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Evaluation of Alternatives for Florida's 2010 Energy Code Update for Residential Buildings

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Author

Philip Fairey

1679 Clearlake Road
Cocoa, Florida 32922, USA
(321) 638-1000
www.floridaenergycenter.org

A Research Institute of the University of Central Florida

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ABSTRACT

This report provides results of analysis of the Florida Energy Code (FEC) with respect to requirements of Florida House Bill 7135. The analysis uses Florida's performance-based code compliance software, EnergyGauge® USA, to conduct detailed analysis of H.B 7135 requirements to significantly increase the efficiency of new homes over time. First, results of an analysis of the long-term, year 2019 requirement for a 50% increase in new home energy efficiency are presented. Next, the 2009 edition of the International Energy Conservation Code (IECC) is analyzed with respect to the H.B. 7135 dual requirements that the 2009 IECC become the foundation code for the FEC and that the 2010 FEC achieve a 20% increase in new home energy efficiency relative to the 2007 FEC. Finally, the report presents results of analysis of three potential prescriptive compliance options for meeting the 20% efficiency improvement requirement of H.B. 7135.

Background

Florida House Bill 7135 requires that the Florida Building Commission (FBC), in coordination with the Florida Department of Community Affairs (DCA), update the Florida Energy Code (FEC) on a triennial basis to improve the efficiency of new Florida buildings. Specifically, the Act requires the FBC and DCA to increase the stringency of the 2010 FEC by 20% as compared with the 2007 FEC. The Act also requires increases of 10% triennially through 2019 when the FEC is required to be 50% more stringent than the 2007 FEC.

The Act further states that: "The Commission shall select the most current version of the International Energy Conservation Code (IECC) as a foundation code; however, the IECC shall be modified by the Commission to maintain the efficiencies of the Florida Energy Efficiency Code for Building Construction adopted and amended pursuant to s.553.901."

The FEC has a long history of providing both a prescriptive compliance option and a performance-based compliance option that allows maximum compliance flexibility. A fundamental principle of the FEC has been that all compliance options result in the same standard of energy efficiency for any given building. To accomplish this, the FEC has always developed prescriptive compliance option(s) using its performance-based compliance methodology.

To remain true to the fundamental principle that all compliance options result in the same standard of energy efficiency, this study uses Florida's performance-based code compliance residential energy simulation software to examine prescriptive options that meet both the minimum standards of 2009 IECC and the 20% energy efficiency increase objective of H.B. 7135 for the 2010 code cycle.

Methods

Florida's 2007 FEC code compliance software, EnergyGauge USA FlaRes, is used to conduct analysis that examines alternatives for residential FEC enhancements that meet Florida's long-term (2019) and near-term (2010) objectives for enhanced energy efficiency in new residential buildings.

The initial step in the analysis is to examine the degree to which building component characteristics might be improved within the limitations of current technology and cost effectiveness. The term "baseline configuration" is used in this report to refer to the configuration of the 2007 FEC Baseline Home as specified by Table 13-613.A.1-1, Florida Building Code, Buildings, Chapter 13.

The analysis is accomplished through incremental evaluation whereby the energy performance characteristics of the principal components of this "baseline configuration" are varied through a full spectrum of alternatives to determine the physical limitations of the available technologies with respect to residential energy use reduction.

For example, the thermal characteristics of ceiling insulation are varied from virtually no insulation to insulation levels far in excess of the 2007 FEC baseline and the results are plotted to show the relationship between ceiling insulation values and energy use in terms of the Energy Performance Index (EPI) of the home. The result is called an "EPI opportunity curve." EPI is defined as the sum of the energy loads for heating, cooling and hot water of the subject (as-built) home divided by the sum of the energy loads for heating, cooling and hot water of a baseline home configured to meet Florida's 2007 FEC performance requirements, the results multiplied by 100.

$$\text{EPI} = (\text{Sum of as-built loads}) / (\text{Sum of baseline loads}) * 100$$

Florida's 2007 FEC performance requirements are, for all intents and purposes, identical to the energy performance requirements of the 2006 International Energy Conservation Code. Thus, an EPI of 100 indicates that the home is minimally compliant with the 2007 FEC (and the 2006 IECC). Likewise, an EPI value of zero (0) indicates that the home uses no energy for heating, cooling and hot water. Thus, to be 50% more efficient than the 2007 FEC, a home needs to achieve an EPI of 50. Likewise, to meet H.B. 7135 requirements for the 2010 code cycle (20% greater efficiency), the EPI requirement would be 80 or less. Due to Florida Governor's Executive Order #07-127, which requested the FBC to increase the efficiency of new homes and buildings by 15% by 2009, Florida's current 2009 supplement to the FEC requires an EPI of 85 or less. Thus, to achieve the H.B. 7135 year 2010 requirement of 20% greater efficiency requires only an additional 5% savings or an EPI of 80 or less.

Since H.B. 7135 requires efficiency increases with respect to the 2007 FEC and because the FBC chose to achieve the 15% savings requirement of Executive Order #07-127 via a change in the EPI compliance requirement from 100 to 85, results of the analysis presented in this report are presented in terms of the achieved EPI of the various alternatives.

Getting to 50 – What Will it Take?

A study using incremental analysis of the principle home components that are considered by the FEC has been conducted and presented to the 2010 FEC Workgroup.[1] This analysis focuses on key challenges with respect to meeting the ultimate 2019 requirements of H.B. 7135, when a 50% increase in efficiency of new homes is required.

- Where do we currently stand on envelope feature cost effectiveness (e.g. wall and ceiling insulation R-Value)?
- What are the technology limits for other energy features (e.g. window U-Factor and solar heat gain coefficient – SHGC)?
- How does climate location impact savings potential (Jacksonville versus Miami)?
- What do the "EPI opportunity curves" look like for various climates and home configurations?
- What will it ultimately take to reach 50%?

The analysis uses a 2,000 ft2, 3-bedroom, single-story, slab-on-grade, frame home as the baseline. This home is distributed as an example (FL-example_Daytona) within Florida's energy code compliance software (EnergyGauge USA FlaRes 2008). The analysis procedure is as follows:

- Alter each energy component incrementally, one component at a time, through a broad range of performance alternatives (e.g. R-values, U-factors, SHGCs, etc.)
- Approximate the current cost effectiveness for envelope insulation improvements
- Determine reasonable technology limits for other "best practice" energy features
- Combine all envelope components together to produce graphical plots that depict the marginal potential for improved energy efficiency through envelope design and construction (referred to as "EPI opportunity curves")

The initial analysis focuses on envelop insulation levels, where the insulation in walls and ceilings is incrementally varied from very small R-values to very large R-values and the incremental energy savings between each R-value step is evaluated for cost effectiveness in accordance with the present value benefit-to-cost ratio (PVBC) analysis methodology specified by FAC 9B-13.0071.[2] This analysis was accomplished using the baseline home configuration for three Florida cities representing north, central and south Florida locations.

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[1] Fairey, P., September 3, 2009, "Getting to 50: What Will it Take." FBC 2010 Workgroup presentation. http://consensus.fsu.edu/FBC/2010-Florida-Energy-Code/FSEC_Presentation_Energy_Increases.pdf

[2] See also http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1794-09.pdf

Figure 1 illustrates typical baseline home configuration results for the Daytona Beach location. Ceiling and wall insulation costs are estimated at 3 cents and 5 cents per square foot per R-value for ceiling and wall insulation, respectively. Wall R-value costs are somewhat greater than ceiling R-value costs due to the fact that wall systems are subject to greater geometric space constraints than ceilings. In other words, increasing wall insulation levels above certain values requires the use of wall framing materials with increased thicknesses while ceiling spaces are normally expansive enough to incorporate increased thickness of ceiling insulation without any required increases to attic spaces to accommodate the increased R-value.

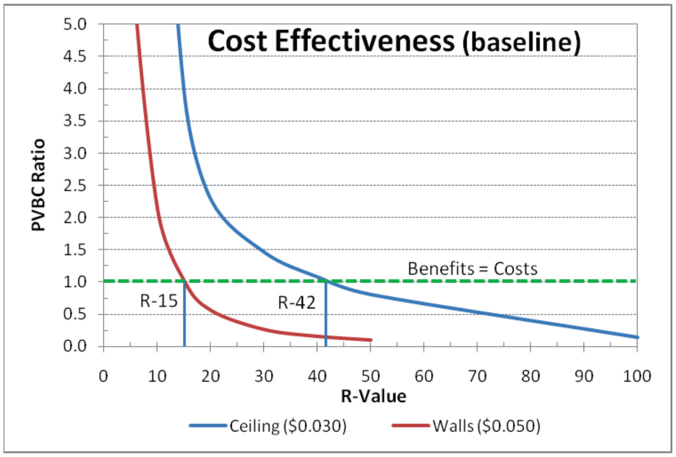

Figure 1. Present value benefit to cost ratio curves for wall and ceiling insulation in Daytona Beach Florida using the baseline home configuration.

One quickly observes from Figure 1 that the marginal benefit of increasing insulation value in both walls and ceilings is quite high where insulation R-values are relatively small. However, as R-values increase the marginal benefit drops precipitously, moving asymptotically toward zero as R-values get significantly larger. If the cost of the insulation per unit of R-value is not changing as a function of R-value, then something else must be changing in a non-linear manner to cause this distinct "bend" in the cost effectiveness curves.

Figure 2 illustrates that this occurs because the marginal energy benefit of adding each additional R-value increment decreases geometrically as the ceiling R-value increases. Let's illustrate by example. The energy savings benefit of increasing the ceiling R-value by R-10 from R-10 to R-20 is about 11 EPI points in Daytona Beach. On the other hand, the energy savings benefit of increasing ceiling R-value by R-10 from R-30 to R-40 is only about 3 EPI points, significantly less than for the first example. Expressed another way, the marginal energy value of additional increments of ceiling R-value diminishes as the R-value of the ceiling increases. Thus, as Figure 2 shows, there is large marginal energy savings benefit from increasing ceiling insulation from R-5 to R-10 (about 17 EPI points or more than 3 points per R-value). However, there is very little marginal energy saving benefit for increasing ceiling insulation from R-50 to R-100 (about 3 EPI points or only 0.06 points per R-value).

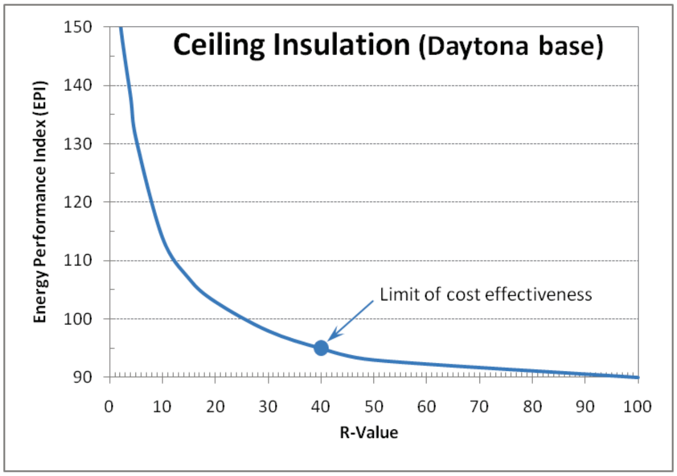

Figure 2. Energy Performance Index for baseline home configuration for various ceiling insulation R-values.

Because the results of the analysis are expressed in terms of the resulting EPI, we will refer to this type of plot as an EPI opportunity curve.

This same type of EPI opportunity analysis may be extended to all of the principal components of the building envelope. However, windows constitute a special case for a number of reasons. First, their energy performance is a function of multiple performance criteria. The “thermal” performance of windows is expressed in terms of U-factor, which is the reciprocal of the sum of the window R-value and the interior and exterior air film resistances for the window. Second, unlike opaque building components, windows directly admit sunlight into the buildings. As a result, windows have two additional performance characteristics. The first is the Solar Heat Gain Coefficient (SHGC), which is a measure of the amount of heat admitted by the window relative to the energy content of sunlight at normal incidence (i.e. striking the window at 90 degrees to the plane of the window). The final window performance characteristic is Visible light Transmittance (VT), which is a measure of the visible light admitted by the window relative to the amount of visible light striking the window at normal incidence.

For the purposes of the thermal performance of windows, it is the U-factor and SHGC that are of primary importance. Of these two, the SHGC has the larger importance in Florida’s cooling load dominated climate. Figures 3a and 3b illustrate how these two window characteristics impact home energy performance in Florida climates.

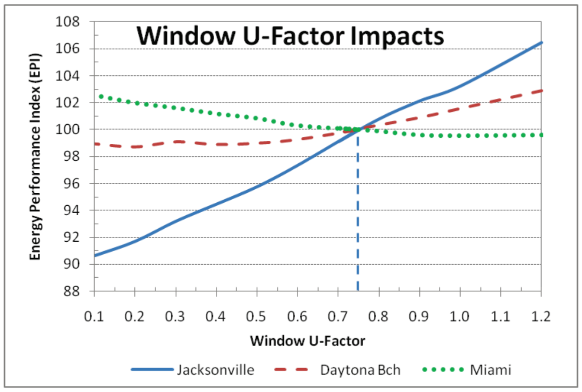

Figure 3a. The impact of window U-factor on home energy performance in Florida climates.

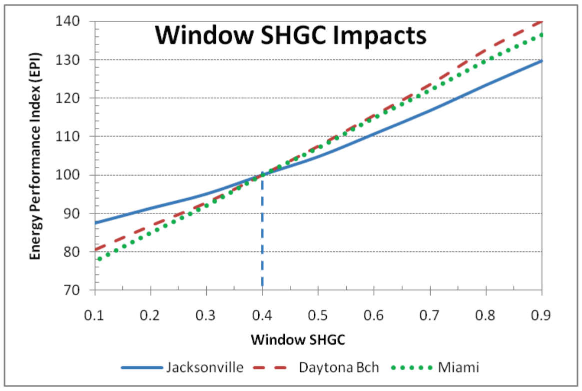

Figure 3b. The impact of window SHGC on home energy performance in Florida climates.

It is significant to note in Figure 3a that window U-factor has very little impact on EPI except in north Florida climates. It is also significant that the impact of U-factor can be counterintuitive, as shown for Miami, where lower U-factors impact EPI in the opposite direction as compared with Jacksonville.

On the other hand, the impacts of SHGC shown in Figure 3b are much more consistent in terms of climate. The impacts in Jacksonville are slightly less pronounced that in Daytona Beach and Miami but all impacts trend in the same direction. Additionally, one observes by the scales of the y-axes in these plots that SHGC has a much larger impact on EPI than does U-factor.

Both of these characteristics can be represented on the same axis as the R-value of other components by taking their reciprocal (i.e. 1/U-factor and 1/SHGC).

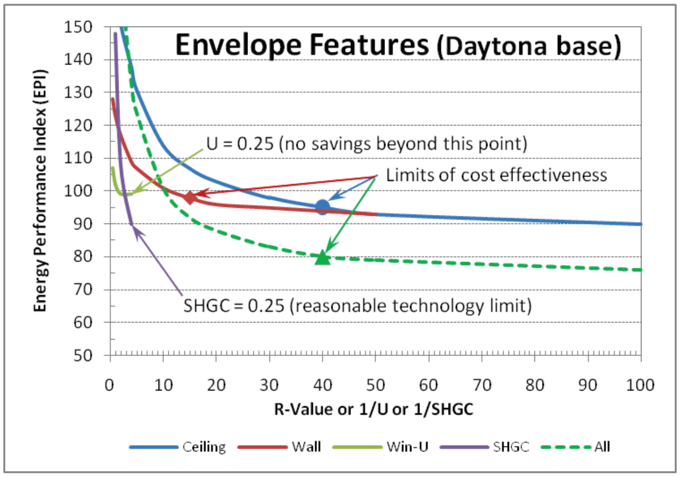

Figure 4. Envelope component EPI Opportunity curves for baseline home configuration in Daytona Beach showing individual and well as combined opportunity curves.

Figure 4 shows results of this type of analysis including each of the primary envelope components for the baseline home configuration in Daytona Beach. For combined analysis, each component is represented as an individual curve and then the components are all taken together to produce a combined opportunity curve (labeled 'All' on the plot). The combined opportunity curve is calculated by incrementing each of the individual characteristics until that component reaches either its cost-effectiveness limit or it technology limit in the case of the window component. As a result, the combined opportunity curve ends up representing what we will call "best practice." For windows, the technology limit that is taken as reasonable is a U-factor of 0.25 coupled with a SHGC of 0.25. The cost effectiveness limits for ceiling and wall insulation are derived as shown in Figure 1.

Figure 4 illustrates to things: first, that the virtual limit of potential for improving the envelope components of the baseline home configuration is an EPI of 80, or a 20% improvement in energy efficiency as compared with the 2007 FEC; and second, that increasing the thermal performance of these envelope components beyond this point will have very little impact on energy use due to diminishing returns. Of course, this 20% improvement is not sufficient to reach the H.B 7135 year 2019 goal of a 50% efficiency improvement.

However, there are characteristics other than the envelope thermal characteristics that can significantly impact energy use in residences. They include the total size of the windows in the home, the efficiency of air distribution system used to condition the home and the efficiency of the heating, cooling and hot water systems of the home.

For example, if we examine the amount of window area in homes, we find that it makes a significant difference in EPI results. Figure 5 illustrates this fact using the baseline home characteristics and variations in the window-to-floor area percentage (WFA). In this figure, WFA is varied from a low value of 6% to a high value of 36%. This range of values exactly corresponds with the range of results from large scale field audits conducted in 1994 on more than 400 Florida homes.[3]

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[3] Fairey, P., R. Vieira, et al., March 1995, "Residential New Construction Research Project Final Report." (Proprietary) Report No. FSEC-CR-788-95, Florida Solar Energy Center, Cocoa, FL. Data released with permission of Dan J. Haywood on behalf of Florida Power & Light Company via personal communication with the author, October 23, 2009.

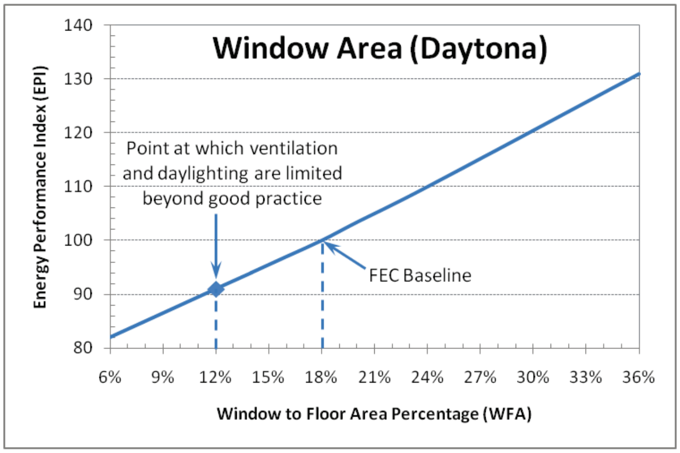

Figure 5. Plot of EPI results as a function of the window-to-floor area percentage of Daytona Beach home with baseline home characteristics.

The 2007 FEC baseline for WFA is set at 18% and, as a result, this value produces an EPI of exactly 100. Figure 5 illustrates that the amount of window area in a home significantly impacts its annual energy use. In addition to the baseline window percentage, Figure 5 also has a marker at 12% WFA, below which it is the author's considered opinion that best practice for ventilation and daylighting likely will be compromised in homes. Figure 5 also illustrates that by decreasing window area to the "best practice" lower limit of 12%, provides energy reductions on the order of 10% (EPI-90).

The air distribution system efficiency of heating and air conditioning systems also plays a key role in home energy efficiency. It is common practice in Florida to locate ductwork and air handling units (AHU) in unconditioned spaces. It is also common practice that these system leak air, causing supply air to be lost to the outdoors and causing unconditioned air to be drawn into the return air stream. Both of these types of air leakage cause pressure imbalances between indoors and outdoors and increase building infiltration in homes. Air distribution systems are not required to be leak free and located in conditioned spaces in Florida homes but the FEC provides for some significant energy efficiency credits if that is the case.

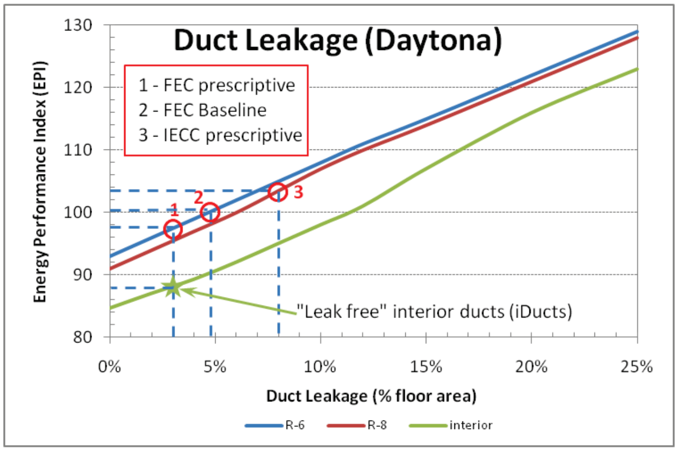

Figure 6. Air distribution system impact on EPI for baseline home configuration in Daytona Beach.

Figure 6 illustrates the importance of this element of home design and construction. The data are plotted as a function of the rate of the air leakage to outdoors (cfm) at a pressure difference of 25 Pascal, where the air leakage rate is expressed as a percentage of the conditioned floor area of the home. This value is also known as the normalized leakage to outdoors or Qn of the home with units normally expressed as $\mathrm{cfm25_{OUT}/ft^2}$.

A number of items are shown in Figure 6. Two levels of duct insulation (R-6 and R-8) are plotted for ducts that are located in attics (the most common location in Florida homes). A third line is plotted for air distribution systems that are located within the conditioned space. In addition, three specific points are marked on the graph. Point #1 represents the minimum requirement of the 2009 FEC for prescriptive code compliance – "substantially leak free." Point #2 represents the 2007 FEC baseline building requirement for performance- based code compliance calculations (i.e. EPI=100). Finally, point #3 represents the minimum prescriptive requirements for tested air distribution systems specified by Section 303.2.2, 2009 IECC. The final star marker shown on the plot is for air distribution systems that are located within the interior conditioned space of a home and are "substantially leak free." By definition, substantially leak free in the FEC means that the tested, normalized air leakage of the air distribution system is less than or equal to 0.03 $cfm25_{OUT}/ft^2$ (expressed as 3% in Figure 6).

Thus, best practice for air distribution systems – interior, substantially leak free – is approximately 12% more energy efficient than the baseline condition. Additionally, once air distribution systems are brought into the interior of the thermal and air barriers of a home, achieving distribution system leakage rates that are less that 3% becomes substantially easier, leading to additional savings potential.

Now we ask the question as to how these best practice window area and air distribution system parameters impact the EPI opportunity curves developed earlier. To evaluate this, we repeat the incremental envelope component analysis incorporating these additional best practices – first one at a time and then in combination to arrive at an overall EPI opportunity curve for all of the best practice elements of building design and construction.

Figure 7 presents the results for Daytona Beach. The combination curve first shown in Figure 4 for the baseline home configuration (Base) is at the top of the opportunity curve set. Next the WFA-12 curve shows the impact of reducing window-to-floor area from 18% to 12%. The next curve down (iDucts) shows the impacts of leak free interior air distribution systems and the lowest curve (Win & Ducts) shows the impact of both WFA-12 and iDucts taken together.

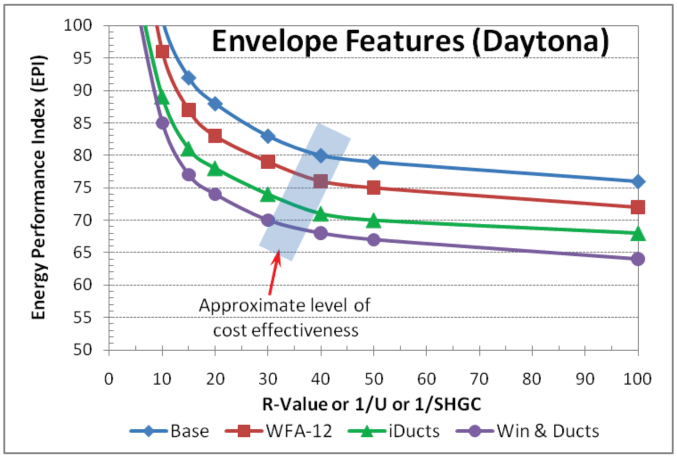

Figure 7. EPI opportunity curves for baseline and best practice home configurations in Daytona Beach showing individual impact of each best practice and the combined impact of all best practices taken together.

The final item shown in Figure 7 is the approximate zone of cost effectiveness for the combined set of opportunity curves. This zone is not perpendicular to the x axis because the cost effectiveness of envelope insulation is not constant but rather is dependent on the other efficiency attributes of the home.

Figure 8 illustrates this fact using the same cost-effectiveness analysis provided in Figure 1 except that the home configuration is changed from the baseline configuration to the "Win & Ducts" configuration shown in Figure 7.

On comparing Figure 1 with Figure 8, one sees that the best practice configuration results in a shift of the cost effectiveness point for ceiling and wall insulation. The point at which each is cost effective under the revised home configuration has resulted in lower R-values at the line where benefits equal costs (PVBC = 1.0). For ceilings, the cost effective insulation R-value has changed from R-42 to R-32 and for walls, it has changed from R-15 to R-14.

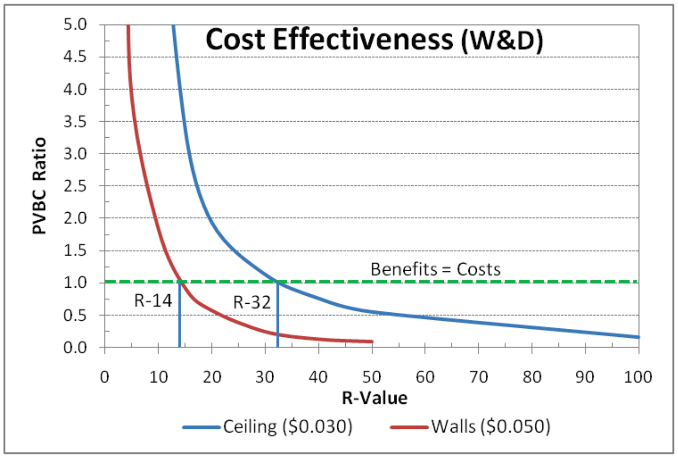

Figure 8. Cost effectiveness curves for ceiling and wall insulation for the combined WFA-12 and iDucts case configuration.

Finally, this same analysis can be repeated for all three of the major Florida climates to determine the EPI opportunity curves for each of Florida's major climate regions. For this purpose only the combined "Win & Ducts" best practice results are reported here but each step in the analysis process described above is accomplished for each location.

Figure 9 shows the composite "best practice" EPI opportunity curves for the three Florida climates studied. Jacksonville stands out among the curves. This occurs primarily because the north Florida region of the state is the only region with space heating requirements of any significance. As a result, the impact of increased thermal insulation shows greater benefit than in other climate regions of the state. At the same time, however, the north region of Florida is responsible for only about 20% of the state's new homes. Figure 9 also clearly shows that the state will not be able to meet the H.B. 7135 goal of 50% reduction in new home energy use by 2019 if only best practice envelope measures are considered. In north Florida, the state can achieve perhaps 35% savings and in central and south Florida about 32% savings.

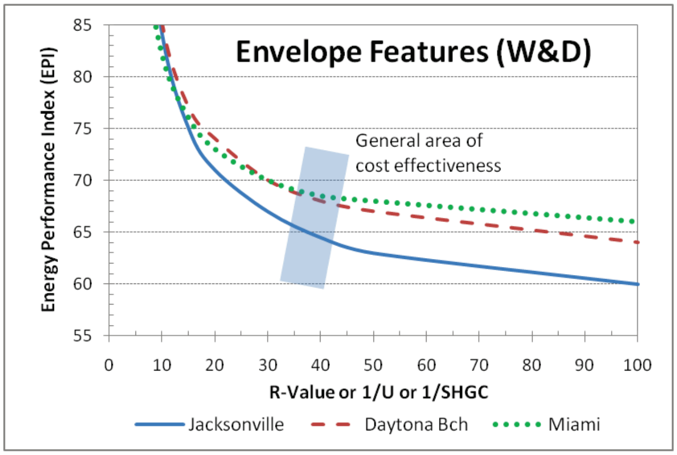

Figure 9. Composite "best practice" EPI opportunity curves for three Florida climate regions.

To achieve greater savings, it will be necessary to consider efficiencies in heating, cooling and hot water systems. Each of these equipment efficiencies can have substantial impacts on energy use in Florida homes. To this end, the analysis is extended to include these systems. Figures 10a and 10b show the impacts of heating system HSPF [Heating Seasonal Performance Factor (Btu/Wh)] and cooling system SEER [Seasonal Energy Efficiency Ratio (Btu/Wh)] on energy performance in Florida climates. The equipment efficiency analysis is accomplished using the baseline home configuration and includes only equipment efficiencies that exceed the prevailing minimum federal standards for these equipment types.

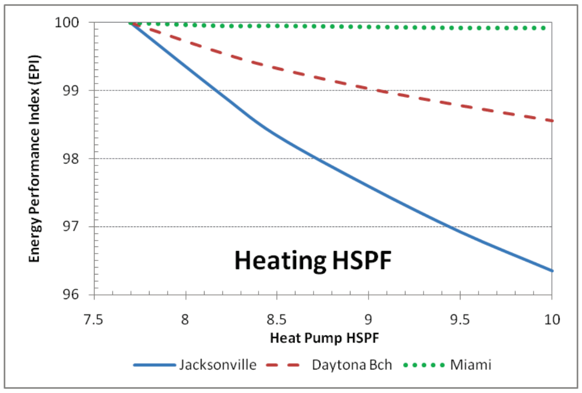

Figure 10a. The impact of heating system HSPF on home energy performance in Florida climates.

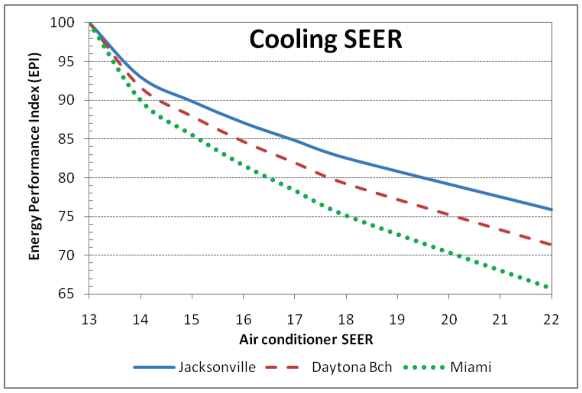

Figure 10b. The impact of cooling system SEER on home energy performance in Florida climates.

Figure 10a is again indicative of the fact that Florida's heating requirements are meager in all climates except north Florida. As a result, improvements in heat pump system performance (HSPF) bring only minor increases in overall efficiency – a maximum of 4% in north Florida. On the other hand, Florida's extensive cooling requirements result in quite substantial potential for cooling system efficiency improvements, with efficiency improvements as large as 35% in south Florida (Miami). It is also important to point out that the SEER range used in this analysis is reasonable with respect to current technology. A number of air conditioning models with SEER's between 18 and 21 are now widely marketed in Florida as a result of federal tax incentives for high-efficiency air conditioning systems.

In addition to heating and air conditioning, Florida's code considers hot water energy use. Hot water system efficiency is expressed in terms of Energy Factor (EF). Figures 11a and 11b address the impacts of hot water system EF on home performance in Florida.

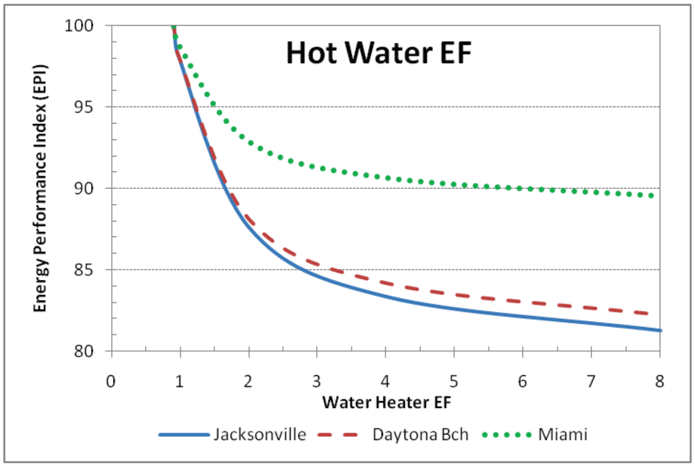

Figure 11a. The impact of hot water system EF on home energy performance in Florida climates.

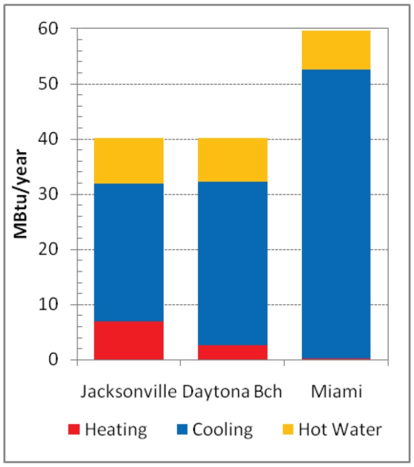

Figure 11b. Annual energy loads in Florida climates.

Note in Figure 11a that there is a substantial difference in the impact of hot water system EF as a function of climate. Figure 11b shows why this difference occurs. The EPI is calculated based on the total energy loads of the home – heating, cooling and hot water. Figure 11b illustrates the fact that total energy load is much larger in Miami, due to a significantly larger cooling energy load. As a result, hot water energy use is a much smaller percentage of the total energy load in Miami and improvements to hot water EF do not create as large a percentage difference in total energy use in Miami as the same EF improvements produce in Jacksonville and Daytona Beach. While similar amount of energy are saved, these saving relative to the total energy load are less in Miami than they are in Jacksonville and Daytona Beach.

Now the final question – what level of systems savings need to be applied to the "best practice" building design and construction savings achieved in Figure 9 to reach the long-term 50% overall savings goal? The final piece of the analysis addresses this question.

Figure 12 provides this final piece of the puzzle. Since the three climate regions are different, different system efficiencies are required to bring the three EPI opportunity curves into alignment with one another. Note that in Figure 9 there is substantial difference between the EPI opportunity curves for Jacksonville and for Daytona Beach and Miami. By adjusting cooling system SEER and heating system HSPF to match the various climate region requirements, we are able to bring all three of the EPI opportunity curves into relatively close alignment and get them to cross the EPI-50 line within the approximate zone of cost effectiveness for envelope insulation.

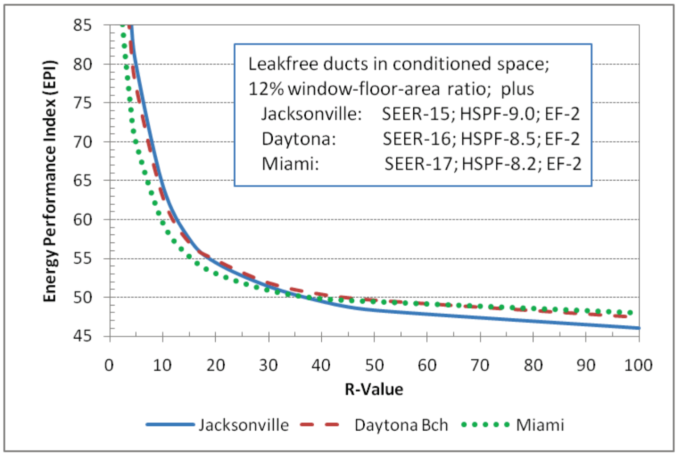

Figure 12. Final EPI opportunity curves showing how EPI-50 is reached with a combination of system efficiencies.

In summary, the analysis has shown that, using best practice design and construction techniques and heating, cooling and hot water efficiencies tailored to the regional climate requirements, we are technically able to reach the long-term, year 2019 goal of 50% improvement in new home energy efficiency.

Analysis of the 2009 International Energy Conservation Code (IECC)

H.B. 7135 also requires that the prevailing IECC be the foundation code for the FEC. The most recent version of the IECC is the 2009 edition. Depending on the information source, the 2009 IECC is reported to be 12-15% more efficient than the 2006 IECC (the basis of the 2007 FEC). Thus, to meet the requirements of H.B. 7135 for 20% greater efficiency than the 2007 FEC, it will be necessary for the 2010 FEC to require greater energy efficiency than the 2009 IECC.

The 2009 IECC has two primary methods of demonstrating compliance: a) the prescriptive compliance option, which is governed by Sections 402, 403 and 404 of the 2009 IECC, and b) the simulated performance alternative, which is governed by Section 405 of the 2009 IECC. Likewise, the 2009 supplement of the FEC has two means of demonstrating compliance: the prescriptive compliance option, called Method B, and the "energy budget" performance compliance option, called Method A. Method A requires an EPI of 85 or less to demonstrate compliance and Method B is constructed to achieve the same level of performance (i.e. EPI of 85 or less) using a specified set of prescriptive requirements. Thus, the two codes are similar in that they both contain two similar means of demonstrating compliance.

The most reasonable means of evaluating the compliance options of the 2009 IECC with respect to the 2009 FEC is to use Florida's code compliance software to calculate the EPI for homes that are configured in accordance with the specific prescriptive requirements of Sections 402 (and 403 & 404) and the Simulated Performance Alternative of Section 405 of the 2009 IECC. The same example home from Florida's code compliance software is selected for this purpose (FL-example_Daytona). The home is "moved" around the state to 6 different Typical Meteorological Year (TMY3) weather cities (Tallahassee, Jacksonville, Tampa, Orlando, Miami and Key West) to evaluate the climate impacts of the 2009 IECC. The 2009 IECC splits Florida into two climate zones with slightly different prescriptive requirements: Zone 1, which consists of Broward, Miami-Dade and Monroe counties, and Zone 2, which consists of the remainder of the state.

Table 1 presents the 2009 IECC component-by-component specifications for the homes used in the analysis. Note that there are only two specification differences between climates zones 1 and 2. The first is the insulation specification for concrete masonry unit (CMU) walls and the second is the U-Factor specification for windows.

It is also important to note a few additional items in Table 1. First, a window-to-floor area (WFA) constraint does not exist in Sections 402,403 and 404 of the 2009 IECC. As a result, the maximum window area constraint required for the Standard Reference Design by Section 405 of 15% is used for the analysis presented here. The location and area of doors is not specified in Sections 402, 403 & 404 of the IECC. Again, the specification required by Section 405 is used for the analysis. Additionally, while Section 403.1.1 of the IECC requires that one thermostat be programmable, Section 405 prohibits the use of programmable thermostats for the simulated performance alternative. As a result, the thermostat used in this 2009 IECC analysis is manual.

Finally, there is a significant difference between the prescriptive specifications for air distribution system performance provided by Section 403 and the performance specification of Section 405. Section 403.2.2 specifies that air distribution system air tightness be tested at 25 Pa pressure difference to not exceed 8 cfm air leakage per 100 ft^2 of conditioned floor area. Table 1 expresses this as 0.08 $cfm25_{OUT}/ft^2$, which is the same value.

Table 1. Home Configurations for IECC 2009 Analysis

Component:	**Type**	**Zone 1**	**Zone 2**	**Notes/Comments:**	
Floors	Area	2000	2000	typical occurrence	
	SOG	0	0	slab edge R-Value per Table 402.1.1	
Roof	shingle	0.75	0.75	per Table 405.5.2(1)	
Ceilings	R-value	30	30	per Table 402.1.1 (vented attic at 1:300)	
Walls	Frame	13	13	cavity R-value per Table 402.1.1	
	CMU	4	6	per Table 402.1.1 (interior application)	
Windows	WFA	15%	15%	taken from Section 405 (not specified in Sections 402, 403 or 404)	
	U-Factor	1.20	0.65	per Table 402.1.1	
	SHGC	0.30	0.30	per Table 402.1.1	
Doors	Location	N.wall	N.wall	taken from sec. 405 specifications	
	Area	40	40	taken from sec. 405 specifications	
	U-Factor	1.20	0.65	per Table 402.1.1	
Ducts	Location	Attic	Attic	most common Florida occurrence	**Sec. 405 requires DSE = 0.88 in lieu of these values**
	Supply area	400	400	20% of floor area (assumed typical)	
	Return area	100	100	5% of floor area (assumed typical)	
	R-value	8	8	per Sec 403.2.1	
	Leakage	0.08	0.08	tested, per Sec. 403.2.2 ($cfm25_{OUT}/ft^2$ floor area)	
	RLF	50%	50%	most reasonable default	
AHU	Location	Garage	Garage	most common Florida occurrence	
Cooling	SEER	13	13	per NAECA Standard (right-sized)	
Heating	HSPF	7.7	7.7	per NAECA Standard (right-sized)	
Controls	tStat	manual	manual	programmable per Sec. 403.1.1 (however, must be manual per Sec. 405)	
Hot Water	Nbr	3	3	determines daily hot water use	
	Use	60	60	gallons per day (= 30 + 10*Nbr)	
	Tstat	120	120	deg F (per plumbing standard)	
	Size	50	50	tank storage gallons	
	Type	Elec	Elec	most common Florida occurrence	
	EF	0.90	0.90	per NAECA Standard	

For the simulated performance alternative (Section 405), the Standard Reference Design specification is for distribution system efficiency (DSE) equal to 0.88. The specific Section 403 duct system parameters that DSE replaces are highlighted and noted within Table 1. Both the Section 403 and the Section 405 specifications for representing minimum air distribution system leakage are evaluated by this analysis.

Analysis results are presented in terms of the EPI that is achieved for each home in each of the six cities. Results are presented separately for homes with frame wall systems and homes with concrete masonry unit (CMU) wall systems. Results are weighted and averaged in two ways. First the frame and CMU wall system EPI results are weighted based on the percentage of CMU wall system homes constructed by geographic region of the state, with significantly more CMU construction in southern Florida than in northern Florida.[4] Additionally, the results are weighted by the expected percentage of new home construction by geographic region of the state to yield a statewide weighted average EPI.[5]

The weighting factors used in the analysis to determine the weighted wall construction averages and the statewide new construction weighted averages are given in Table 2.

Table 2. Factors Used to Determine Weighted Averages

Factor type	**North**	**Central**	**South**
New home construction:	20%	50%	30%
CMU wall type:	33%	75%	77%

Results of the 2009 IECC analysis are presented in Table 3 for both the prescriptive option (Sections 402) and for the simulated performance alternative (Section 405).

Table 3. EPI Results for 2009 IECC Specifications by Section (a)

Location	**Section 402(b):**			**Section 405(c):**		
	Frame	**CMU**	**Wgt'd**	**Frame**	**CMU**	**Wgt'd**
Tallahassee	92	92	92	80	81	80
Jacksonville	91	92	91	79	81	80
Tampa	89	92	91	77	80	79
Orlando	89	91	91	78	81	80
Miami	89	95	94	79	85	84
Key West	90	96	95	80	86	85
Weighted Average:	**90**	**93**	**92**	**79**	**82**	**81**

Table 3 Notes:

(a) Component characteristics as specified by Table 1
(b) Distribution system normalized air leakage (Qn) = 0.08 $cfm25_{OUT}/ft^2$
(c) Distribution system Efficiency (DSE) = 0.88

Table 3 shows a significant performance difference between the 2009 IECC prescriptive option (Sections 402) and the simulated performance alternative (Section 405). It is important to point out that the entire difference between these results is attributable to the

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[4] Personal communication with Bob Stroh, Schimberg Center, University of Florida, October 23, 2009.

[5] Rose, M., et al., 1993. "Electricity Conservation and Energy Efficiency in Florida: Technical, Economic and Achievable Results." Synergic Resources Corporation, Bala Cynwyd, PA. *(Percentages for central and south Florida are modified by the author to account for IECC climate regions, which differ substantially from the Florida regions used in the original study – south Florida percentage is reduced by 10% and central Florida percentage is increased by 10%).*

difference in the specification of distribution system efficiency – all other component specifications are held constant between the two sets of analysis. This result underscores what has been shown consistently in Florida through both field testing and simulation – that air distribution system efficiency is critically important to building energy performance.

Table 3 also shows that the differences between frame wall and CMU wall EPI results are greater in south Florida than in central Florida, with a 2-3 point difference in central Florida and a 6 point difference in south Florida. Much of this difference is likely attributable to the fact that CMU R-value requirements in the IECC are lower in south Florida (IECC climate zone 1) than in central and north Florida (IECC climate zone 2). The data also indicate that CMU walls, at the specified insulation levels, perform more like their frame wall counterparts in northern climates than they do in southern climates, indicating that for parity, the required R-values should be larger in climate zone 1 than in climate zone 2 – exactly backward from the actual case in 2009 IECC.

The tested air distribution system leakage requirement of Method B of the 2009 FEC differs from Section 403 of the 2009 IECC. For Method B of the 2009 FEC, the requirement for air distribution systems located outside the conditioned space is that they be "substantially leak free." Substantially leak free is defined as having a tested leakage to outdoors not greater than 3 cfm per 100 ft^2 of conditioned floor space at a pressure difference of 25 Pa (i.e. normalized leakage (Qn) not greater than 0.03 $cfm25_{OUT}/ft^2$). This 2009 FEC Method B performance requirement is substantially more stringent than the Section 403.2.2, IECC requirement of 0.08 $cfm25_{OUT}/ft^2$. To evaluate the impact of Florida's Method B requirement, the same set of home configurations specified in Table 1 is analyzed using the FEC's Method B minimum requirement for tested air distribution system normalized leakage (Qn) of 0.03$cfm25_{OUT}/ft^2$. This analysis is assigned the name '*Sec. 402 (Qn=0.03).*'

To further examine the impacts of air distribution system leakage and duct location on EPI results, the above Method B analysis is repeated with the air distribution system located inside the conditioned space. The first interior distribution system analysis assumes the Method B minimum air leakage (i.e. Qn=0.03 $cfm25_{OUT}/ft^2$). This analysis is assigned the name '*Sec. 402 (iDucts/Qn=0.03).*' The second interior distribution system analysis assumes "best practice" for air distribution systems, with air leakage reduced from 0.03 to 0.01 $cfm25_{OUT}/ft^2$. This analysis is assigned the name '*Sec. 402 (iDucts/Qn=0.01).*' If the entire air distribution system is located interior to the thermal and air barrier of a home, the normalized air distribution system leakage to outdoors can fairly easily be brought to this level.

Table 4 presents the results of this analysis.

Table 4. Improved Distribution Systems in 2009 IECC homes

Location	Sec. 402 (Qn=0.03)			Sec. 402 (iDucts/Qn=0.03)			Sec. 402 (iDucts/Qn=0.01)		
	Frame	CMU	Wgt'd	Frame	CMU	Wgt'd	Frame	CMU	Wgt'd
Tallahassee	85	85	85	76	77	76	74	75	74
Jacksonville	84	85	84	75	77	76	73	75	74
Tampa	82	84	84	74	77	76	71	74	73
Orlando	82	84	84	75	77	77	72	74	74
Miami	82	87	86	75	81	80	72	77	76
Key West	83	88	87	76	81	80	72	77	76
Weighted Avg:	**83**	**85**	**85**	**75**	**78**	**77**	**72**	**75**	**74**

Table 4 shows that the FEC Method B requirement for tested, “substantially leak free” air distribution systems (Qn = 0.03) results in a significant reduction of EPI compared with the minimum 2009 IECC requirement (Qn = 0.08). On a statewide weighted average basis, EPI is reduced from 92 (Sec. 402 in Table 3) to 85 for the Method B “substantially leak free” result – a reduction in energy use of about 7%. Moving this same “substantially leak free” air distribution system to the conditioned space provides an additional 8% energy savings at a statewide weighted average EPI of 77. And “best practice” for interior air distribution systems (Qn =0.01) reduces energy use by an additional 3%, bringing the statewide weighted average EPI to 74. Clearly, the data provided in Tables 3 and 4 underscore the importance of air distribution system efficiency with respect to home energy efficiency performance.

2009 FEC Analysis and Recommendations for 2010 FEC

A similar analysis was conducted for the 2009 FEC using the prescriptive requirements of Method B. Table 5 provides the building component characteristic used for the 2009 FEC analysis.

Table 5. Home Configurations for 2009 FEC Analysis (a)

Component:	Type	Zone 1	Zone 2	Notes/Comments:
Floors	Area	2000	2000	typical occurrence
	SOG	0	0	per Table 13-613.A.1-1
Roof	shingle	0.75	0.75	per Table 13-613.A.1-1
Ceilings	R-value	30	30	per Form 1100B-08
Walls	Frame	13	13	per Form 1100B-08
	CMU	6	6	per Form 1100B-08
Windows	WFA	16%	16%	per Form 1100B-08
	U-Factor	0.65	0.65	per Form 1100B-08
	SHGC	0.35	0.35	per Form 1100B-08
Doors	Location	N.wall	N.wall	per Table 13-613.A.1-1
	Area	40	40	per Table 13-613.A.1-1
	U-Factor	0.65	0.65	per Table 402.1.1
Ducts	Location	Attic	Attic	most common Florida occurrence
	Supply area	400	400	20% of floor area (assumed typical)
	Return area	100	100	5% of floor area (assumed typical)
	R-value	6	6	per Form 1100B-08
	Leakage	0.03	0.03	tested, per Form 1100B-08 ($\text{cfm25}_{\text{OUT}}/\text{ft}^2$)
	RLF	50%	50%	most reasonable default

Component:	Type	Zone 1	Zone 2	Notes/Comments:
AHU	Location	Garage	Garage	most common Florida occurrence
Cooling	SEER	13	13	per Form 1100B-08
Heating	HSPF	7.7	7.7	per Form 1100B-08
Controls	tStat	program	program	per Form 1100B-08
Hot Water	Nbr	3	3	determines daily hot water use
	Use	60	60	gallons per day (= 30 + 10*Nbr)
	Tstat	120	120	deg F (per plumbing standard)
	Size	50	50	tank storage gallons
	Type	Elec	Elec	most common Florida occurrence
	EF	0.90	0.90	per Form 1100B-08

Table 5 Notes:

(a) Highlighted cells indicate differences from the 2009 IECC requirements

Note in Table 5 that there are some differences between the 2009 FEC prescriptive requirements and those of the 2009 IECC. These differences are highlighted. For the most part, the differences tend to make the 2009 FEC more stringent than the 2009 IECC but there are two notable exceptions. First, the attic duct R-value for the FEC 2009 is R-6 instead of R-8 as in the 2009 IECC; and second, the window SHGC is 0.35 rather than 0.30 as in the 2009 IECC. Results of the 2009 FEC analysis are presented in Table 6.

Table 6. 2009 FEC Method B Results

Location	EPI Results		
	Frame	CMU	Wgt'd
Tallahassee	85	86	85
Jacksonville	84	85	84
Tampa	85	87	87
Orlando	84	87	86
Miami	85	88	87
Key West	85	88	87
Weighted Average:	**85**	**87**	**86**

Table 6 shows that while frame wall construction will meet the 2009 FEC requirements of an EPI of 85 or less in all regions of the state, CMU construction fails to meet this requirement by 2 EPI points (2%) on a overall statewide basis. This is due to the fact that the 2009 FEC accepted and used the greater value of IECC 2006 requirement for CMU wall insulation (R-6) in all areas of Florida. The current analysis indicates that this CMU wall R-value should be increased to achieve better parity between frame and CMU wall construction, especially in Florida where a large percentage of wall construction is CMU.

The remaining issue is how to achieve the 20% efficiency increase above 2007 FEC required by H.B. 7135 for the 2010 FEC. To remain true to minimum 2009 IECC requirements, we will need to remove the Method B thermostat credit, increase the Method B attic duct insulation requirement from R-6 to R-8 and decrease the Method B window SHGC from 0.35 to 0.30. However, it is clear from the 2009 IECC analysis that the FEC Method B requirement for substantially leak free air distribution systems (normalized leakage [Qn] no greater than 0.03 $cfm25_{OUT}/ft^2$) must remain as a Florida efficiency that exceeds the 2009 IECC requirement.

To achieve greater parity between frame and CMU wall construction, it will be necessary to increase minimum CMU insulation levels. It is recommended that a common construction practice, which can provide the needed additional insulation, be selected for this purpose. The following CMU construction practice is recommended: ¾ inch rigid polyisocyanurate insulation board (e.g. Dow Tuff-R) interior to the CMU followed by ¾ inch wood furring interior to the insulation board (creating a ¾ inch air space) followed by interior drywall applied to the furring. This CMU wall construction provides R-7.8 and is labeled as such on the insulation board product. The equivalent exterior CMU insulation is found to be R-6.

However, it is also clear that this set of component specifications may not achieve the EPI-80 required by H.B. 7135. Therefore, it is also recommended that minimum ceiling insulation level be increased to R-38, commensurate with previous cost effectiveness analysis.[6] The results from this set of Method B trial criteria are presented in Table 7.

Table 7. EPI Results for Method B Trial
(Includes R-38 ceilings, R-8 ducts,
SHGC-0.30 windows and Qn = 0.03)
[R-7.8 CMU wall insulation]

Location	**EPI Results**		
	Frame	**CMU**	**Wgt'd**
Tallahassee	82	82	82
Jacksonville	81	82	81
Tampa	79	81	81
Orlando	80	82	82
Miami	80	82	82
Key West	80	83	82
Weighted Average:	**80**	**82**	**81**

While this set of Method B trial criteria improves substantially on the FEC 2009 Method B results (see Table 6), the criteria remain about 1% short of meeting the requirements of H.B. 7135 for a 20% improvement over the 2007 FEC (i.e. EPI-80 or less). It is also important to point out that windows are evenly distributed in all orientations for this analysis. Under worst-case window orientation EPI results would not be as low as reported here and elsewhere in this report.

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[6] Fairey, P., September 3, 2009, "Getting to 50: What Will it Take." FBC 2010 Workgroup presentation. http://consensus.fsu.edu/FBC/2010-Florida-Energy-Code/FSEC_Presentation_Energy_Increases.pdf

From previous analysis we know that EPI (and energy consumption) is a strong function of the window-to-floor area percentage. Figure 13 illustrates this fact showing results of the window area analysis conducted for the principal climate regions of the state.[7] Thus, one method of reducing energy use for the prescriptive compliance option is to reduce allowable window area.

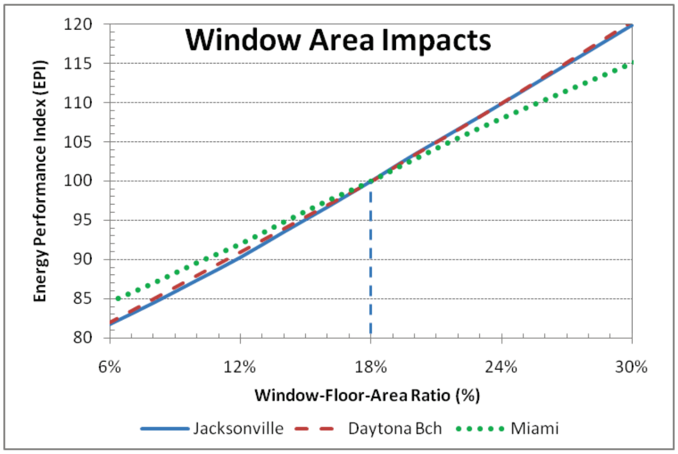

Figure 13. Relationship between window to floor area percentage and EPI for FEC baseline window characteristics.

To that end, the window-to-floor area percentage (WFA) is evaluated at values of 15% and below to determine the point at which the above Option 1 for Method B will come into compliance with the 20% energy reduction requirements of H.B. 7135. The analysis finds that WFA of 13% is required to achieve an overall statewide average EPI of 80 using the criteria established above. This represents Option 1 for achieving the 2010 energy savings requirements of H.B. 7135.

In 1994, as part of the "Residential New Construction Research Project" funded by Florida Power & Light Company, FSEC conducted field audits of 423 new homes. WFA data were collected for each home in the study. Figure 14 provides a summary of these data in the form of a histogram.[8] The mean WFA is 16.8% and the median is 16.3%. More than 76% of the homes in the study exceed 13% WFA. Based on these data, establishing a prescriptive compliance option that limits window-to-floor area percentage to a maximum of 13% may be overly restrictive.

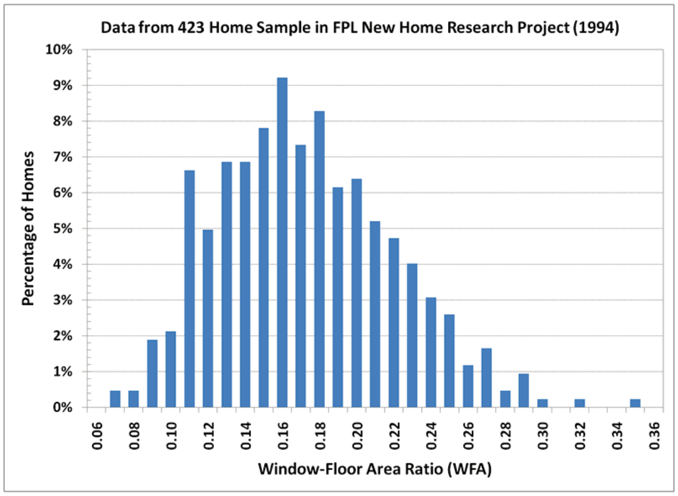

Figure 14. Histogram of window-floor area ratio (WFA) for new homes as audited in 1994 FPL Residential New Construction Research Project.

Therefore, additional analysis is undertaken to examine other prescriptive options for achieving EPI-80 that would allow WFA to be larger. Recalling from Tables 3 and 4 that air distribution system efficiency is very important to home energy efficiency, the air

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[7] *Ibid.*

[8] Fairey, P., R. Vieira, et al., March 1995, "Residential New Construction Research Project Final Report." (Proprietary) Report No. FSEC-CR-788-95, Florida Solar Energy Center, Cocoa, FL. Data released with permission of Dan J. Haywood on behalf of Florida Power & Light Company via personal communication with the author, October 23, 2009.

distribution system is more closely evaluated. As seen in the results presented in Table 4, there are two components to air distribution system efficiency: the thermal heat transfer portion and the air leakage portion. Where ducts are located in attics (most of Florida) the heat transfer portion can be mitigated by an attic radiant barrier system (RBS). Thus, we select as the starting point for an Option 2, an attic RBS. The RBS also reduces heat transfer through the ceiling of the home so we also relax the ceiling insulation from R-38 to R-30. Now we perform the analysis to determine the WFA that achieves our goal of EPI-80 and find that maximum WFA increases from 13% to 16% – a value consistent with the median value of 16.3% for the Figure 14 data.

For Option 3, the entire air distribution system is moved into the conditioned space. Since this removes the possibility of heat transfer to the ducts, an attic RBS is not included in this option. The same analysis to determine the minimum WFA that will achieve the EPI-80 goal is performed for the Option 3 configuration. The result is a maximum WFA equal to 20% of the conditioned floor area. From Figure 14 one observes that this value represents the higher end of the WFA distribution with approximately 75% of new homes having smaller WFA and approximately 25% of new homes exceeding this WFA. Table 8 presents the EPI results for this options analysis.

Table 8. EPI Results for Three 2010 FEC Method B Options

Location	**Option 1**			**Option 2**			**Option 3**		
	Frame	**CMU**	**Wgt'd**	**Frame**	**CMU**	**Wgt'd**	**Frame**	**CMU**	**Wgt'd**
Tallahassee	78	79	78	79	80	79	80	80	80
Jacksonville	77	79	78	78	79	78	79	80	79
Tampa	76	78	78	76	78	77	77	78	77
Orlando	77	79	79	77	79	79	78	79	79
Miami	77	80	79	77	80	79	77	79	79
Key West	78	81	80	78	81	80	77	79	79
Weighted Average:	**77**	**79**	**79**	**77**	**79**	**78**	**78**	**79**	**79**

Based on the above analysis, a set of options for prescriptive requirements (Method B) that would meet or exceed the minimum requirements of the 2009 IECC as well as the requirements of H.B. 7135 for a 20% increase in efficiency can be proposed as presented in Table 9.

Table 9. Proposed Prescriptive Options for 2010 FEC (Method B)

Component:	**Type**	**Option 1**	**Option 2(a)**	**Option 3(a)**	**Notes/Comments:**
Roof	reflectance	0.25	0.25	0.25	Tested (per N1104.A.4)
Ceilings	R-value	R-38	R-30	R-30	
	Attic RBS	No	Yes	No	
Walls	frame	R-13	R-13	R-13	
	CMU (int)	R-7.8	R-7.8	R-7.8	
	CMU (ext)	R-6	R-6	R-6	
Windows	U-Factor	0.65	0.65	0.65	
	SHGC	0.30	0.30	0.30	
	WFA-max	13%	16%	20%	% of floor area
Doors	insulated	U-0.65	U-0.65	U-0.65	
Air Dist System	air leakage	Qn=0.03	Qn=0.03	Qn=0.03	Tested (per N1110.A.2)
AHU	location	uncond(b)	uncond(b)	cond(c)	
Ducts	insulation	R-8	R-8	R-6	

Component:	Type	Option 1	Option 2(a)	Option 3(a)	Notes/Comments:
	location	uncond(b)	uncond(b)	cond(c)	
Cooling	SEER	13	13	13	
Heating	HSPF	7.7	7.7	7.7	
Hot Water	electric				
	40gal	EF-0.92	EF-0.92	EF-0.92	
	50gal	EF-0.90	EF-0.90	EF-0.90	
	other	formula	formula	formula	EF = 0.97-(0.00132 *gal)
	natural gas				
	40gal	EF-0.59	EF-0.59	EF-0.59	
	50 gal	EF-0.58	EF-0.58	EF-0.58	
	other	formula	formula	formula	EF = 0.67-(0.0019 * gal)

Table 9 Notes:

(a) Highlighted cells represent differences from Option 1
(b) uncond = any portion located outside of thermal or air barrier of home
(c) cond = entire distribution system located inside thermal and air barrier of home

While each of these options has been shown to be capable of complying with the requirement for 20% greater efficiency than the 2007 FEC, they do not represent all of the possible options that could be considered. For example, it might be equally appropriate to construct a prescriptive option around a requirement that a solar hot water heater be included in the home.

Conclusions

The analysis indicates that Florida technically can achieve the required 50% reduction in new home energy use by 2019. However, to accomplish this, the efficiency of heating, cooling and hot water systems in Florida homes will have to be considered and may, depending on other energy efficiency measures, need to be greater than the current federal minimum standard.

The analysis of the 2009 IECC indicates that this code is either 8% more efficient than the 2007 FEC (i.e. 2006 IECC) or 19% more efficient than the 2007 FEC, depending on whether compliance is by the prescriptive procedures of Section 402, 403 and 404 or by the simulated compliance alternative specifications of Section 405. The 2009 IECC analysis further shows that air distribution system efficiency is a major determinant of overall home energy efficiency in Florida. Finally, the analysis shows that the 2009 IECC mass wall R-value requirements of Table 402.1.1 and equivalent U-factor requirements of Table 402.1.3 do not comport well with the frame wall R-value and U-factor requirements in Florida’s climates. As a result, this study also recommends that minimum R-value for mass walls in the prescriptive compliance procedure be increased from R-6 to R-7.8 for all of Florida.

The final sets of analysis of options for the 2010 FEC, which must be 20% more efficient than the 2007 FEC showed that at least 3 options exist to select from for the 2010 FEC prescriptive compliance procedure. Depending on strategy, the resulting options incorporate a broad range of minimum window area limitations that span the range of likely window-to-floor area percentages in new Florida homes.