEEC-2018 based and ASHRAE based 2020 FEC combined using equal weights was lower by about 0.15% compared to ASHRAE 90.1-2016 code building. The annual site energy use and energy cost differences between the 2020 FEC and ASHRAE 90.1-2016 code can be considered within margin of error of model input assumptions.

Cost benefit analysis was performed on nine proposed commercial code modifications summarized in Appendix-B. Out these nine proposed code modifications, only five code modifications EN7318, EN7536/EN1842, EN7326, EN7533, and EN7503 were approved by Florida Building Commission as of March 31, 2019 for addition to the 2020 FEC. These five code modifications were included in the quantitative analysis under *approved-II* 2020 FEC scenario. However, cost benefit analysis was conducted for eight of the nine code modifications. The cost benefit analysis demonstrated that five of the nine code modifications were cost effective. Savings to investment ratio (SIR) value was used for cost effectiveness determination.

7. Conclusion

The 7th Edition (2020) FEC provides two performance compliance options – one IECC 2018 based and other ASHRAE 90.1-2016 based. The study demonstrates that the deviations of the 2020 FEC from the ASHRAE 90.1-2016 Standard are quite small and can be considered within the margin of error – either favorable or otherwise. In terms of annual energy use the IECC based option is somewhat better performing by about 1.61% while the amended ASHRAE option is somewhat worse by about 2.20%. In terms of annual energy cost the IECC based option is somewhat better performing by about 1.75% while the amended ASHRAE option is somewhat worse by about 1.48%. The 2020 FEC performance when the two performance compliance options aggregated using equal weights is within ±0.30% and ±0.15% in terms of annual energy use and annual energy cost, respectively. Hence the 2020 FEC overall, for all practical purposes, may be considered equivalent to the original ASHRAE 90.1-2016.

8. Reference

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Appendix-A: Approved-I 2020 Florida Energy Code Changes with Energy Impact

Table-A contains summary of approved code changes for the 7th Edition (2020) Florida Commercial Energy Code. The proposed energy code modifications include that has already been approved as of October 31, 2018.

Table-A: Summary of Approved Commercial Code Change between 6th and 7th Edition Florida Energy Code

S. No.	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC	Included in quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
Section 402 Building Envelope Requirements					
Section 403 Building Mechanical Systems					
1	C403.10.2.1 Performance standards (Mandatory), CE126-16	Approved	Added new mandatory subsection and related tables: TABLE C403.2.16.1(1), TABLE C403.2.16.1(2) and TABLE C403.2.16.1(3). Increases costs. New US federal minimum efficiency requirement for walk-in coolers and freezers. Also provides design flexibility.	Yes	No. Federal minimum.
2	TABLE C403.2.3(3), CE132-16	Approved	Updated Table C403.2.3(3) Minimum Efficiency Requirements of electrically operated: PTACs, PTHPs, Single Package Vertical ACs, Single Package Vertical HPs, Room ACs and Room Air Conditioner heat Pumps. US federal minimum efficiency requirement increased. Increases cost. DOE analysis shows that minimum payback period is 2.1-10.1 years.	Yes	No. Federal minimum.
3	TABLE C403.3.2 (8), CE152-16	Approved	Changed TABLE C403.2.3 (8) minimum efficiency requirement for Propeller or axial fan closed-circuit cooling towers from 14.0 to 16.1 gpm/hp to match ASHRAE 90.1 requirement. None or minimal effect on first cost.	Yes	No. Federal minimum.
4	TABLE C403.3.2 (5), CE154-16	Approved	Changed TABLE C403.2.3 (5) minimum efficiency requirement for hot water and steam boilers to match the US federal minimum efficiency requirement. Increases first cost but also saves energy.	Yes	No. Federal minimum

Table-A: Summary of Approved Commercial Code Change between 6th and 7th Edition Florida Energy Code (continued)

S. No.	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC	Included in quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
Section 403 Building Mechanical Systems					
5	C403.9 Heat rejection equipment, CE165-16	Approved	Modified code section C403.4.3. Heat rejection equipment shall comply with requirements in this section with exception of heat rejection devices whose energy usage is included in the equipment efficiency rating and listed in Tables C403.2.3(6) and C403.2.3(7). Increases first cost but cost effective.	Yes	No. Already approved
6	C403.9.1 Fan speed control, CE165-16	Approved	Modified code section C403.4.3.1. Changed the title from "General" to "Fan speed control". Reduced the variable speed fan motor power threshold from 7.5 hp (5.6 kW) to 5 hp (3.7 kW) and modified the exception. Increases first cost. PNNL study shows that this code change is cost effective, SIR=1.4.	Yes	No. Already approved
7	C403.6.6 Multiple-zone VAV system ventilation optimization control, CE167-16	Approved	Modified code section C403.4.4.6. Deleted exceptions for exhaust air ERV optimization item 2. This code change allows to use OA control for multi-zone system with ERV. This code change is cost effective in all climate zones. This code change is similar to ASHRAE 90.1-2013 addendum j.	Yes	No. Already approved
8	C403.6.7 Parallel-flow fan-powered VAV air terminal control, CE168-16	Approved	Added a new code section C403.4.4.7. Parallel-flow fan-powered VAV air terminals shall have automatic controls configured to turn-off the terminal fan when there is no heating. This is a control logic change. No effect on first cost. Saves energy.	No. Prototype building does not have PFP VAV	No. Already approved

Table-A: Summary of Approved Commercial Code Change between 6th and 7th Edition Florida Energy Code (continued)

S. No.	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC	Included in quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
Section 404 Service Water Heating					
9	TABLE C404.2 MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT, CE171-16	Approved	Updated Table C404.2, minimum efficiency values and equations of water heating equipment to meet the US federal minimum efficiency requirement. Increases equipment cost and reduces operating energy cost.	Yes	No. Federal minimum.
Section 405 Electric Power and Lighting Systems					
10	C405.2.1.3 Occupant sensor control function in open plan office areas, CE185-16	Approved	Added new code section C405.2.1.3. Added occupant sensor control function in open plan office areas as a requirement. Increases first cost but cost effective.	Yes	No. Already approved
11	C405.2.1.1 Occupant sensor control function, CE187-16	Approved	Modified code section C405.2.1.1. Lights shutoff time after occupant leaves the unit reduced from 30 to 20 minutes. No cost increase but saves lighting energy significantly.	Yes	No. Already approved
12	C405.2.6.1 Daylight shutoff, CE196-16	Approved	Added new code section C405.2.6.1. Lighting shall be automatically turned off when there is sufficient daylight. No first cost increase.	Yes	No Already approved
13	C405.2.6.2 Decorative lighting shutoff, CE196-16	Approved	Added new code section C405.2.6.2. Building facade and landscape decorative lighting shutoff requirement. No first cost increase.	Yes	No Already approved
14	C405.2.6.3 Lighting setback, CE196-16	Approved	Added new code section C405.2.6.3. Lighting setback requirement. No first cost increase.	Yes	No Already approved
15	C405.2.6.4 Exterior time-switch control function, CE196-16	Approved	Added new code section C405.2.6.4. Exterior time-switch control function requirement. No first cost increase.	Yes	No Already approved

Table-A: Summary of Approved Commercial Code Change between 6th and 7th Edition Florida Energy Code (continued)

S. No.	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC	Included in quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
			Section 405 Electric Power and Lighting Systems		
16	TABLE C405.3.2 (1), CE206-16	Approved	Reduced the LPD values in Table C405.4.2(1) for most of the building area types. May increases first cost also but decreases energy use. Cost effective especially when the 2018 code become into effect due to decline in LED first cost and maintenance cost.	Yes	No Already approved
17	TABLE C405.3.2 (2), CE206-16	Approved	Reduced LPD values in Table C405.4.2(2) for most of the space types. Cost effective especially when the 2018 code become into effect due to decline in LED first cost and maintenance cost.	Yes	No Already approved
18	C405.3.2.2.1 Additional interior lighting power, CE209-16	Approved	Modified code section C405.4.2.2.1. Edited equation 4-10 and LPD values of additional interior lighting power allowance for retail display area. Increases cost but not life cycle cost, and decreases energy use. This is cost effective due to no net increase in life cycle cost.	Yes	No Already approved
19	C405.3.2.2.1 Additional interior lighting power, CE210-16, same as above	Approved	Modified code section C405.4.2.2.1. Edited equation 4-10 and LPD values of additional lighting power allowance for retail display area. Excludes museum exhibition areas for additional lighting power allowance. Increases cost but not life cycle cost, and decreases energy use. This is cost effective due to no net increase in life cycle cost.	Yes	No Already approved
20	Table C405.6 MINIMUM NOMINAL EFFICIENCY LEVELS FOR 10 CFR 431 LOW-VOLTAGE DRY-TYPE DISTRIBUTION TRANSFORMERS, CE221-16	Approved	Modified Table C405.7. Added a decimal point to minimum efficiency values for single-phase transformers and increased baseline minimum efficiency values of three-phase transformers due to change in US federal energy efficiency standard. No cost increase but Decreases Energy Use due to efficiency increase.	Yes	No. Federal minimum.

Table-A: Summary of Approved Commercial Code Change between 6th and 7th Edition Florida Energy Code (continued)

S. No.	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC	Included in quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
Electric Power and Lighting Systems					
21	C405.7 Electrical motors (Mandatory), CE223-16	Approved	Modified code section C405.8. Added new exceptions for electric motors from minimum efficiency requirements. No first cost increase.	No	No. Already approved
22	Table C405.7(1) MINIMUM NOMINAL FULL-LOAD EFFICIENCY FOR NEMA DESIGN A, NEMA DESIGN B, AND IEC DESIGN N MOTORS (EXCLUDING FIRE PUMP ELECTRIC MOTORS AT 60 HZ) CE223-16	Approved	Modified Table C405.8(1). Modified table format and increased electric motors minimum efficiency requirements due to new US federal minimum motor efficiency change and added new footnotes to this table for clarification. Increases first cost but also decreases energy use compared to the previous minimum efficiency. Cost effective with payback period of 2.9 – 4.5 years.	Yes	No. Federal minimum.
23	Table C405.7(2) MINIMUM NOMINAL FULL-LOAD EFFICIENCY FOR NEMA DESIGN C AND IEC DESIGN H MOTORS AT 60 HZ, CE223-16	Approved	Modified Table C405.8(2). Modified table format and increased electric motors minimum efficiency requirements due to new US federal minimum motor efficiency change and added new footnotes to this table for clarification. Cost effective with payback period of 2.9 – 4.5 years.	Yes	No. Federal minimum.

Appendix-B: Additional Approved 2020 Florida Energy Code Changes with Energy Impact

Table-B contains summary of additional approved code changes for the 7th Edition (2020) Florida Commercial Energy Code. The proposed energy code modifications that has been approved since November 1, 2018 and as of March 31, 2019.

Table-B: Summary of Proposed Commercial Code Changes between 6th and 7th Edition Florida Energy Code

S. No.	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC, and Analysis	Included in quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
Section 402 Building Envelope Requirements					
1	C402.4.1.2 Increased skylight area with daylight responsive controls, CE97-16	EN7499 Approved	Modified code section C402.4.1.2. Skylights area percentage allowed with daylight response control is used increased from 5% to 6%. No net first cost change is anticipated. **Prototype Buildings Investigated**: Primary School, Secondary School, and Non-refrigerated warehouse. **Quantitative Analysis**: there is no energy savings for changing skylight area fraction from 5.0% to 6.0% in gymnasium and bulk storage space type. **Cost Benefit Analysis**: savings to investment ratio (SIR) value for this change was much less than 1.0; hence, this code change is not cost effective.	No	Yes

Table-B: Summary of Proposed Commercial Code Changes between 6th and 7th Edition Florida Energy Code (continued)

S. No.	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC, and Analysis	Included in quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
Section 402 Building Envelope Requirements					
2	C402.5.6 Loading dock weatherseals, CE116-16	EN7515 NAR	Modified code section C402.5.6. Door openings shall be equipped with weatherseals to restrict infiltration and provide direct contact along the top and sides of vehicles when parked in the doorway. Increase first cost of construction. **Prototype Buildings Investigated**: non-refrigerated warehouse. Quantitative Analysis: there is no significant energy savings for adding weatherseals in loading dock. **Cost Benefit Analysis**: savings to investment ratio (SIR) value for this change was about 0.07; hence, this code change is not cost effective.	No	Yes
Section 403 Building Mechanical Systems					
3	C403.4.1.4 Heated or cooled vestibules (Mandatory), CE136-16	EN7523 NAR	Added new code section C403.4.1.4. Defines heating and cooling temperature limits for heated or cooled vestibules and air curtain. It is mandatory. Increases first cost. **Prototype Buildings Investigated**: Standalone-Retail. **Quantitative Analysis**: there is potential energy savings, about. **Cost Benefit Analysis**: savings to investment ratio (SIR) value for this change was about 9.0; hence, this code change is cost effective.	No	Yes

Table-B: Summary of Proposed Commercial Code Changes between 6th and 7th Edition Florida Energy Code (continued)

S. No.	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC, and Analysis	Included in quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
Section 403 Building Mechanical Systems					
4	C403.7.6 Automatic control of HVAC systems serving guest rooms, CE138-16 C403.7.6.1 Temperature setpoint controls, CE138-16 C403.7.6.2 Ventilation controls, CE138-16	EN7536 NAR Or EN8142 Approved	Added new code section C403.7.6. Control requirement for each guest room in buildings containing over 50 guest rooms. Increases first cost but cost effective. Added new code section C403.7.6.1. Add set point temperature setback or setup control requirement when each guest room is not occupied. Increases first cost but cost effective. Added new code section C403.7.6.2. Controls shall be provided on each HVAC system that can automatically turn off the ventilation and exhaust fans 30 minutes after the occupant leaves the guest room. Increases first cost but cost effective. Added new code section C403.4.1.4. Defines heating and cooling temperature limits for heated or cooled vestibules and air curtain. It is mandatory. Increases first cost. **Prototype Buildings Investigated**: Small Hotel and Large Hotel. **Quantitative Analysis**: there is potential energy savings. **Cost Benefit Analysis**: savings to investment ratio (SIR) value for this change was found out to be about 1.2; hence, this code change is considered cost effective.	Yes	Yes

Table-B: Summary of Proposed Commercial Code Changes between 6th and 7th Edition Florida Energy Code (continued)

S. No	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC, and Analysis	Included in Quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
Section 403 Building Mechanical Systems					
5	C403.7.7 Shutoff dampers (Mandatory), CE139-16	EN7558 NAR	Edited code section C403.2.4.3. Restricts gravity dampers use for "exhaust and relief" system only. This change is restrictive and if adopted requires motorized dampers for outdoor air intake. Increases first cost. Added new code section C403.4.1.4. Defines heating and cooling temperature limits for heated or cooled vestibules and air curtain. It is mandatory. Increases first cost. **Prototype Buildings Investigated**: Medium Office and Large Office. **Quantitative Analysis**: there is no energy savings potential. **Cost Benefit Analysis**: savings to investment ratio (SIR) value for this change was found out to be less than 1.0; hence, this code change is not cost-effective.	No	Yes
6	C403.2.4.2.3 Automatic and optimal start capability, based on ASHRAE 90.1-2016	EN7533 Approved	Modifies Section C403.2.4.2.3 Automatic start capability. Individual heating and cooling systems with setback controls and direct digital control shall have optimum start controls. The control algorithm shall, as a minimum, be a function of the difference between space temperature and occupied set point, the outdoor temperature, and the amount of time prior to scheduled occupancy. May increase first cost.	Yes	Yes

Table-B: Summary of Proposed Commercial Code Changes between 6th and 7th Edition Florida Energy Code (continued)

S. No	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC, and Analysis	Included in Quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
			Section 405 Electric Power and Lighting Systems		
7	C405.2.4 Specific application control, CE179-16	EN7318 Approved	C405.2.4 Specific application control. Permanently installed luminaires within dwelling units shall be provided with controls complying with Section C405.2.1.1 or C405.2.2.2. No first cost increase. **Prototype Buildings Investigated**: Medium Rise Apartment, and High Rise Apartment. **Quantitative Analysis**: there is high potential energy savings. **Cost Benefit Analysis**: savings to investment ratio (SIR) value for this change was found out to be very large positive number since the change incurs zero net life cycle investment cost; hence, this code change is cost effective.	Yes	Yes

Table-B: Summary of Proposed Commercial Code Changes between 6th and 7th Edition Florida Energy Code (continued)

S. No	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC, and Analysis	Included in Quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
Section 405 Electric Power and Lighting Systems					
8	C405.2.5.3 Lighting setback, CE196-16	EN7503 Approved	Increase exterior lighting automatic reduction threshold from 30 to 50 percent by selectively switching off or dimming luminaires. Modifies the new code section C405.2.6.3. Not net first cost increase. **Prototype Buildings Investigated**: Small Office, Medium Office, Large Office, Stand-Alone Retail, Strip Mall, Primary School, Secondary School, Outpatient Health Care, Non-Refrigerated Warehouse, Quick Service Restaurant, and Full Service Restaurant. **Quantitative Analysis**: there is energy savings potential in each prototype building investigated. **Cost Benefit Analysis**: savings to investment ratio (SIR) value for this change was very large positive number since the change incurs zero net life cycle investment cost; hence, this code change is cost effective.	Yes	Yes

Table-B: Summary of Proposed Commercial Code Changes between 6th and 7th Edition Florida Energy Code (continued)

S. No	2018 IECC Section and Title, ICC Code # or Other Code	Mod # or Comment	Change Summary b/t 2017 FEC and Proposed 2020 FEC, and Analysis	Included in Quantitative Analysis (Yes/No)	Included in Economic Analysis (Yes/No)
Section 405 Electric Power and Lighting Systems					
9	Table C405.4.2(2) LIGHTING POWER ALOWANCES FOR BUILDING EXTERIORS, CE215-16	EN7326 Approved	Modified Table C405.5.2 (2). Reduced the exterior lighting power allowance values for tradable exterior building surfaces and modified the table format. No first cost increase.	Yes	Yes
	Table C405.4.2(3) INDIVISUAL LIGHTING POWER ALOWANCES FOR BUILDING EXTERIORS, CE215-16		Modified Table C405.5.2 (3). Reduced the exterior lighting power allowance values for non-tradable exterior building surfaces and modified the table format. Modest net first cost is expected. **Prototype Buildings Investigated**: all the sixteen prototype buildings. **Quantitative Analysis**: there is potential energy savings in each prototype building investigated. **Cost Benefit Analysis**: average savings to investment ratio (SIR) value for this change was found out to be about 6.6; hence, this code change is cost effective.		Yes

Appendix-C: Florida Energy Rates

A representative energy rate structure shown in Table C-1 was used for this analysis. Since the same energy rates were used for the proposed 2020 Florida Energy Code and the 2016 ASHRAE 90.1 prototype building energy models, the impact of energy rates variation by service territory is not significant in the final results of the analysis.

Table C-1 Time of Use Rate Electricity Cost Structure and Natural Gas Rates

Charges Type	Charge Items	Units	Rate
Customer and Demand Charge[4]			
Customer Charge		$/Month	25.46
Demand Charges	Base Demand Charge	$/kW	9.58
	Capacity Payment Charge	$/kW	0.70
	Conservation Charge	$/kW	0.48
Total Demand Charge		$/kW	10.76
Electric Energy Charges			
Non-Fuel Energy Charges	Base Energy Charge		
	On-Peak Base Energy Charge	cents /kWh	4.355
	On-Peak Base Energy Charge	cents /kWh	1.152
	Environmental Charge	cents /kWh	0.105
	General Service Load Management Program	cents /kWh	0.0
	Fuel Charge		
	Jan-Mar, Nov-Dec, On-Peak Fuel Charge	cents /kWh	3.052
	Jan-Mar, Nov-Dec, Off-Peak Fuel Charge	cents /kWh	2.429
	Apr-Oct, On-Peak Fuel Charge	cents /kWh	3.792
	Apr-Oct, Off-Peak Fuel Charge	cents /kWh	2.462
	Storm Charge	cents /kWh	0.091
	Franchise Fee	cents /kWh	0.0
	Tax clause	cents /kWh	0.0
Total Energy Rate	Jan-Mar, Nov-Dec, On-Peak Energy Rate	cents /kWh	7.603
	Jan-Mar, Nov-Dec, Off-Peak Energy Rate	cents /kWh	3.777
	Apr-Oct, On-Peak Energy Rate	cents /kWh	8.343
	Apr-Oct, Off-Peak Energy Rate	cents /kWh	3.810
Natural Gas Energy Rates[5]			
Customer Charge		$/Month	150.0
Distribution Charge	GS-25K Range	$/Therm	0.32696
Total Natural Gas Energy Rate		$/Therm	0.32696

[4] General Service Demand Time of Use. https://www.fpl.com/rates/pdf/electric-tariff-section8.pdf
[5] Florida City Gas Rates. https://www.floridacitygas.com/-/media/files/fcg/17353_FCG_ApprovedRates_directmail_f.pdf

Energy price escalation rates shown in Table C-2 was used for life cycle energy cost calculation for the baseline and upgrade energy models.

Table C-2 Energy Price Escalation Rate for Electricity and Natural Gas[6]

Year	Electricity	Natural Gas
1	1.0241	1.0196
2	1.0496	1.0638
3	1.0499	1.0933
4	1.0418	1.1178
5	1.0361	1.1571
6	1.0336	1.1706
7	1.0382	1.1840
8	1.0386	1.1890
9	1.0389	1.1939
10	1.0389	1.1926
11	1.0393	1.2012
12	1.0396	1.2012
13	1.0400	1.2012
14	1.0393	1.2025
15	1.0372	1.2037
16	1.0347	1.2037
17	1.0315	1.2037
18	1.0290	1.2123
19	1.0273	1.2172
20	1.0276	1.2221
21	1.0276	1.2245
22	1.0276	1.2270
23	1.0265	1.2307
24	1.0244	1.2393
25	1.0209	1.2429
26	1.0195	1.2454
27	1.0173	1.2528
28	1.0124	1.2589
29	1.0120	1.2650
30	1.0163	1.2712

[6] Energy escalation rates were taken from EnergyPlus V9.1 data sets for the U.S. south region for commercial buildings.

Appendix-D: Florida Commercial Building Floor Area Distribution

Floor Area Weighting Factors Determination

The conditioned floor area weighting factors used in this study were generated by processing building stock information obtained from a PNNL report by Jarnagin and Bandyopadhyay (2010). The information obtained include: total floor areas by building type for the state of Florida and national average building weighting factors by climate zones. The national average weighting factors by building type and climate zones 1A and 2A obtained from the PNNL report were used to split the Florida building stock total floor area into climate zones 1A and 2A for each of the prototype buildings type. Two sets of weighting factors were generated for this investigation: weighting factors for the two Florida climate zones for each prototype buildings type, and the state's average weighting factors by buildings type and climate zone. The former weighting factors for climate zones 1A and 2A were used to estimate the EUI for each of the sixteen prototype buildings in Florida. And the later weighting factors were used to determine an aggregate EUI across the sixteen prototype commercial buildings for the state of Florida. Table D-1 summarizes commercial buildings total floor area stock distribution by prototype building in the state of Florida.

Table D-1 Commercial Prototype Buildings Floor Area Distribution in Florida

Building Type	Prototype Building	Prototype Building Floor Area, ft^2	Total Building Floor Area, 1000 ft^2	Floor Area Weighting Factors, %
Office	Small Office	5,502	37,889	5.27
	Medium Office	53,628	42,765	5.94
	Large Office	498,588	16,558	2.30
Retail	Stand-Alone Retail	24,692	83,481	11.60
	Strip Mall	22,500	44,652	6.21
Education	Primary School	73,959	30,815	4.28
	Secondary School	210,887	52,709	7.33
HealthCare	Outpatient Health Care	40,946	20,381	2.83
	Hospital	241,501	16,210	2.25
Lodging	Small Hotel	43,202	4,682	0.65
	Large Hotel	122,120	27,389	3.81
Warehouse	Non-Refrigerated Warehouse	52,045	104,327	14.50
Food Service	Full Service Restaurant	2,501	4,003	0.56
	Quick Service Restaurant	5,502	3,296	0.46
Apartment	Mid-Rise Apartment	33,741	41,402	5.75
	High-Rise Apartment	84,360	188,913	26.25
Total		1,515,674	719,472	100.00

Floor Area Weighting Factors by Florida Climate Zones

Figure D-1 shows the weighting factors by climate zones for the state of Florida by prototype buildings type. The weighting factors for each prototype building type sum to 1.0. These weighting factors split the total floor areas stock of each of the prototype buildings in the state into climate zone 1A and 2A fractions. For instance, for High Rise Apartment 95.0% of the total floor area in the state of Florida is in climate zone 1A and the remaining 5.0% is in climate zone 2A.

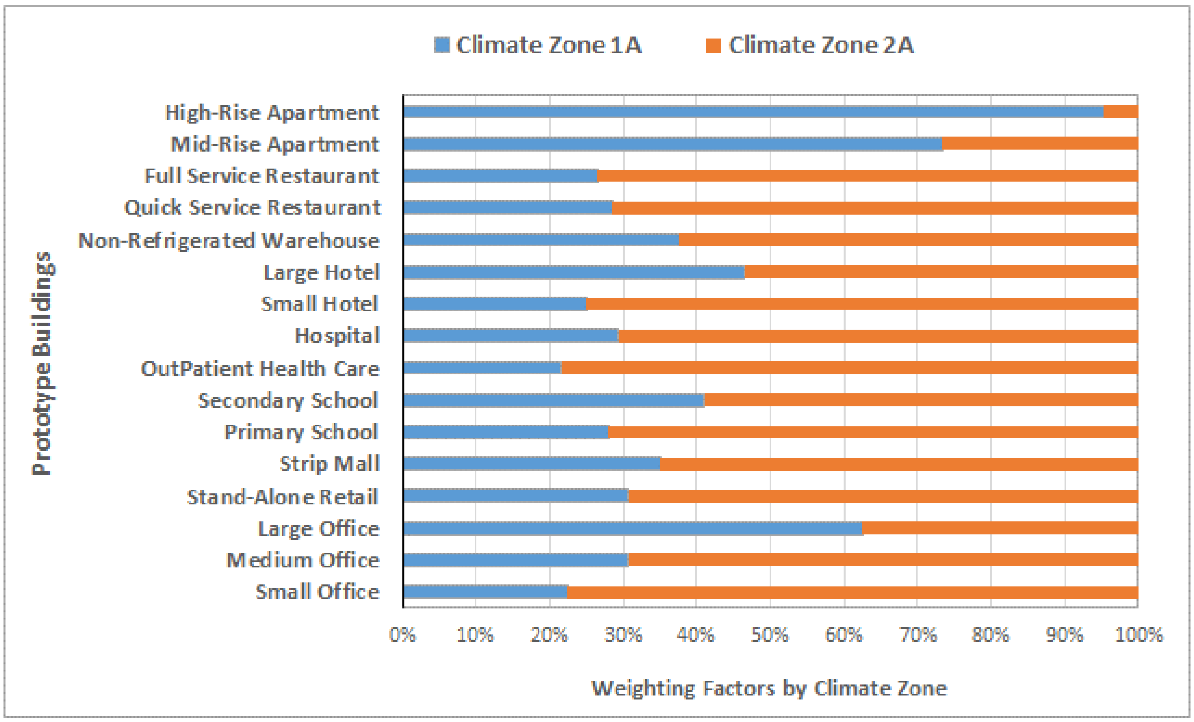

Figure D-1 Florida Floor Area Weighting Factors by Climate Zone and Building Type

Average Floor Area Weighting Factors by Building Type

The average weighting factors were used to determine an aggregate EUI across the sixteen prototype buildings type for the state of Florida. The weighting factors across the sixteen prototype buildings and the two climate zones sum to 1. Figure D-2 shows the average weighting factors by building type (sum of climate zones 1A and 2A) for the state of Florida. The High Rise Apartment building type represents the highest fraction of total floor area stock in the state of Florida and it is 26.26% of Florida commercial buildings total floor area stock. Warehouse and Standalone Retail commercial buildings type are the second and third largest buildings type by floor area in the state, respectively.

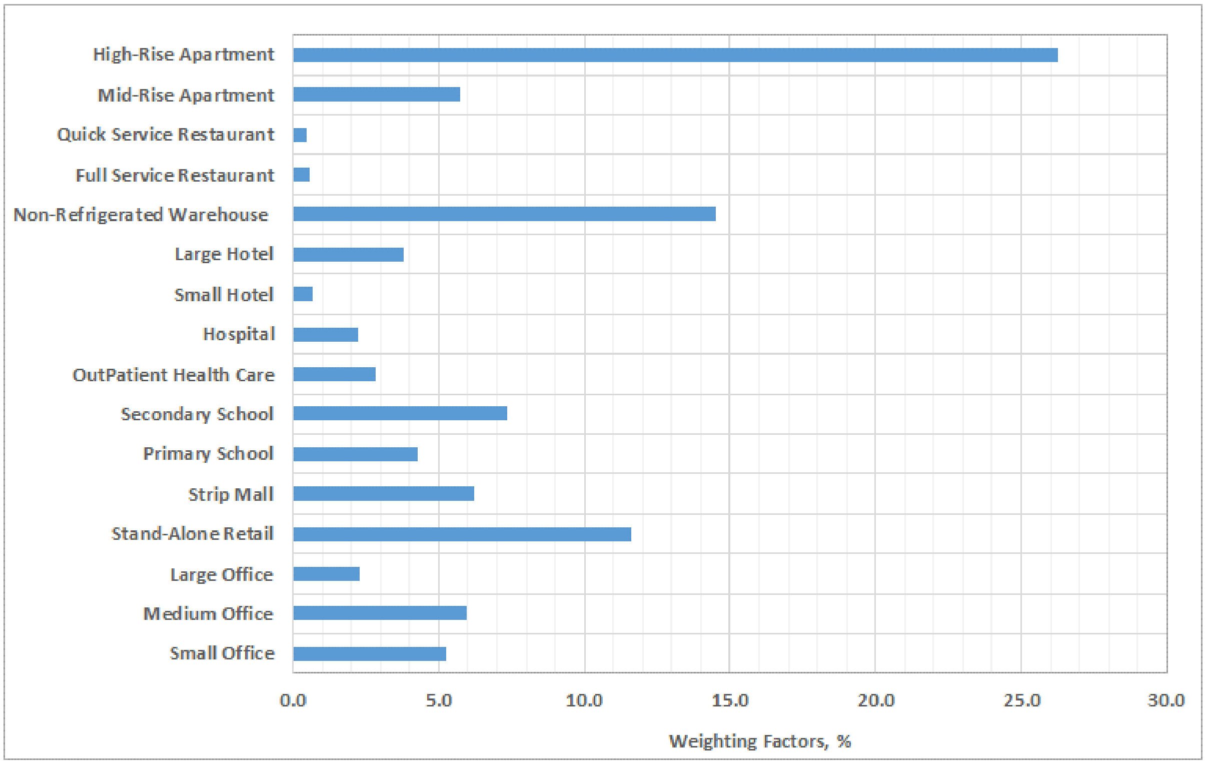

Figure D-2 Commercial Buildings Floor Area Weighting Factors by Prototype Building

The commercial building conditioned floor area distribution for the State of Florida presented here were derived from data published by Jarnagin and Bandyopadhyay (2010). Assumptions were made to split the State's total floor area by climate zones 1A and 2A due to absence commercial floor area distribution by state and climate zones. Florida commercial building conditioned floor area distribution by climate zones and building type needs to be determined from recent new building construction record in the State.

Appendix-E: Cost Assumption for Life Cycle Analysis

Table E-1 Parking Lot Lighting Upgrade Cost Assumptions for Small Office Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P[7] Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	1	155	200.0	25%	443	12
Lamp, 20000 Hours life	1	40.0	25.0	35%	87	4
Ballast, Dimming[8]	1	115	200.0	25%	394	12
2020 FEC						
LED, Lamp & Driver	1	285	200.00	25%	606	12

Table E-2 Parking Lot Lighting Upgrade Cost Assumptions for Medium Office Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	2	241	200.0	25%	1102	12
Lamp, 20000 Hours life	2	69	25.0	35%	254	4
Ballast, Dimming	2	172	200.0	25%	930	12
2020 FEC						
LED, Lamp & Driver[9]	4	285	200.00	25%	2425	12

Table E-3 Parking Lot Lighting Upgrade Cost Assumptions for Large Office Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	8	241	200.0	25%	4410	12
Lamp, 20000 Hours life	8	69	25.0	35%	1015	4
Ballast, Dimming	8	172	200.0	25%	3720	12
2020 FEC						
LED, Lamp & Driver	16	285	200.00	25%	9700	12

[7] OH&P stands for overhead and profit cost.

[8] http://www.elliottelectric.com/P/Category/List/3142-High-Intensity-Discharge-Balla?

[9] https://www.ledlightexpert.com/40000-Lumen--300-watt-NextGen-II-LED-Shoebox-Lights--Dimmable--With-Photocell--SLIP-FIT-Mount_p_184.html?gclid=EAIaIQobChMImeiHzKa54AIVCFgNCh3jYgjUEAkYASABEgJiMPD_BwE

Table E-4 Parking Lot Lighting Upgrade Cost Assumptions for Stand-alone Retail Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	1	241	200.0	25%	551	12
Lamp, 20000 Hours life	1	69	25.0	35%	127	4
Ballast, Dimming	1	172	200.0	25%	465	12
2020 FEC						
LED, Lamp & Driver	2	285	200.00	25%	1212	12

Table E-5 Parking Lot Lighting Upgrade Cost Assumptions for Strip Mall Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	1	241	200.0	25%	551	12
Lamp, 20000 Hours life	1	69	25.0	35%	127	4
Ballast, Dimming	1	172	200.0	25%	465	12
2020 FEC						
LED, Lamp & Driver	2	285	200.00	25%	1212	12

Table E-6 Parking Lot Lighting Upgrade Cost Assumptions for Primary School Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	1	155	200.0	25%	443	12
Lamp, 20000 Hours life	1	40.0	25.0	35%	87	4
Ballast, Dimming	1	115	200.0	25%	394	12
2020 FEC						
LED, Lamp & Driver	1	285	200.00	25%	606	12

Table E-7 Parking Lot Lighting Upgrade Cost Assumptions for Secondary School Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	2	241	200.0	25%	1102	12
Lamp, 20000 Hours life	2	69	25.0	35%	254	4
Ballast, Dimming	2	172	200.0	25%	930	12
2020 FEC						
LED, Lamp & Driver	4	285	200.00	25%	2425	12

Table E-8 Parking Lot Lighting Upgrade Cost Assumptions for Outpatient HealthCare Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	2	241	200.0	25%	1102	12
Lamp, 20000 Hours life	2	69	25.0	35%	254	4
Ballast, Dimming	2	172	200.0	25%	930	12
2020 FEC						
LED, Lamp & Driver	4	285	200.00	25%	2425	12

Table E-9 Parking Lot Lighting Upgrade Cost Assumptions for Hospital Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	2	241	200.0	25%	1102	12
Lamp, 20000 Hours life	2	69	25.0	35%	254	4
Ballast, Dimming	2	172	200.0	25%	930	12
2020 FEC						
LED, Lamp & Driver	4	285	200.00	25%	2425	12

Table E-10 Parking Lot Lighting Upgrade Cost Assumptions for Small Hotel Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	2	241	200.0	25%	1102	12
Lamp, 20000 Hours life	2	69	25.0	35%	254	4
Ballast, Dimming	2	172	200.0	25%	930	12
2020 FEC						
LED, Lamp & Driver	2	285	200.00	25%	1212	12

Table E-11 Parking Lot Lighting Upgrade Cost Assumptions for Large Hotel Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	2	241	200.0	25%	1102	12
Lamp, 20000 Hours life	2	69	25.0	35%	254	4
Ballast, Dimming	2	172	200.0	25%	930	12
2020 FEC						
LED, Lamp & Driver	4	285	200.00	25%	2425	12

Table E-12 Parking Lot Lighting Upgrade Cost Assumptions for Warehouse Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	1	241	200.0	25%	551	12
Lamp, 20000 Hours life	1	69	25.0	35%	127	4
Ballast, Dimming	1	172	200.0	25%	465	12
2020 FEC						
LED, Lamp & Driver	2	285	200.00	25%	1212	12

Table E-13 Parking Lot Lighting Upgrade Cost Assumptions for Fast Food Restaurant Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	1	155	200.0	25%	443	12
Lamp, 20000 Hours life	1	40.0	25.0	35%	87	4
Ballast, Dimming	1	115	200.0	25%	394	12
2020 FEC						
LED, Lamp & Driver	1	285	200.00	25%	606	12

Table E-14 Parking Lot Lighting Upgrade Cost Assumptions for Full-Service Restaurant Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	1	241	200.0	25%	551	12
Lamp, 20000 Hours life	1	69	25.0	35%	127	4
Ballast, Dimming	1	172	200.0	25%	465	12
2020 FEC						
LED, Lamp & Driver	2	285	200.00	25%	1212	12

Table E-15 Parking Lot Lighting Upgrade Cost Assumptions for Mid-Rise Apartment Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	1	241	200.0	25%	551	12
Lamp, 20000 Hours life	1	69	25.0	35%	127	4
Ballast, Dimming	1	172	200.0	25%	465	12
2020 FEC						
LED, Lamp & Driver	2	285	200.00	25%	1212	12

Table E-16 Parking Lot Lighting Upgrade Cost Assumptions for High-Rise Apartment Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
HID, Lamp and Ballast	2	241	200.0	25%	1102	12
Lamp Cost, 20000 Hours life	2	69	25.0	35%	254	4
Ballast, Dimming	2	172	200.0	25%	930	12
2020 FEC						
LED, Lamp & Driver	4	285	200.00	25%	2425	12

Table E-17 Facade Lighting Upgrade Cost Assumptions for Medium Office Building

Items	Quantity	Material Cost, $	Labor Cost, $	OH&P Cost, $	First Cost, $	Service Years
2017 FEC						
T5 Fluorescent Lamp, 20000 Hours life	2	14	25.0	35%	105	8
Ballast, Dimming Linear Fluorescent[10]	1	190	200.0	25%	488	12
2020 FEC						
LED, Lamp & Driver	2	100	200.00	25%	750	12

Table E-18 Assumptions for Life Cycle Cost Analysis of Code Modification EN7523

Prototype Building	Reference Code	Service Life, Years[11]	First Cost, $	Maintenance Cost, $/Yr
Stand-Alone Retail	2017 FEC	10	0.0	0.0
	2020 FEC	10	70.0	20.0

[10] Dimming fluorescent ballast. http://www.elliottelectric.com/P/Category/List/3139-Dimming-Fluorescent-Ballasts?a=416767
[11] Service life span of thermostats: https://xp20.ashrae.org/publicdatabase/system_service_life.asp?selected_system_type=7

Table E-19 Assumptions for Life Cycle Cost Analysis of Code Modification EN7536

Prototype Building	Reference Code	Service Life, Years	First Cost[12], $	Maintenance Cost, $/Yr
Scenario I: Cost of HVAC Controller Installed Cost Per Guest Room $150.0				
Small Hotel	2017 FEC	12	0.0	0.0
	2020 FEC	12	11550.0	500.0
Large Hotel	2017 FEC	12	0.0	0.0
	2020 FEC	12	26850.0	500.0
Scenario II: Cost of HVAC Controller Installed Cost Per Guest Room $200.0				
Small Hotel	2017 FEC	12	0.0	0.0
	2020 FEC	12	15400.0	500.0
Large Hotel	2017 FEC	12	0.0	0.0
	2020 FEC	12	35800.0	500.0

Table E-20 Assumptions for Life Cycle Cost Analysis of Code Modification EN7558

Prototype Building	Quantity	Installed First Cost Per Unit, $	Total Installed Cost, $	Service Life, Years
2017 FEC				
Medium Office, 15" x 15"	3	56.0	168.0	18
Large Office, 20" x 20"	12	67.0	804.0	18
2020 FEC				
Medium Office, 15" x 15"	3	142.0	426.0	18.0
Large Office, 15" x 15"	12	168.0	2016.0	18.0

[12] First cost of card-key based occupancy control technology: https://store.leviton.com/products/hotel-key-card-switch-white-wss0s-h0w?variant=18216141635