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Creating Energy Independence

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

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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	NAR
* EN7536 NAR / * /EN8142 AS	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	-∞	AS
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 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 AS

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 6th Edition (2017) FEC and the 7th 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	$-\infty$
Secondary School	0.0	-8906.5	$-\infty$
Non-Refrigerated Warehouse	0.0	-459.9	$-\infty$

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 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 NAR

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.

NAR AS

Automatic control of HVAC Systems Serving Guest Rooms: EN7536/EN8142

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

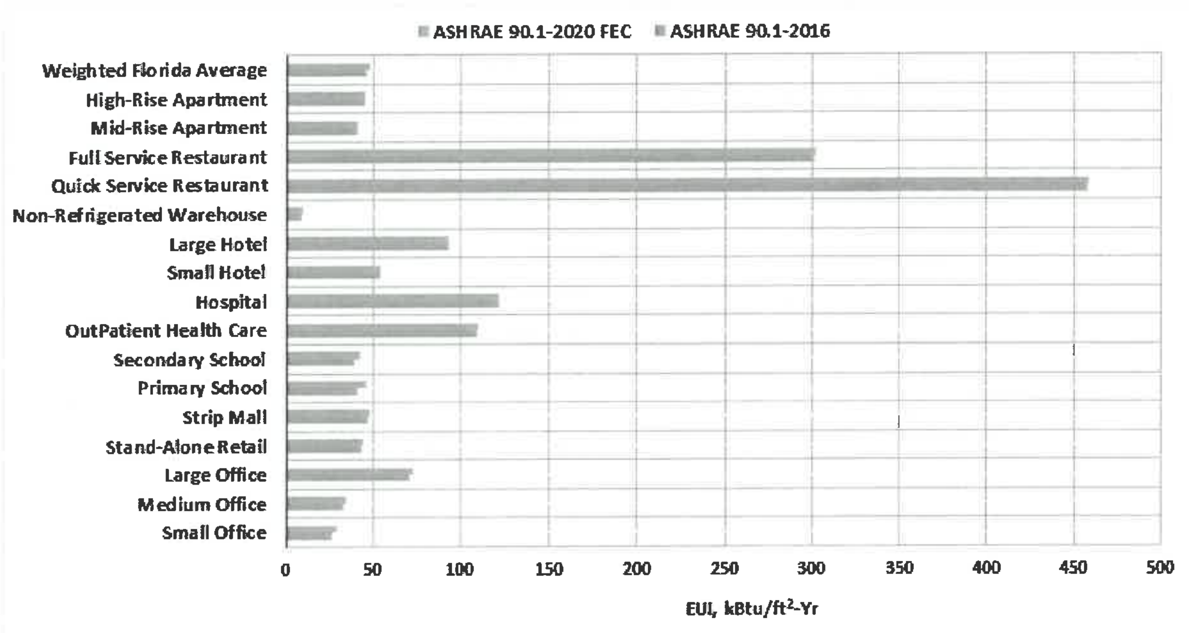

Figure IV Annual Site Energy Use Intensity of the ASHRAE 90.1-2020 FEC by Prototype Building

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 slightly worse by 0.30% and slightly better by 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.

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