Where Should We Focus Efforts to Improve Building Energy Code Enforcement Rates? Results From A Research Study in Florida

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ABSTRACT

Most states have adopted commercial and residential building energy codes and many are planning adoption of more conservative codes over time. While code language that requires measures for decreased energy use will help improve conservation, the realized conservation related to future construction is limited in part to how well energy codes are enforced. A research study was completed in 2012 that evaluated the residential and commercial energy code compliance enforcement in the State of Florida for buildings built to the 2007 code with 2009 code supplement. Buildings were selected randomly around Florida using guidance from the U.S. Department of Energy's Building Energy Codes Program. Residential research involved a sample size of 43 buildings and was limited to single-family detached homes. Commercial building research included a random sample size of 50 buildings in various size groups classified from less than 25,000 ft^2 up to 250,000ft^2. Primary areas of the energy code were selected to evaluate how well compliance was enforced in each building. Submitted energy code forms were sought for randomly selected buildings where owners granted access for an evaluation. The as-built audited building was compared to the claimed efficiency submitted on energy code forms. Ninety percent of the residential buildings were found to be passing the performance code although forms submitted had one or more items incorrectly specified in almost all cases. On average, 84% of what was specified on the form complied. Many jurisdictions did not have sufficient commercial building code forms to conduct a field evaluation. This occurred 25% of the time based on our commercial building sampling process. Of those commercial buildings field audited, on average 81% of the specified components were found to be in compliance. This paper describes the research method, audit procedure and results, which include a list of the top occurring areas of non-compliance and suggestions to improve compliance enforcement.

Introduction

In support of measuring state energy code compliance, the U.S. Department of Energy (DOE) and its Building Energy Codes Program (BECP) provides recommended processes that have/are being developed to not only help states measure compliance with their building energy codes but also to include considerations about the codes themselves and suggestions regarding the improvement of building energy code compliance. At the time the Florida code compliance research was carried out, DOE Building Technologies Program had a report, "Measuring State Energy Code Compliance" available for guidance (DOE, 2010). As such, the DOE document and the BECP refer to the 2009 IECC and Standard 90.1-2007 as the "target codes" against which compliance is measured.

BECP recognizes prescriptive, trade-off and performance-based methods of compliance and suggests using checklists to track compliance. In the case of the performance-based methods, the evaluator is instructed to compare the building construction to the submitted documentation. Florida Energy Code allows the option of following either a prescriptive or performance method.

Florida contractors nearly always choose to use the performance-based method in new residential and commercial building construction. In fact, all code forms pulled during the project happened to be performance-based. To that end, a methodology was established based on guidance from the DOE BECP, to evaluate the code compliance rate for a sample of residential and commercial buildings. The methodology of finding and evaluating building code compliance as well as the results follow.

Research Method

Target sample sizes for each group studied were based upon the DOE BECP "State Sample Generator" easily found online at https://energycode.pnl.gov/SampleGen/. This allows a random sample to be generated for any state where the numbers of samples are shown for each county of the state. The climate zone and number of construction starts within a given period is used to weigh the distribution of where samples are located. This means there can be some counties with more than one sample and others with no samples. The total target sample size was forty-four buildings for each the commercial and residential sets. A sample size of this amount was reported to be able to detect a compliance score of 85% as being different from 90% compliance 80% of the time (DOE 2010). Once the distribution of the sample size was determined, efforts to find buildings started by searching public databases and contacting local code enforcement departments to locate suitable buildings.

Finding Buildings

Researchers studied the code enforcement of commercial buildings built to the 2007, with 2009 supplement, Florida energy code. A procedure was established by the Florida Solar Energy Center (FSEC) to select potential commercial study buildings in a systematic method. The method involved the following steps:

1. For each target building, obtain energy code forms for 3 permits for each specific building type (small, medium, or large based on target) needed for the study.
2. Search County and then larger city code records within counties.
3. Start with March 2011 permits.
    a. If not enough buildings identified, go to February 2011 permits.
    b. If still not enough buildings identified, go to January 2011 permits.
    c. Continue search to previous month as needed or until reach April 1, 2009 date.
4. If the first three steps fail to produce a suitable study building, the search begins anew in a similar county.
5. Contact owner/occupant to gain permission to audit building. If turned away from all retrieved code forms, repeat steps 2 -4.

Overall, fifty buildings were studied with the following distribution: 18 were small ($\leq$ 25,000 ft^2), 18 medium (>25,000 ft^2 - $\leq$ 60,000 ft^2), and 14 large (>60,000 ft^2 - $\leq$ 250,000 ft^2), meeting or exceeding the DOE target sample sizes.

The residential research study was focused on single-family, detached homes built to the 2007, with 2009 supplement, Florida energy code. Residential buildings were selected with floor area in the range from 1500-2300 ft^2. The method of finding residential buildings varied some from the commercial method. Many of the home residents were contacted to participate in a concurrent monitoring program (Withers et al. 2012). Homeowners were paid but there may have been some bias with respect to who was willing to participate. The first step in finding homes was to research public records and sort through thousands of homes to find those meeting the focused criteria described above. Next, mailing lists were generated to mail homeowners a postcard to invite them to participate in the study. Interested owners had to confirm the study criteria and not be absent much of the year. Homes not confirmed to be built during the appropriate code period or those having changes to the home since final construction were deemed unsuitable for the study. The next step involved requesting the submitted energy code forms from building departments of specific houses of homeowners that agreed to participate in study and that were suitable for code compliance evaluation. The final step was to schedule energy audits. A total of forty-three homes were audited and compared against energy code submissions. The total number of homes is just one less than suggested by the DOE target. The study was able to obtain samples from 19 different counties compared to the target distribution of 23 counties.

Building Code Compliance Enforcement Evaluation Method

Code enforcement can be evaluated in different ways and during various stages of construction. Almost all of the commercial buildings evaluated in this study were finished and occupied. Those that were not occupied, were near completion and evaluated with completed envelopes, HVAC, lighting, and DHW. Also only new buildings were selected, not renovations

The code enforcement evaluation started with a request for a copy of the energy code form that is required to be submitted at the time of the building permit. The lack of this form was considered as one count of non-compliance. If there was no energy code form then there was no document to which the built structure could be compared to, and thus the evaluation of that specific building would end. Buildings, in which there were forms and site access granted, were visited and the building was compared to the code forms.

Given that there is a limited amount of time owners are willing to grant on site, there were limits to how much detail could be covered. Other limitations involved limited access to secure areas, inability to view inside completed assemblies such as roof and exterior walls. In the case of very large buildings, representative floors were evaluated instead of the entire building.

Commercial energy code compliance was evaluated by focusing on the primary items evaluated on code form 400A-2008. Residential code compliance was based on primary items on code form 1100A-08. Following is just a general summary of the areas of the investigations.

- Reasonable representation of floor areas and space use classification
- Interior and exterior lighting power density and controls (commercial)
- HVAC efficiency and controls
- Space heating, cooling and air distribution efficiency
- Reasonable representation of envelope type, areas and orientation
- R value of floors, walls, and roof
- Window performance qualities, areas and orientation and shading
- DHW efficiency

The commercial code compliance general areas were split into twenty-three more focused categories shown in Table 2. The residential code compliance general areas were split into fourteen more focused categories shown in Table 4. Greater details in the method of evaluating the commercial and residential code categories can be found in a research final report (Withers, Montemurno and Vieira. 2012). As with any building inspection, portions of the methodology rely on subjective evaluations. Field inspectors were provided the same methodology to promote uniformity in the evaluations completed by different evaluators. The final determination of compliance rested with project management.

Results

The detailed results in this section are organized by commercial and residential types.

Commercial Results

Nearly half of the fifty buildings included in the commercial study group had non-compliance issues directly related to energy code form documentation. These have been organized into six categories shown in the upper section of Table 1. The lower Audit section of Table 1 shows the number and distribution of buildings that had code forms and on-site code compliance evaluations completed.

Table 1. Commercial Energy Code Form documentation issues and buildings inspected

Building Energy Code Form Documentation Issue	Small	Medium	Large	totals	% of totals
Missing Input Data Reports	2	4	1	7	29.2%
Incomplete Input Data Reports	2	0	0	2	8.3%
Old Code Forms (post March 1, 2009 permit issue date)	2	3	4	9	37.5%
Old Code Forms & Incomplete Input Data Reports	1	1	1	3	12.5%
No Code Forms	0	0	1	1	4.2%
Code Form Substitution	0	0	2	2	8.3%
Totals:	7	8	9	24	48.0%
Audits	Small	Medium	Large	total	% of total
Total Buildings Inspected	11	10	5	26	52.0%
Percent of Buildings Inspected	42.3%	38.5%	19.2%	-	-
Totals:	18	18	14	50	-

Overall compliance of site inspected commercial buildings with adequate documentation was 81%, however if lack of adequate documentation is included, the compliance rate plummets to about 48%. There is some bias in the total number of permit issues found in the group of fifty buildings as we had to go to the next building when access was not granted for an audit. When a building did not have a code form, we accepted it into the sample as a non-compliant form. As such, applying a 48% (24 out of 50 studied buildings) non-compliant code form submission is an exaggerated claim. A more accurate estimate of the frequency of these problems is 24 out of 97 random sample attempts to acquire code forms, or 24.7% based on our data collection. Nevertheless, the study shows there are significant energy code form collection issues at time of permit.

Commercial on-site enforcement compliance. This section addresses the 26 buildings that had on-site energy code enforcement evaluations completed. The size distribution is eleven small

(<25,001ft2), ten medium (25,001-60,000 ft2) and five large (60,001-250,000 ft2). Table 2 shows the total number of non-compliance counts for each of the twenty-three evaluated categories of code. The percentage is calculated as the number of non-compliant counts divided by the total of twenty-six buildings. Each individual building only has one possible count given per evaluated item. For instance, a particular building may have six different cooling systems installed where three out of five had less efficient systems installed compared to the claim made on the code form. This building in our example would only have one count of non-compliance in the cooling systems category. The most common difference was incorrect window orientation (approximately 85% of the 26 buildings inspected).

Table 2. Number and percentage of non-compliance items for twenty-six commercial buildings

	# Non-Comply	% Non-Comply		# Non-Comply	% Non-Comply
Conditioned Area [ft^2]	1	3.8	Light Exterior Controls	0	0.0
Space Classification	2	7.7	Duct Thermal Efficiency	0	0.0
Floors	2	15.4	Air Distribution	0	0.0
Wall Type	7	26.9	Cooling Systems	10	38.5
Wall R Value	2	7.7	Heating Systems	8	30.8
Roof	3	11.5	Ventilation Control	3	11.5
Window Performance	0	0.0	DHW Systems	8	30.8
Window Orientation	22	84.6	Piping Insulation	8	30.8
Window Shade	0	0.0	Joints/Cracks	0	0.0
Light Power Indoor	7	26.9	Plant	2	7.7
Light Interior Controls	6	23.1	Other Compliance	2	7.7
Light Power Exterior	13	50.0			

Figure 1 below shows the rates of non-compliance for the ten highest categories. The five highest categories are: window orientation, exterior lighting, cooling efficiency, heating efficiency and domestic hot water efficiency. The annual energy impact of window orientation also largely depends upon total glass area, presence of shading, and window performance characteristics.

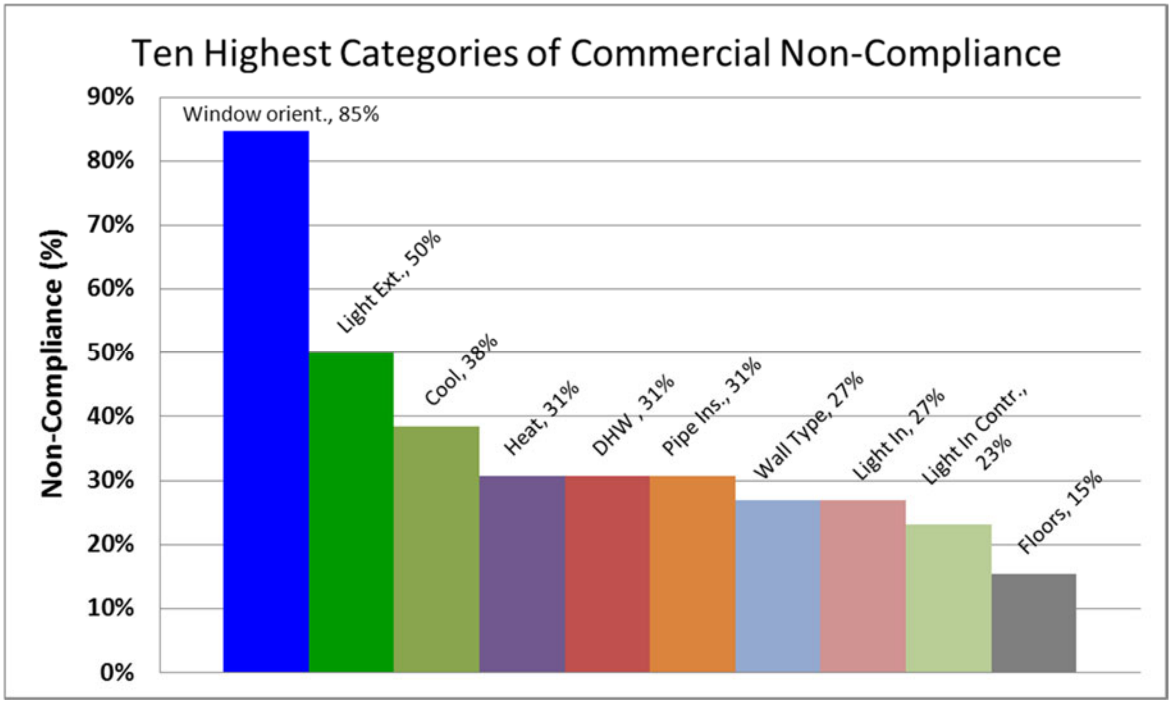

Figure 1. Top ten highest non-compliance categories.

Table 3 shows the percentage of non-compliance for each individual building. Each building has an identity number and ends in either S, M or L for small, medium and large respectively. The percentage has been rounded to the nearest whole number. The percentage of non-compliance was calculated as the total number of items that did not comply divided by the total number of categories relevant to each specific building. For example, building 1C had non-compliance in six categories out of twenty-one relevant categories. While there are twenty-three total possible categories, Plant and Other Compliance were not relevant in this particular case. Of the 26 inspected buildings, on average 19% of items were not in compliance. %.

Table 3. Percent of enforced compliance for each of the twenty-six commercial buildings

Blg.ID	% Non-Comply	Blg.ID	% Non-Comply
1CS	29	14CM	9
2CS	10	15CM	5
3CS	24	16CM	5
4CS	41	17CM	29
5CS	36	18CL	24
6CS	33	19CM	24
7CS	19	20CL	9
8CM	15	21CS	33
9CS	19	22CS	38
10CM	19	23CM	5
11CL	19	24CL	5
12CM	29	25CS	0
13CM	18	26CL	6

A trend is indicated when the average non-compliance is sorted by the building size category as illustrated in Figure 2. The average non-compliance by building size is about 26% for small, 16% for medium and 13% for large buildings showing a trend for better compliance enforcement as buildings become larger.

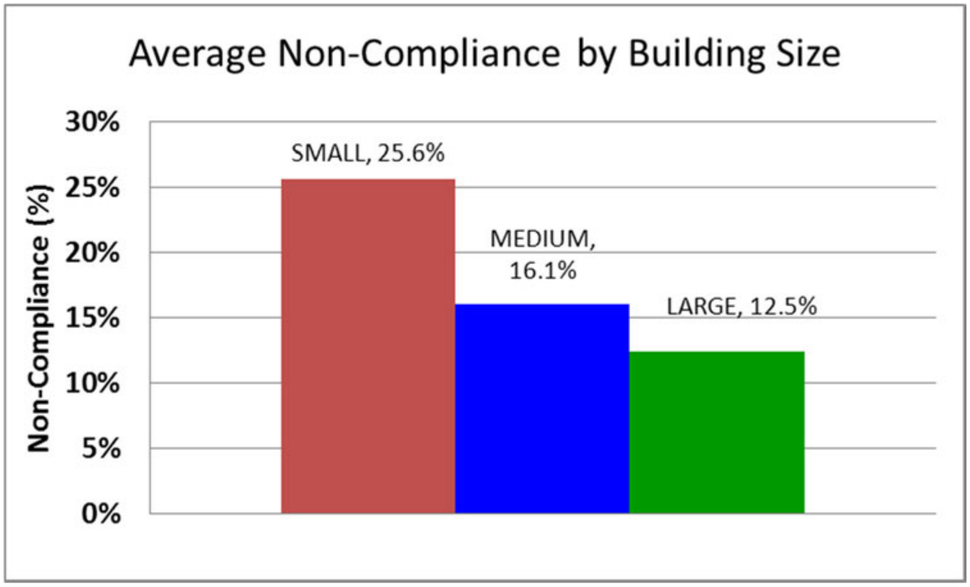

Figure 2. Average non-compliance sorted by building size classification.

Figure 3 illustrates the number of audited buildings that fell into bins of percentage of problems. Just one of the inspected buildings had no compliance issues. Nine of the 26 buildings had 10% or fewer issues; however 16 buildings had over 10% non-compliance issues. When you consider that 24 buildings had some non-compliance issues at permit time, there are significant enforcement issues both during permitting and inspection.

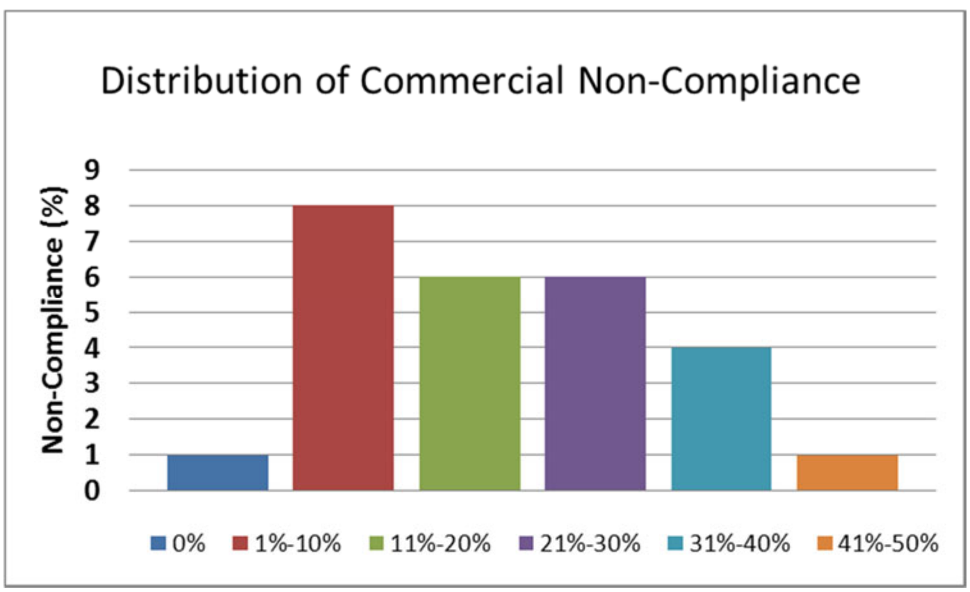

Figure 3. Frequency distribution plot for commercial energy code compliance. The height of each bar represents the number of inspected buildings that had the binned value of non-compliance issues.

Residential Results

All residences had submitted permits using Florida's performance methodology. In considering compliance for these homes then, the real issue is whether the audited home passes the performance based method of code, not a prescriptive method. Thirty-one homes were fully audited and entered into Florida's code performance software. Twenty-eight of those passed for an overall 90% compliance rate. The DOE target goal of compliance is at 90% or better (DOE 2010). The average agreement of submitted code form components with audited result was 84%. Details of these two different methods of evaluating code compliance are given below.

Overall, forty-three homes were included in the residential study of code form submissions versus field audit findings. Unlike the commercial group, the residential group had only a few (9%) non-compliance issues directly related to energy code form documentation. The residential group had a total of fourteen different code compliance categories that were evaluated through on-site comparisons between the submitted code form and the built home.

The average characteristics of all houses were 1829 ft^2, single story, slab on grade with R-31 on ceilings under vented attics. All homes had CMU walls with average R-value of 4.7. Ninety percent of homes had central electric heat pumps with an average SEER of 14.1 and HSPF of 8.3. Eighty-four percent of homes had electric domestic hot water (DHW) with an average EF of 0.92. Average gas DHW EF was 0.66. The average claimed window U-value was 0.66 and SHGC was 0.44. Performance testing measured an average house airtightness of 5.6 air changes per hour at 50 pascals of pressure (ACH50). Fluorescent bulbs were found in 26% of illuminated areas.

Table 4 shows the total number of non-compliance counts for each of the fourteen evaluated categories of code. The percentage is calculated as the number of non-compliant counts divided by the total of forty-three buildings. Each individual building only has one possible count given per evaluated item. For instance, a particular home may have the incorrect wall R-value and incorrect wall type (two errors), but this would only have one count of non-compliance in the Wall Type category.

Table 4. Number and percentage of non-compliance items for forty-three residential buildings

	# Non-Comply	% Non-Comply		# Non-Comply	% Non-Comply
Correct Code Form	4	9.3	Ducts (Air Distribution)	8	18.6
Number Bedrooms	0	0.0	Cooling Systems	7	16.3
Conditioned Area [ft3]	3	7.0	Heating Systems	7	16.3
Windows	20	46.5	DHW Systems	15	34.9
Floor Type/R-Value	2	4.7	Credits	2	4.7
Wall Type/R-Value	12	27.9	Glass/Floor Area	12	27.9
Ceiling Type/R-Value	4	9.3	e-ratio (performance base)	3	9.7*

* percentage based on three non-compliance out of thirty-one homes evaluated

Figure 4 below shows the rates of non-compliance for the ten highest categories. The most common non-compliance was in the Windows category at a rate of 47%. Window non-compliance was related to window area, orientation or shading related errors. Window U value and SHGC labels are removed when the home is completed; however window performance data was available in about 3 houses. In those cases we confirmed that the installed performance data met or exceeded the claimed efficiency. Non-compliance could be counted based on performance rating if the claimed window performance was not plausible.

After windows, the next five highest rates of non-compliance occurred in domestic hot water heating (35%) where the claimed EF was higher than installed, glass/floor ratio (28%) where the ratio claimed was lower than installed, Walls (28%), Ducts (19%) and Cooling and Heating each having 19% non-compliance. The reason for wall non-compliance was usually related to over-stated R-value on code forms or significant wall area errors. Duct issues were typically related to wrong claimed location (indoor versus attic) or claiming much smaller duct surface area than installed. Non-compliance in cooling and heating was due to installation of lower efficiency equipment in half of the cases. Most of the time the SEER difference was about 1 SEER lower and HSPF about 0.3 lower. The other half of non-compliance in heating and cooling was noted for installation of significantly oversized equipment. Figure 5 illustrates the audited buildings that fell into bins of non-compliance.

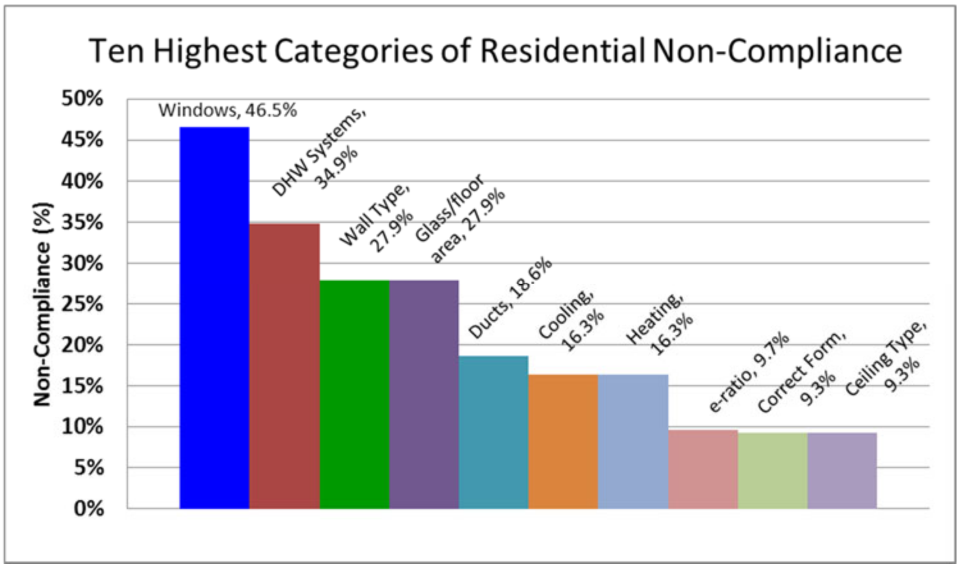

Figure 4. Top ten highest residential non-compliance categories.

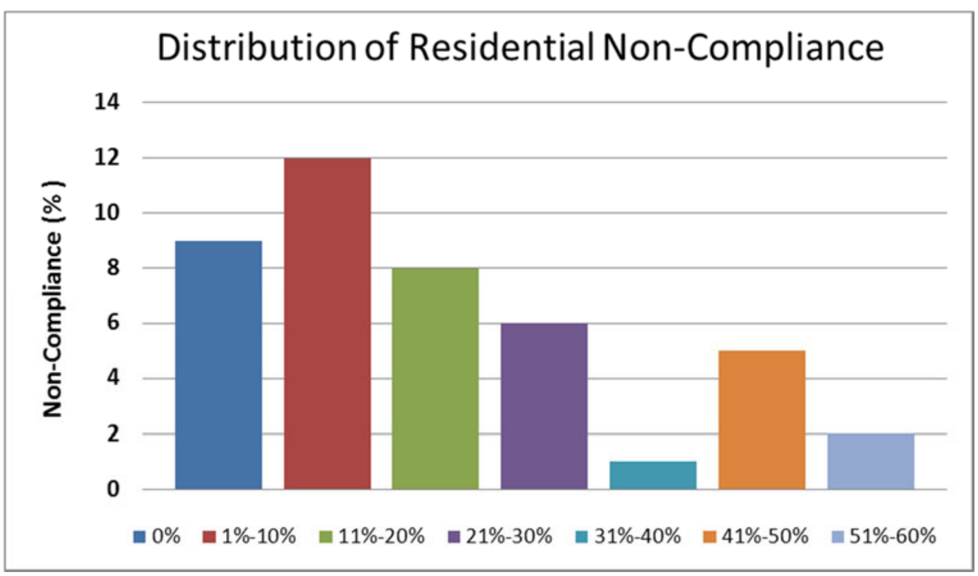

Figure 5. Frequency distribution plot for residential energy code compliance. The height of each bar represents the number of inspected buildings that had the binned value of non-compliance issues.

Code compliance based on performance method a. A comparison was made between the e-ratio on the as-submitted code forms and the site collected data (audited) in 31 homes. Recall that all the homes in the study had contractors that chose to comply with the energy code by the performance-based method instead of the prescriptive method. EnergyGauge USA is a State of Florida approved code compliance software program and was used to calculate the as-audited e-ratio. This is the same software that was used to calculate all submitted code forms and e-ratios. By this measure, 28 of the 31 homes met the calculated e-ratio for the energy code or a 90% state-wide compliance. The average submitted e-ratio (lower is better) 0.80 and the average audited e-ratio of 0.81 were nearly the same. While the averages are nearly the same, significant differences between the proposed and audited values were observed on a house by house basis. Three houses had audited e-ratios that exceeded the maximum passing limit of 0.85. The audited e-ratio was lower (more efficient) or the same in 52% of the homes. The remaining 48% had audited e-ratios greater than the submitted form claimed. Most of these homes still had audited e-ratios low enough to pass the code.

Most homes with several counts of forms not agreeing with the installed audited building components pass code based on the code e-ratio score limit for two primary reasons.

1. The proposed home was less than the required 0.85 e-ratio 87% of the time, thus giving some room to pass with some non-compliance. The item(s) not in compliance are often only significant enough to cause an increase of the e-ratio by a point or two. As an example consider that if the DHW EF of house 42 had an EF = 0.90 instead of 0.92, then the total house e-ratio would have been 0.79 instead of 0.78. Twenty-two of the thirty-one houses (71%) have e-ratios low enough to be able to pass with some relatively minor non-compliance items.
2. The second reason most homes pass e-ratio is due to over-compliance that occurs where more efficient features are installed in the home than the code form claimed. Houses with as-built e-ratios substantially lower than the as-submitted have resulted typically from greater efficiency heating and cooling equipment installed or more efficient envelope measures taken in the attic that were not in submitted code form. The more efficient attic measures have been R-38 attic insulation instead of R-30 and radiant barrier system installed that was not claimed on the code form.

Three audited home e-ratios were greater than the maximum limit of 0.85. The two highest audited e-ratios occurred in house # 70 and 29 due to a number of failures to build what was submitted (category non-compliance of 57% and 43% respectively). The third home with a failing e-ratio=0.91, house 81, failed primarily due to fairly high window to floor area ratio with windows having very poor window performance and orientation. It was found that 16 of the 31 homes had at least one or more items of over-compliance (installed component exceeded the efficiency of the submitted form) compared to items on the code forms. Many of these homes also had one or more components that under-complied compliance (installed component was less efficient than on the submitted form).

So the question arises, how much might non-enforcement impact residential energy? Data available from fourteen homes having only non-compliance and no over-compliance items was evaluated to help answer this question. Results from (Withers et al. 2012) suggests there may be an average increase in the built home e-ratio of 0.02 for every 5% of non-compliance in Florida. Actual impacts would of course vary on a case by case basis depending upon the severity of non-compliance. A home with only one non-compliance issue that had a central air conditioner installed with a SEER value one less than claimed on a code form would have a more significant increase in e-ratio than the same home having only one non-compliance issue of a DHW EF that is 0.02 lower than claimed

Improving Energy Code Compliance

The study has revealed that the State of Florida commercial energy code enforcement needs substantial improvement. First of all, building departments are often not verifying that the current energy code form is being submitted. Secondly, they are not verifying that they have the full form required for inspection. Third, they are not doing a detailed inspection to catch non-compliance. Our researchers were able to find one or more areas of non-compliance on almost every building. For commercial buildings with proper code documentation, the overall compliance of was 81%. There are three ways to improve the situation: statewide code changes, education and local changes.

Code changes. Commercial: It was obvious in this study that there is a high rate of missing or inadequate documentation. It is recommended that the first sheet of any statewide energy code form list exactly what documents are expected by the department for the submission. Since shell and full buildings may have different submission types, a different cover sheet is required for each. This will help both the applicant and the one receiving the permit application for the city or county. If possible such a cover sheet should list the number of pages expected in each submission.

Residential: The form submittal process seems to be working well here. There are still significant problems with differences between what is submitted and what gets built. Most of the issues are reasonably accessible on site and simply require more effort by inspectors. One issue, that is particularly difficult to verify and has significant impact on energy, is the claimed duct surface area. One possible way to deal with this is to take away the option of software entry for duct area and apply a default so that this cannot be a way to cheat in an area of difficult evaluation.

Education. Building officials need to be better trained on what to look for when inspecting a building for energy code compliance. They need to make sure they are taking the complete energy code form to the field and checking window area and orientation. They also need to know how to inspect for HVAC efficiency.

Building departments need to be educated about the commercial building energy code. Classes have been developed and are available from a number of vendors in Florida (Sonne, 2012). Other methods of educating could be in-person visits of thirty minutes that explain the key points and leave information (one page summary about the key findings of this study). Information sheets or posters that describe the required documents for both applicants and the officials could be developed and distributed. The state may want to consider a themed poster that could be done for energy and other codes that may have enforcement issues. Particular emphasis could be placed on inspection categories having the greatest impact on energy use such as space conditioning and plant efficiency as well as lighting and ventilation control in commercial buildings. Strongly emphasizing these as well as window compliance issues, which had the highest rate of non-compliance in both commercial and residential buildings, should allow Florida and other states to reach a compliance rate of 90% or better.

Local changes. The building inspector sent to the site with an incomplete form accepted at time of permit has little to inspect. The building department must make sure that the permit is not granted without the proper forms. Building inspectors need to take responsibility to finding code violations on the energy code. This study indicates the areas of most typical violations. Florida's commercial code is often met through improved equipment efficiencies so those parameters should be carefully examined.

Readily accessible efficiency data. Verification of HVAC or other efficiency data relies not only knowing what information to look for, but also where to go to find rated equipment or other product efficiencies. Many things are reasonably available online, but some things are more time consuming and require accessing manufacturers or other resources. Limited access or time consuming searches for efficiency data presents a significant barrier to effective code enforcement. Efforts should be developed at national, state and local levels to provide easy to access efficiency data particularly HVAC, lighting and thermal insulation barriers. One way to help code enforcement officials increase the enforcement rate, would be to require published efficiency data to be located on site.

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