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CONTRACT REPORT

Final Report of Task 8
ARRA: Energy Code Compliance and Effectiveness Measurement Project

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ARRA: Energy Code Compliance and Effectiveness Measurement

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EXECUTIVE SUMMARY

This report presents data on Florida energy code enforcement and makes recommendations for targeting areas to improve compliance.

This residential research study was focused on single-family, detached homes built to the 2007, with 2009 supplement, Florida energy code. Homes permitted after March 1, 2009 were selected by researching public records. A total of forty-three homes were audited and compared against energy code submissions. Non-compliance among the residential sample occurred most often in domestic hot water heating (37%), window (35%), and walls (30%), respectively. Cooling (21%) and heating (19%) efficiency followed in the order of occurrence.

While domestic hot water (DHW) leads the group in frequency, the actual impact on energy is likely modest since 81% (13/16) of the installed energy factors (EF) were within 0.02 of the claimed value. The reason for window non-compliance was related to window area/orientation errors. The reason for wall non-compliance was usually (62%) related to significant wall area errors, while the other 38% was related to overstated R-value on code forms. The primary cause, 67% of the time, for non-compliance in cooling and heating was due to installation of lower efficiency equipment. Usually, the seasonal energy efficiency ratio (SEER) difference was about 1 point lower, and the heating seasonal performance factor HSPF about 0.3 lower. Heating and cooling non-compliance was noted for installation of significantly oversized equipment in 33% of all homes in these categories.

Researchers studied the code enforcement of forty-four commercial buildings built to the 2007, with 2009 supplement, Florida energy code. Following a planned sample procedure, public records were used to select buildings permitted after March 1, 2009. Of the fifty buildings studied, 18 were small (≤ 25,000 ft^2), 18 medium (>25,000 ft^2 - ≤ 60,000 ft^2), and 14 large (>60,000 ft^2 - ≤ 250,000 ft^2), meeting or exceeding the U.S. Department of Energy (DOE) target sample sizes.

Twenty-two of the commercial building energy code forms were the incorrect code form, were missing input data reports necessary to inspect the building, or had incomplete data reports. One building had no energy code form. Two other buildings used an alternate compliance method that made checking inputs difficult. Of the twenty-six buildings inspected, certain differences between the submitted energy code and the inspected buildings were found. The most common difference was incorrect window orientation (84% of the 26 buildings inspected). Other areas of frequent violation are shown in Figure 1.

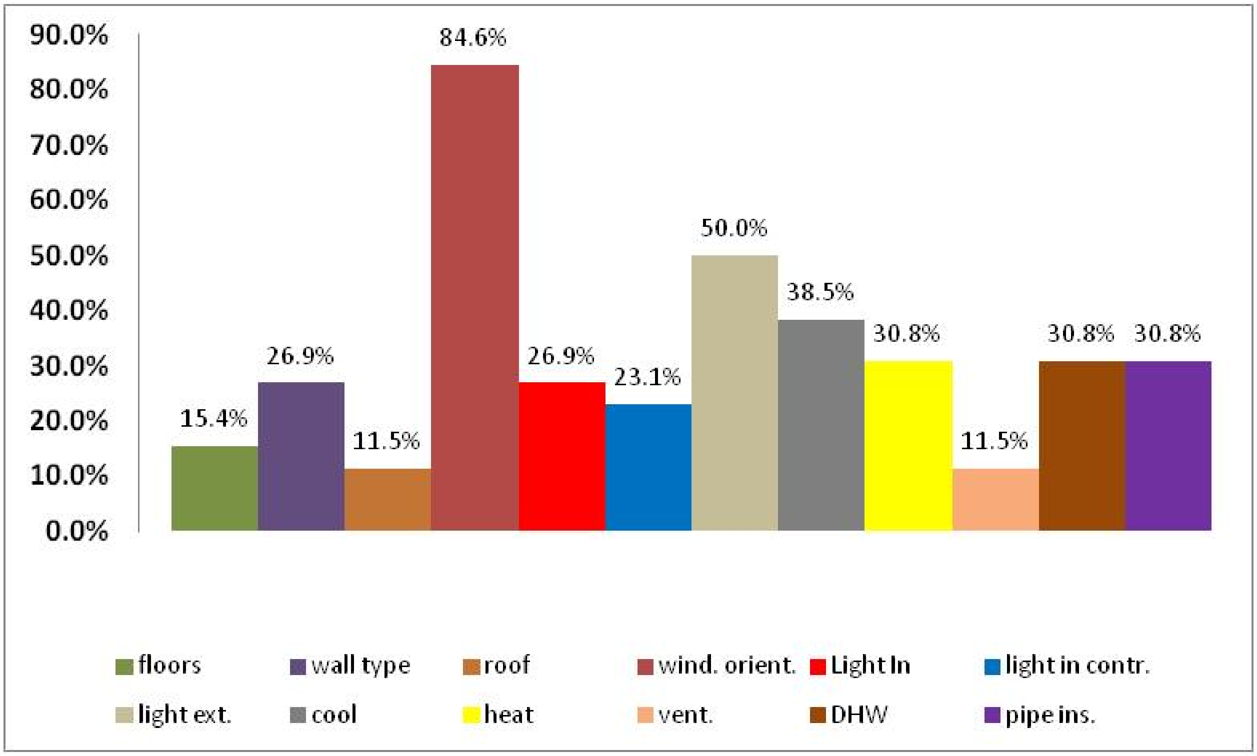


Figure 1. Frequency of code violations by category found in new commercial buildings

In light of this study, it is recommended that the Florida Building Commission, the DBPR, the Building Officials Association of Florida (BOAF), and training organizations provide simple, energy code compliance information regarding what should be collected at the time of building permit. This information should also include what should be checked in the field. Perhaps an informative poster located in building departments/permit application areas for applicants and officials would be beneficial.

I. INTRODUCTION

Current and future economic, environmental, and energy security challenges facing the United States make the goal of greater energy savings a major priority. Since buildings use roughly 40% of the nation's energy, activities related to building energy codes and standards represent a key factor for achieving energy savings and the corresponding benefits to our county.

In response to the Recovery Act, State Governors sent letters of assurance to the Secretary of Energy regarding energy codes . Based on the 2009 International Energy Conservation Code1 (2009 IECC) for residential buildings and the ANSI/ASHRAE/IESNA2 Standard 90.1–2007 (90.1-2007) for commercial buildings, or equivalent codes, a number of states have followed up on these letters by developing plans for measuring compliance with their codes. Some states are also developing plans to achieve 90% compliance with these target codes within eight years and for an annual measurement of the rate of compliance. To help support the endeavor of measuring code compliance, 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. As such, the BECP refers to the 2009 IECC and Standard 90.1-2007 as the "target codes" against which compliance is measured (DOE, 2010).

A. Department Of Energy Code Evaluation Approaches

1. Approaches

A 2010 report by the DOE's Building Technology Program list the following evaluation approaches to be considered when evaluating energy code compliance.

a. ***Building department***. The state or local building regulatory agency verifies compliance on a regular basis through plan review and inspection. This could be viewed as another form of self-certification because the building department staff would be gathering data that would be used to assess their own work associated with building plan review and inspection.

b. ***Public sector third-party agency***. A state agency, commission, or other official arm of state government without direct responsibility for code compliance verifies compliance. This process is done in some states where a state agency is responsible for oversight of local government enforcement of a state building or fire code. The state agency can accredit local government agencies, which would not have a vested interest in the outcome, to enforce the state code.

c. ***Private sector third-party entities***. Anyone who does not have a vested interest in the outcome of a compliance evaluation and is not a public sector agency would be classified as a private sector third-party entity. These can include any number of individuals and entities such as Home Energy Raters (HERS), energy service providers (utilities), architects, engineers, contractors, builders, code officials and others. If third-party evaluators are paid by the entity being evaluated, appropriate measures should be in place to ensure their objectivity. In all instances these third party evaluators should have the proper qualifications to conduct the required work.

It is important for a state to choose a defensible and objective evaluation approach that fits its capabilities and works within or in concert with its current building regulatory programs and funding mechanisms (DOE, 2010).

2. Assessment Methods: Commercial & Residential Buildings

Referencing BECP's "Measuring State Energy Code Compliance" report, it summarizes code compliance assessment methods for both commercial and residential buildings. By in large, BECP recommends a prescriptive approach to both the commercial and residential compliance assessments assuming prescriptive codes. In Florida contractors have chosen to use performance criteria, not prescriptive. The DOE approach to selecting buildings uses a random sample generator using building start data to come up with a statewide sample of 44 buildings for the type (new residential, new commercial, existing residential, existing commercial) desired. Due to resource limitations, only new buildings were included in this study.

3. Assessing Level of Compliance

Once the buildings samples have been obtained the next step is evaluation. The BECP proposed two approaches be considered to generate an effective building metric while evaluating compliance with building energy codes and are as follows:

Method 1 - Evaluated buildings either pass or fail the energy code evaluation, and the percentage of buildings within the state that are deemed to comply is reported. For example, if 90% of the buildings sampled in the state receive a passing score, the reported metric is 90%.

Method 2 - Evaluated buildings are each assigned a compliance rating of 0–100% based on the proportion of code requirements that each has met, and the evaluated buildings' scores within a state are averaged to derive an overall compliance metric with an associated confidence.

According to BECP, the idea that the adoption of more energy efficient codes is only effective if those codes are implemented and buildings are compliant with those codes offers us an opportunity to:

1. Understand the actual compliance rates in states, resulting in a better estimation of potential energy savings through greater compliance and better return on investments made to increase compliance.
2. Improve the rate of compliance through training and process improvements, thus increasing the effectiveness of more efficient codes to reduce energy use.
3. Understand where selected energy code criteria may need revision or enhancement to improve implementation and enforcement.

In pursuing the above opportunities, the BECP has also considered the following additional goals for assisting states in these endeavors:

- Make sure compliance efforts are objective and consistently applied
- Provide guidelines that are appropriate to all states, understanding that states differ in the maturity of the code adoption and enforcement practices at the state and local level
- Consider the logistics and manpower issues that states will be attempting to address
- Provide an opportunity to consolidate results into regional and national metrics
- Collect additional data that can be used in furthering the effort to measure and understand code compliance issues, to increase compliance rates, and to strengthen future energy codes and standards

BECP concluded after evaluating both of the measurement methods against these criteria, that Method 2 is more supportive of the above objectives than is Method 1. Therefore, BECP is recommending Method 2 as the official metric to be used by states (DOE, 2010).

B. Code Compliance Efforts in Other States

A Pilot study were conducted in 2010 throughout the U.S. (Figure 2) with a focus on measuring state energy code compliance using BECP guidelines and tools and were implemented over a 10-month period, ending June 2011. Four building populations were evaluated; New residential; New commercial; Residential renovations; and Commercial renovations.

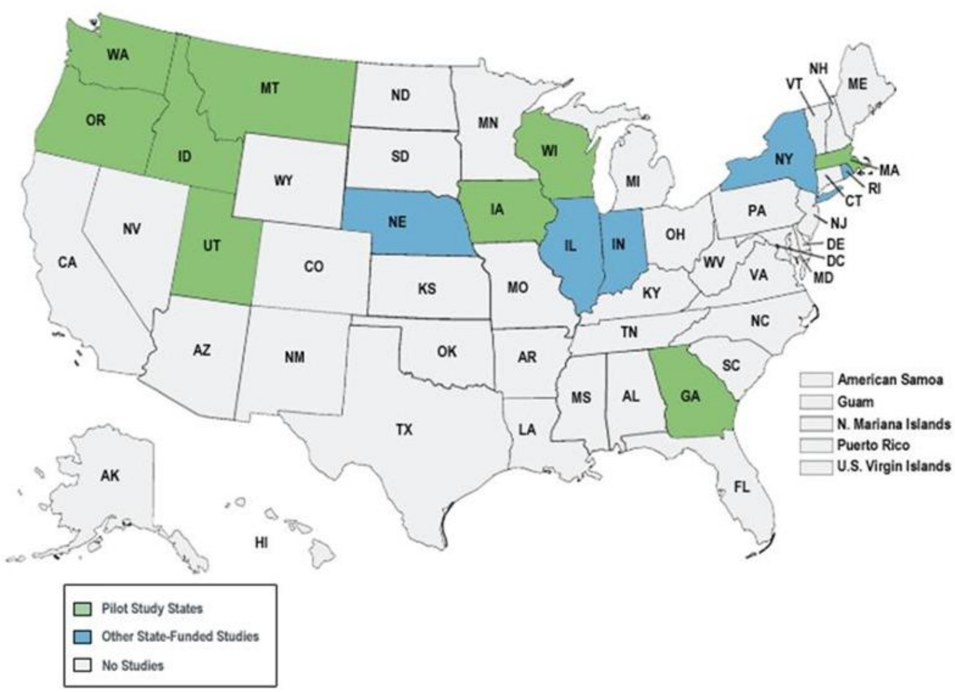


Figure 2. 2010 BECP Pilot study (picture courtesy of DOE)

Some of the States involved in the pilot and their area of study focus are listed below:

- Iowa: 44 new residential buildings
- Georgia: 44 new commercial buildings
- Massachusetts: 44 new residential buildings
- Utah: 44 new residential buildings
- Wisconsin: 44 commercial buildings
- Montana: 30 new residential buildings inside jurisdictions where building officials enforce the code, and 30 new residential buildings inside jurisdictions where builders self-certify
- Northwest States (Montana, Idaho, Washington, and Oregon)

The pilot studies were intended to help states in their compliance efforts, while at the same time providing insight into the effectiveness of the BECP guidelines and tools and suggestions for their improvement. The pilot studies were to also provide a better understanding by states of: (1) Their compliance rates; (2) Where training might be appropriately focused; (3) Needs of their jurisdictions; (4) What those jurisdictions consider most common impediments to compliance; (5) Identification of common code compliance issues; (6) Where to focus training and compliance efforts; and (7) Potential issues with the code itself (e.g. NFRC labels on commercial buildings) (DOE, July 28, 2011).

States involved in the pilot study took various approaches as clearly shown between Utah, Wisconsin, and Georgia.

1. Utah

a. Evaluated new residential construction against the 2006 IECC rather than their current code or target code (2009 IECC for residential)
b. Included a jurisdictional survey as part of their study
c. Used BECP's Store+Score Tool (averaged 30 minutes to enter data per home)
d. Four hours on average to address each home (scheduling, travel, plan review, onsite assessment, reporting)

2. Wisconsin

a. Commercial buildings fall under State jurisdiction and used state staff to perform compliance study for the 2009 IECC and ASHRAE 90.1-2007 codes

3. Georgia

a. Began with 2-day kickoff meeting with stakeholders (i.e. state officials, building officials, local business, etc.)
b. Included a jurisdictional survey as part of their study
c. Conducted plan reviews (avg. 85 minutes) in building officials' offices & scheduled project visits/evaluations (avg. 50 minutes) with building officials assistance during their daily inspections
d. Completed building data collection checklist (PNNL) then uploaded to PNNL

Despite preference of conducting third-party enforcement evaluation, some states did not really check on the level of enforcement, having gone side-by-side with the building inspector.

C. History of Florida Energy Code Compliance

In 1978, the State Energy Office under the Department of Administration issued Florida's first statewide building Energy Code. Modeled after ASHRAE Standard 90-75, this code became effective in 1979 and from that point forward, Florida has successfully managed a statewide residential Energy Code, which consistently receives high marks in U.S. Department of Energy national code studies.

A 2009 modeling study (Fairey, 2009) was commissioned by the Florida Department of Community Affair's Codes & Standards Section to determine the impacts of Florida's Energy Code over time and recommend possible changes that would increase residential efficiency. It examines each of the 15 residential Energy Code cycles that have occurred during the 30 year period and determines the relative change in Energy Code stringency and its impact on energy use and energy cost throughout the period. The study was recently revised to include Florida's 2009 supplement to its 2007 Energy Code.

EnergyGauge USA, Florida's current compliance software, was used to compare the changing levels over time. These results were combined with Florida's historical energy cost data and new home construction data to determine statewide energy use and cost changes across each Energy Code cycle and across all years since 1979. The change in median home size over the 30-year period is also considered by the analysis.

The major findings of the study were:

- Florida has had considerable success using its Energy Code since 1979, increasing efficiency requirements by more than 65% and cumulatively saving Floridians more than 39 billion kWh of electricity – enough to power more than 3 million new Florida homes for a year. The cost savings have also been significant, estimated at almost $4.7 billion, cumulatively. Compared to the 1979 Energy Code, the estimated 67,000 new homes estimated to be built during 2009 will produce annual cost savings of more than $126 million per year.

- Florida's 2009 Energy Code will likely result in new homes that are about 17% more efficient than homes built to the standards of the 2006 IECC and about 3% less efficient than the 2009 IECC, which was just promulgated.

- "Other" residential energy uses, which have not been considered by Florida's Energy Code, constituted 28% of total home energy use in 1979. In 2009, the share of these "other" home energy uses has increased significantly to more than 55% of the total home energy use.

- Home sizes have consistently increased over time, from a median of 1736 ft2 in 1979 to a median of 2344 ft2 in 2009, taking back about 20% of the whole-home energy savings that would have been otherwise achieved.

The Fairey study does not evaluate compliance with the code. However, Florida Power and Light (FPL, 1995) studied homes built to the 1991 energy code in conducting its research for the BuildSmart program. It found that energy code submissions were usually submitted at a level that just passed code. Some audited homes tended to be built better than the code submission while 23% of audited homes were not in full compliance. FPL found that while 13% of the Central Florida homes were not in compliance, 28% of South Florida homes were not in compliance. FPL concluded, “For those homes that were not in compliance, the Code was exceeded by 5%.”

FPL’s comparison of code baseline energy use with its metered data and the performance of certain efficiency measures led to some changes in Florida’s energy code. For example, instead of assuming ducts to be fully sealed, the code now assumes leaky ducts unless tested to be airtight. Water heating loads were shown to be largely overestimated and were revised, and the credit for heat recovery units and ceiling fans were reduced. Light colored roofs were shown to be a significant energy saver and were provided credit in recent code editions.

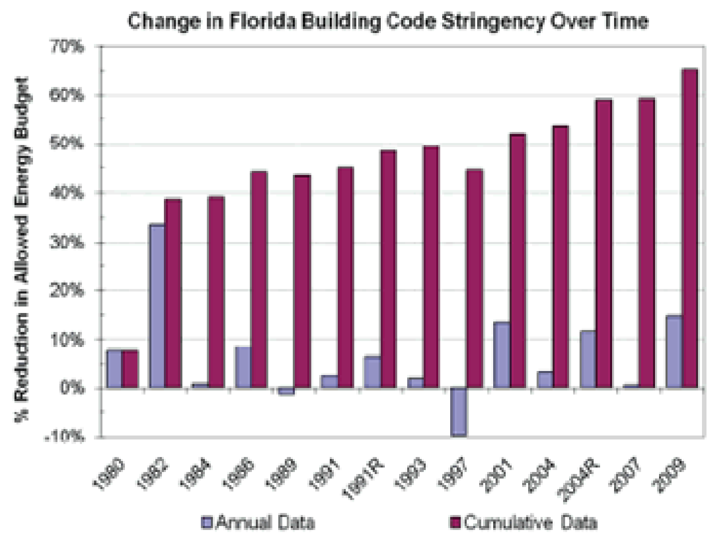


Figure 3. Florida Energy Code Stringency Levels 1979 -2009 (Fairey, 2009)

The study also showed that many items given credit in the code showed up statistically significant to reducing energy use:

- High SEER equipment
- Reduced glass area
- Additional ceiling insulation
- Wood frame wall construction (higher R-value than block)
- Attic radiant barriers
- Heat pump versus electric resistance heat
- Heat recovery units
- Solar water heating systems.

FPL also recommended revising the heating baseline as their data tended to show less heating than projected by the code. The most recent code software (March 2009 effective code date) uses recently developed TMY3 meteorological data that represents 1970 -2000 weather data as opposed to the older TMY and TMY2 data used to derive earlier code multipliers. For most Florida cities, the newer data represent a warming trend with warmer winter temperatures which should predict less heating consistent with the FPL study.

II. COMMERCIAL ENERGY CODE ENFORCEMENT RESEARCH

A. Research Approach

The following process was used by the Florida Solar Energy Center's (FSEC) staff to undertake the commercial aspect of the study.

1. Random Selection process

To randomly choose the buildings' location, size, and number of specific buildings in a location FSEC used the DOE sample generator which provided the following sample distribution.

Table 1. State Sample Commercial Generator results

Location	Construction Starts	Sample Size Small	Sample Size Medium	Sample Size Large
Climate Zone 1	229	2	3	5
Broward County	82	1	2	1
Miami-Dade County	143	1	1	4
Climate Zone 2	1422	13	12	9
Bay County	37	-	1	-
Brevard County	54	1	-	2
Duval County	94	1	2	2
Escambia County	26	-	1	-
Holmes County	1	1	-	-
Lake County	38	-	1	-
Lee County	58	-	1	-
Manatee County	33	1	-	-
Marion County	40	-	-	1
Martin County	15	-	-	1
Okaloosa County	27	1	-	-
Orange County	140	4	2	2
Palm Beach County	105	1	-	-
Pinellas County	52	1	-	-
Polk County	54	-	-	1
Sarasota County	37	-	2	-
Seminole County	35	1	-	-
Volusia County	56	1	1	-
Walton County	11	-	1	-
State Total	**1651**	**15**	**15**	**14**

A procedure was established by FSEC to select potential study buildings in a systematic method. The method involved the following steps:

a. Identify 3 permits for each specific building type (small, medium, or large based on target) needed for the study.
b. Search county and then larger city code records within counties.
c. Start with March 2011 permits.
   1) If not enough buildings identified, go to February 2011 permits.
   2) If still not enough buildings identified, go to January 2011 permits.
   3) Continue search to previous month as needed or until reach April 1, 2009 date
d. If above 3 steps fail to produce a suitable study building, search begins anew in a similar county.

2. Obtaining Energy Code Forms

The process and steps to track down targeted commercial buildings to audit involved the following steps:

a. Permit Search
   1) The first step is finding the appropriate building/code department that contained historic permit records.

   2) Once the correct department was found, the ability to do an online permit search was investigated. If an online permit search feature did indeed exist, the next step was to ascertain if the system is suitable to handle our search criteria and methodology (this basically involved knowing the permit date and the size of the building). Even if a search feature existed, often an address or permit number was needed to do a search for the specific building and that information was often not available from public online searches Further, many permit files were found not to be organized by type of work (e.g. new construction, renovations, etc.) which meant that even small work irrelevant to this project, such as simple electric or plumbing renovation, were included with new construction projects. And if new construction permits were found, often times they included both commercial and residential buildings. Nevertheless, having a permit search feature still led to much time spent mining for targeted buildings due to all the particulars of how the online search system is set up.

   If initial permit building information was not available to search online or was not capable of the type of search needed, then the building department was contacted directly via phone and/or email to request help/search of their permit records. It is interesting to note that not all building departments had the capability/staff/other to assist the researchers in the permit search. Persistent effort and speaking to many different people was often necessary to obtain the assistance needed. Since our process starts with a date and size as opposed to an address and permit number, our request was no typical of what they received. However, some building departments were very helpful while others seemed to be befuddled as to how to obtain the information.

3) Once one or more eligible permits were found researchers requested the Florida Energy Efficiency code forms for the associated building permits.

b. Energy Code Forms request
   1) The requests were made through the building or other department.
   2) Once Energy Code Forms were received they are reviewed for (i) Current version based on code period permit was issued and (ii) Completeness. If form was correct the next step was to seek permission to access building. Because almost all Florida contractors choose to use the performance path, the forms are necessary for determining on-site compliance

3. Building Access/Scheduling
The steps to schedule an on-site audit included the following:

a. A letter was drafted to explain the scope and details of the study to be offered to targeted buildings (i.e. owners, tenants).
b. Based on the methodology of searching for buildings starting with permits issued beginning with March 2011 many of the buildings audited in the study were either completed and occupied or very near to completion.
c. Building access was given largely based on "cold-calling" to find the decision maker who could grant access. Sometimes access was denied. In those cases the next building obtained through the process was tried.
d. Set up and coordinated schedule with building staff and field staff.

4. Commercial Code Compliance Audit Method
Commercial energy code compliance was evaluated by focusing on the primary items evaluated on code form 400A-2008. The broad range of items reviewed were:

- Reasonable representation of floor areas and space use classification
- Interior and exterior lighting power density and controls
- HVAC efficiency and controls
- Heating and cooling distribution efficiency
- Piping insulation
- Reasonable representation of envelope type, areas and orientation
- R value of floors, walls, and roof
- Window qualities
- DHW efficiency

The general method of evaluation of each item is discussed in more detail below. As with any building inspection, portions of this methodology rely on subjective evaluations. Field inspectors were provided this same methodology to promote uniformity in the evaluations completed by different evaluators. The final determination of compliance rested with project management.

1) Conditioned floor area (ft2)
This is the total of all conditioned areas in the building. Floor area on code form should be no more than 5% greater than the built building.

2) Space Classification
The type of classification should be a reasonable representation. Non-compliance should be noted if the total of all areas having a classification substantially different than as found that represent more than 25% of the entire floor space.

Energy code rules specify limits to qualities such as lighting power or ventilation requirements per square foot of space. Space classification also establishes the qualities of the baseline building during code compliance simulation.

3) Floor Construction
The type of floor and the R value of floor are considered in this evaluation. Most of new Florida commercial construction is slab on grade that usually does not have any added R value. Floor types may also be upper story floors over unconditioned garage or cantilevered over outside space as well as raised floor over crawl space.

4) Wall Type
The type of construction is considered as well as the general accuracy of the areas and orientations. The type of construction described on the code form should be reasonably close to the as-built structure. The areas representing various orientations should also be within 25% compared to the as-built. The absolute total area of all walls was not evaluated as a compliance factor.

5) Wall R Value
Since observation of insulation inside enclosed wall assemblies would require damage to finished wall surfaces, it is not evaluated by visual observation. The code form wall R-value is assumed correct unless site measurements show the R-value claimed is not plausible. The built wall insulation is estimated based on construction type and measured wall thickness. After subtracting the construction material from the total dimension, the space available for insulation can be known. Often Florida commercial exterior wall construction is eight inch concrete block or pre-cast solid concrete. Consider the following example where a block wall was measured from interior finish surface to exterior stucco finish surface. If the construction material (interior gypsum board, concrete block and exterior stucco) add up to 9-3/8 inches and the measured wall thickness is 10 inches thick there is 5/8 inch space for insulation. Foil-faced Polyisocyanurate that is 5/8 inches thick can provide an R-value of 4.1.

6) Roofs
The type of roof and R value of insulation claimed is the primary criteria for determining compliance. The type of roof or construct should be reasonably close to the actual built roof. Ceiling space inspections are completed to look for insulation that may be applied to the under deck or elsewhere. Often roof insulation is enclosed within the roof assembly and cannot be

directly evaluated. When possible, the thickness of the roof assembly will be measured and the plausibility of the claimed R value considered. The procedure is the same as described for walls.

Non-compliance will also be noted where: insulation is not at least R10 at roof, the intended thermal barrier is located on top of suspended ceiling tiles, and ceiling cavity used as air plenum does not have at least R19 at roof deck.

7) Window Performance

The primary window performance data inputs are the U-value and the solar heat gain coefficient (SHGC), which are applied to a NFRC label on each window. This can also be looked up on NFRC website if the manufacturer and model number are known. However, the actual performance data is typically not available by the time the audit begins and windows do not have a model # that can be seen on each unit. When actual window performance data is not available, the code form values will be assumed as long as the values claimed are reasonable. Consider an example, where the audit finds windows that are double pane tinted glass with metal frame, then a form that claims U=0.6 and SHGC of 0.33 is considered plausible.

8) Window Orientation

Non-compliance is noted where the orientation is significantly different. The total area of glass is summed for each orientation. Non-compliance is noted if it is clear any window/glass assembly was not included on the code form or the difference in total window area for any orientation exceeds 10%.

9) Window Shade

Non-compliance is noted if shading input is listed yes for windows that do not have qualified shading. Shading must come from a permanent part of the building structure such as a roof overhang or covered entry. A fabric awning is an example of a shading device that does not qualify as window shade in the code.

10) Interior Lighting Power

Commercial lighting differentiates between interior and exterior lighting. These are evaluated separately. Building lighting power compliance considers lighting power density (LPD) (watts / ft^2).

Lighting power density is established for each specified type of space in the building. A lighting type is specified along with watts per fixture and total number of fixtures in the space. Then a total is determined for each space during the code calculation. Building lighting compliance is evaluated on a budget method that considers the balance of the whole building. This means that some "tradable" spaces may exceed the limit established, but can still comply if other "tradable" spaces are under enough to compensate for the other space overages. Some spaces specified on code forms are very generically specified and difficult to determine where they start and stop in the built building. Since the building lighting density passes or fails based on the whole building, all interior lighting watts of the as-built building is summed and divided by the representative floor area (ft2). The same is completed on the code form where the total of all interior light watts is divided by floor area. If the code form W/ft2 is equal to or greater than the built building, it is in compliance. The same exercise is repeated for exterior lighting.

In cases where site evaluators are not able to access portions of a building, the lighting power density will only be based on the areas accessed. Non-compliance will be noted if the site evaluation LPD exceeds code form by more than 20%. This amount is chosen because ballast factors of lighting fixtures alone can result in about 15%-20% difference in lighting power for fluorescent lamp systems. The evaluators are asked to look at a sample of ballasts where it does not cause interference to the business. Therefore assumptions on ballast factors must be made when estimating the wattage for each type of fixture.

11) Interior Lighting Control

Commercial lighting control is evaluated based upon the number and type of lighting controls. Energy credit can also be obtained by using certain types of lighting limiting controls such as timer based, photo sensor and occupancy sensors. Presence of the claimed type of lighting controls is verified during the building evaluation. Automatic control is required for applicable portions of interior lighting in buildings > 5,000 ft^2.

12) Exterior Lighting Power

Exterior commercial LPD is evaluated similar to interior LPD. Lighting power density is established for all applicable exterior lighting. Non-compliance is noted if the installed exterior lighting exceeds that claimed on the code form.

13) Exterior Lighting Control

Exterior commercial lighting control is evaluated based on type of control claimed. Non-compliance is noted if the installed exterior lighting has a less-efficient control than claimed on form or if a photosensor or astronomical time control is not present for building > 5,000 ft^2.

14) Duct Thermal Efficiency

Duct thermal efficiency compliance is primarily evaluated based on correct R value and location of supply and return ducts. The quality of installation is also considered.

The field audit includes inspection of representative areas of ducts and evaluates the location of ducts and the R value.

15) Air Distribution

Duct thermal efficiency compliance is primarily evaluated based on if the ducts are mechanically fastened well, if there is any observable air leakage and reasonable layout and installation of the ducts. Visible signs of leakage would be obvious holes, tares, or open seams at duct connections. Metal tape may be used to seal connections and seams provided the UL 181 marking is on the tape. Mastic applied to seals should overlap seams by about 1 inch or more and be applied thick enough that open cracks have not developed. Poor mechanical integrity could be observed as ducts not supported every six feet, inadequate support causing support to cut into the duct or "choking" of duct. Other signs of poor mechanical integrity would be where part of a duct assembly is pulling or trying to pull away seen as substantial bulging or sagging of duct material.

A poor quality of layout could be observed as flex duct runs using much more duct than actually needed or kinked ducts resulting from very sharp abrupt turns.

16) Cooling systems

The primary item evaluated under cooling systems is the cooling efficiency based on the energy efficiency ratio (EER), seasonal energy efficiency ratio (SEER), or integrated part load value (IPLV). The model information of the outside and inside unit is collected on site and the data used to look up the rated efficiency. The rated efficiency is first researched using published source such as AHRI. Most data is found under AHRI, however, if the unit is not listed there, other industry published data is used as a last resort. The amount of cooling credit allowed during the code compliance simulation depends upon the capacity of the systems. The cooling capacity should also be compared between the code form and built building. Grossly oversized equipment would also be noted as non-compliance.

17) Heating systems

Heating system code compliance is evaluated by the efficiency. Heating efficiency can be rated by the heating seasonal performance factor (HSPF) for heat pumps, the coefficient of performance (COP) for electric resistance heat, and Gas fuel based system efficiency is known as annual fuel utilization efficiency (AFUE). The same sources noted in the preceding cooling systems section are used to verify efficiency.

18) Ventilation controls

Ventilation control compliance is determined by verification of a mechanical means of closing the outside air intake by either a motorized damper or gravity damper. The gravity damper is acceptable for use with 1) exhaust systems and 2) systems with design outside air intake or exhaust capacity less than or equal to 300 cubic feet per minute. This may not be able to be evaluated in some buildings since the presence of damper(s) can be difficult to find or access. Effort is generally best used by locating the outside air duct and looking for mechanical linkage on the outside of this duct. If the outside air comes in through an intake on a roof top package system, look into the intake for a damper. The view may be blocked by a screen or filter. In cases where the presence and type of ventilation control cannot be determined, the code form input will be assumed.

19) Hot water systems

Electric and gas hot water system energy compliance are evaluated by the efficiency factor (EF). If the hot water tank is connected to a circulated system, then insulation should be around the first 8 feet of outlet pipe from the storage tank and also between the inlet pipe and heat trap.

The DHW system manufacturer, make and model number data should be taken from the name plate so that the efficiency rating can be looked up using AHRI. It should be noted if the tank is electric, or gas fired. If it is gas fired, note whether it is atmospherically or forced fan drafted. The inspection should also look for insulation around the tank and pipes.

20) Piping Insulation
Type and thickness of insulation on cold and hot water pipe lines are noted and compared to code form. The quality of installation should also be determined. Poor quality installation will have significant gaps, tares or compression of the insulation layer and will result in non-compliance evaluation. Code specifies limits on when insulation is required and the thickness based on fluid temperature and pipe size. Generally, it is required on plant circulation lines, or other hot water lines distributing fluid greater than 105 degrees. The thickness of insulation varies depending on the temperature range and pipe diameter.

21) Joints/Cracks
The exterior envelope should have sealed seams and penetrations. The evaluation should look for the presence of caulking, gaskets or other suitable weather stripping on or around seams and penetrations. The quality should be suitable to block wind driven rain from penetrating the exterior side of the envelope.

22) Plant
Very large heating and cooling requirements may use a central plant such as a chilled water plant for cooling or central boiler for heating. The type of plant, model number and any other available information is to be gathered so that the chiller and boiler efficiency can be determined.

23) Other Compliance
This category is to cover other specialty items noted on page 8 of code form "checklist" as needed. This category covers items that are not as common across the wide range of building size and types such as limits on pool equipment or special exhausts or make-up air units.

B. State Commercial Sample Set

Contact inquiries were made in all twenty-one counties specified by the DOE sample set along with additional municipalities within the counties as needed based on research methodology. Contacts and effort was put forth in additional counties and municipalities outside the DOE sample set as needed due to (1) buildings not existing in county or (2) inability to ascertain building information or assistance from building departments/other departments within a specified county. As such other locations and samples not included in the original DOE sample set (Table 1) are listed in Table 2 (shown in "*italicized*"). Table 2 includes the final sample distribution of the study. In total, over one hundred commercial energy code forms were acquired throughout the state.

Table 2. Commercial building final distribution set

	Small	***Medium***	***Large***		
Counties	**0-25,000 ft²**	**25,001-60,000 ft²**	**60,001-250,000 ft²**	**Target**	**Completed**
Totals (DOE Target based on Climate Zone totals)	15	15	14	44	-
Climate Zone 1	2	3	5	10	3
Broward County	2	0	0	4	2
Miami-dade County	1	0	0	6	1
Climate Zone 2	13	12	9	34	47
Bay County *(Santa Rosa)*	-	0	-	1	0
Brevard County	2	*1*	1	3	4
Duval County	1	2	4	5	7
Escambia County	-	1	-	1	1
Holmes County *(Okaloosa)*	0	-	-	1	0
Lake County	*1*	1	-	1	2
Lee County	-	1	-	1	1
Manatee County	1	-	-	1	1
Marion County	-	-	1	1	1
Martin County (*St. Lucie - Port St. Lucie)*	-	-	0	1	0
Okaloosa County	2	-	-	1	2
Orange County	4	2	0	8	6
Palm Beach County	1	*3*	*3*	1	7
Pinellas County	1	-	*1*	1	2
Polk County	-	*1*	1	1	2
Sarasota County	-	2	-	2	2
Seminole County	1	*1*	*1*	1	3
Volusia County	1	1	-	2	2
Walton County *(Leon)*	-	0	-	1	0
Counties Used as Substitutes					
Santa Rosa County		*1*		0	1
St. Lucie-Port St. Lucie			*1*	0	1
Leon County		*1*		0	1
Hillsborough County			*1*	0	1
Totals (Completed)	**18**	**18**	**14**	**-**	**50**

C. Code Compliance Assessments

1. Submittal Enforcement Issues

In the process of obtaining (or trying to obtain) the energy code forms a number of non-compliance issues were discovered directly related to energy code form documentation or lack there-of which "fell" into six categories and a total of twenty-four code forms:

(1) Missing Input Data Reports (29.2%);
(2) Incomplete Input Data Reports (8.3%);
(3) Old Code Forms utilized post permit issue date of March 1, 2009 (37.5%);
(4) Old Code Forms that also included Incomplete Input Data Reports (12.5%);
(5) No Code Forms (4.2%); and
(6) Code Form substitution with other documentation (8.3%)

In each and every occurrence of the documentation issues stated above, researchers contacted the specific county or municipality where the documentation was sourced from and received confirmation the specified issue was indeed "correct". The twenty-four occurrences of documentation issues were recorded by researchers during the course of the study, a summary of which is shown in Table 3.

A total of twenty-six commercial buildings were audited and evaluated for code compliance. Most of the audits occurred in small and medium buildings as large buildings were more difficult to find and if found, difficult still to be granted access – particularly if occupied. Some examples for denial of building access occurred due to security and privacy issues (e.g. banks), in the case of a building being part of a national "chain", permission had to be granted through the corporate office which most often was located outside the state and led to a "disconnect" being involved in the study, or simply no interest in participating in the research study for various reasons. Of the 26 buildings inspected, 11 (42%) were Small ($\leq$ 25,000 ft^2), 10 (39%) were Medium (>25,000 ft^2 - $\leq$ 60,000 ft^2), and 5 (19%) were Large (> 60,000 ft^2 - $\leq$ 250,000 ft^2) as shown in Table 3.

Table 3. Summary of 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***	-

There may be a slight bias in the total number of permit issues found versus the total number. We only counted audited buildings that we were able to inspect. That required permission of the owner or occupant. If permission was not granted, research staff moved on to the next building found in the process outlined earlier. However, if the code form was not compliant by one of the reasons shown in Table 3, that building was automatically counted as non-compliant for that location. No further steps or permissions were required. As such, applying a 44% (22 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 22 out of 97 or 22.7% based on our data collection. Nevertheless, the study clearly shows there are significant energy code collection issues at time of permit.

2. Level of Compliance

To determine level of compliance of the audited buildings, the inspected items were evaluated as either insignificant differences, or a difference on the performance code form that would have benefited the ability to pass the code relative to what was found installed. Each of these areas was then equally weighted to determine a percent compliance/accurate for each building.

The fact that some submitted code forms have exaggerated energy features does not necessarily mean they would have failed the code had they been submitted with the correction. Since the buildings typically complied with a performance method, the buildings in some cases may have sufficiently exceeded the code to supply some “cushion” to allow for such differences. Also, at times as-built features were found that exceeded the code submission efficiency level. Recreating commercial energy code submissions from the forms and audit data was beyond the scope of the project.

3. On-Site Enforcement Issues

Table 4 shows the discrepancy areas for each building along with the percentage compliance by building and by category. The latter is particularly significant for learning where problems exist in enforcement. The most common difference was incorrect window orientation (approximately 85% of the 26 buildings inspected). Boxes highlighted in blue represent non-compliant items in 26 commercial buildings audited. Specific item being audited are listed in left most column. Next to last column on right shows total non-compliance items found for specific building items (i.e. Window orientation, DHW systems, etc.) while the last column shows these total items as a percentage. Thus the average non-compliance is 19.2%. The overall distribution of discrepancy categories is illustrated in Figure 4.

Figure 5 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 22 buildings had some non-compliance issues at permit time, there are significant enforcement issues both during permitting and inspection.

Table 4. Inspection vs. Code Submittal Discrepancies for Each Audited Building

	1C	2C	3C	4C	5C	6C	7C	8C	9C	10C	11C	12C	13C	14C	15C	16C	17C	18C	19C	20C	21C	22C	23C	24C	25C	26C	**Total**	**%**
Conditioned Area [ft²]																	■										1	3.8
Space Classification	■					■																					2	7.7
Floors				■	■								■							■							4	15
Wall Type				■	■	■	■										■				■	■					7	27
Wall R value	■					■																					2	7.7
Roofs				■			■					■															3	12
Window Performance																											0	0
Window orientation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■				■	22	85
Window Shade																											0	0
Light Power Indoor					■	■		■									■	■			■	■					7	27
Light Int Controls								■	■	■	■	■							■								6	23
Light Power Exterior			■	■	■					■	■	■	■	■				■	■		■	■	■				13	50
Light Ext Controls																											0	0
Duct Eff. Thermal																											0	0
Distribution																											0	0
Cooling Systems			■	■	■	■						■					■	■	■			■	■				10	39
Heating Systems					■		■	■									■	■	■		■	■					8	31
Ventilation Control	■	■	■																								3	12
DHW systems	■			■		■							■			■					■	■		■			8	31
Piping Insulation	■		■	■					■		■	■									■	■					8	31
Joints/Cracks																											0	0
Plant					■				■																		2	7.7
Other Compliance				■						■																	2	7.7
Percent Non-Compliance	28.6	9.5	23.8	40.9	36.4	33.3	19.0	15.0	19.0	19.0	19.0	28.6	18.2	9.1	4.5	4.5	28.6	23.8	23.8	9.1	33.3	38.1	4.8	4.8	0.0	5.6	**Ave:**	**19.2**

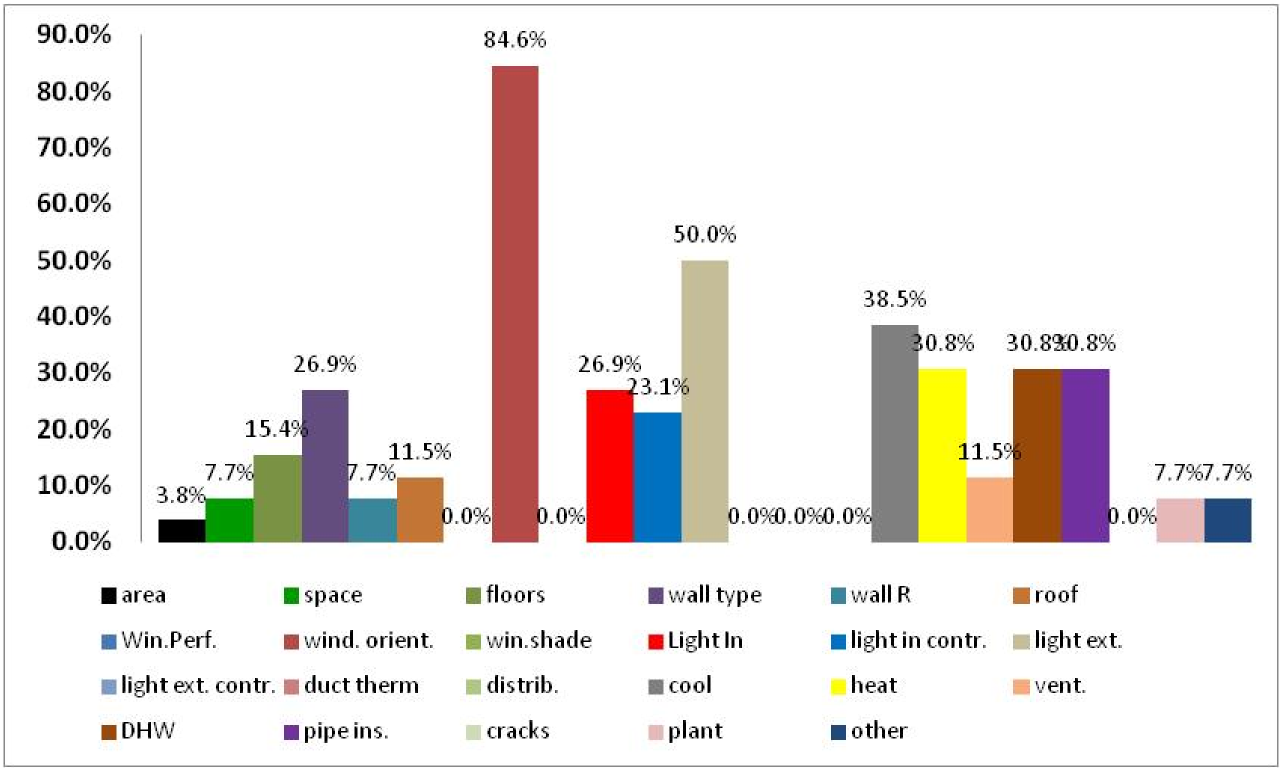


Figure 4. Amount of non-compliance (percent of buildings) for each inspection category. The key is listed left to right in the order of the bars on the chart.

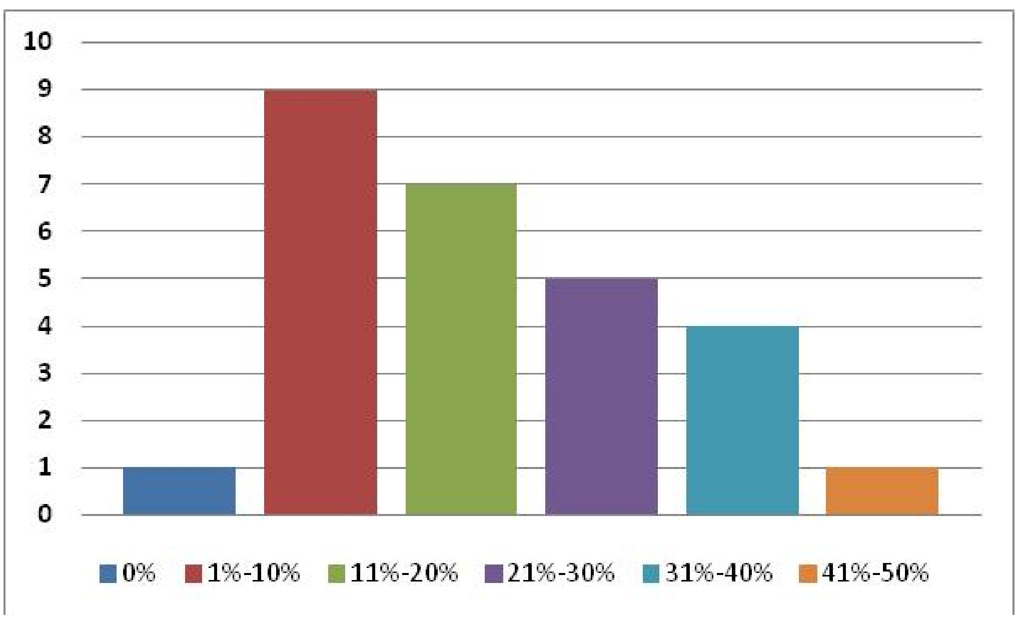


Figure 5. Frequency distribution plot for commercial energy code compliance. The height of each bar represents the number of inspected buildings that had the binned value of non-compliance issues.

D. Commercial Enforcement Recommendations

The study has revealed that as a state, commercial energy code enforcement is not very good. 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 problems. There are three ways to improve the situation: statewide code changes, education and local changes.

1. Code Changes

The building commission determines the code forms that need to be submitted and currently approves software used for performance method calculations. 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.

2. Education

Building departments need to be educated about the commercial building energy code. Classes have been developed and are available from a number of vendors (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.

3. 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 code is often met through improved equipment efficiencies as the thermal envelope properties have small effect on many internal load dominated buildings, so those parameters should be carefully examined.

III. RESIDENTIAL ENERGY CODE ENFORCEMENT RESEARCH

A. Research Approach

The following process was used by the Florida Solar Energy Center's (FSEC) staff to undertake the residential aspect of the study.

1. DOE Sample Generator

To randomly choose the buildings' location, size, and number of specific buildings in a location FSEC used the DOE sample generator shown in Table 5.

2. Assessment Methods: Residential & Commercial Buildings

Finding willing new homeowners to allow researchers to spend a few hours in their home is difficult. Alternatively builders of typical new homes aren't likely to allow researchers on site to inspect energy properties for fear of violations and project delays. Thus, examining enforcement issues on-site for residential buildings can be a challenge. The process used was not as scientifically methodical as under the commercial building sample.

Table 5. State Sample Residential Generator results

Location	Total Permits	Sample Size
Climate Zone 1	1915	3
Miami-Dade County	948	3
Climate Zone 2	31808	41
Brevard County	1094	1
Citrus County	620	3
Clay County	600	1
Duval County	2143	3
Escambia County	551	1
Hillsborough County	2874	2
Lake County	778	1
Lee County	1088	2
Leon County	487	1
Manatee County	1009	1
Marion County	754	1
Orange County	2188	4
Osceola County	859	2
Pasco County	1187	1
Polk County	1727	4
Santa Rosa County	495	2
Sarasota County	496	2
Seminole County	792	1
St. Johns County	1189	2
Sumter County	2282	3
Suwannee County	52	2
Taylor County	24	1
State Total	**33723**	**44**

This enforcement project was dovetailed with a residential code effectiveness study that is examining differences in energy performance from Central Florida new homes and those built in 1984- 1985 (report will be completed later this year). The new homes obtained in that study were used as part of the sample for this project (this strategy was proposed from the beginning). The

Central Florida homes for that study took longer than expected largely due to low response rate to study invitation postcards (example in Figure 6). The participation rate was only about one-half of one percent of homes being solicited became part of the study. That study included monitoring of energy use and a financial incentive for homeowners. In order to obtain homes outside of Central Florida, contractors were given parameters and asked to make inspections. This often involved finding available model homes or sites nearing completion to examine the homes.

3. Obtaining Energy Code Forms

For the code effectiveness study (See next section for qualifying home criteria), code forms were obtained after participants homes were inspected and monitoring put in place. For the non-Central Florida homes, locating random permits ahead of time was not usually successful as those homes were not accessible. Thus the audit homes were found and then code forms retrieved to find any differences. This necessitated detailed collection at the site.

Figure 6. Example of a study invitation postcard

4. Scheduling and Accessing Homes

The following steps were undertaken in order to find the Central Florida code effectiveness study homes.

a. Research public data for potential study homes and start an initial list
b. Review list and screen homes by:
  1) Year built (homes to be built under 1984 code or 2009 code).
  2) Conditioned square feet (homes will be between 1,500-2,300 square feet).
  3) Single family detached building.
  4) Owner occupant (screen out homes owned by builders).
  5) Send out study invitation to participate in study to homeowners of potential study homes.

6) Receive calls and messages from interested homeowners and discuss concerns and expectations.
7) Create a database of interested parties with contact information. Request energy code forms from building departments of specific house where homeowner agreed to participate in study.
8) Begin sending homeowner agreement contracts to homeowners to read, sign, and return.
9) Schedule energy audits as signed agreements are returned. Coordinate schedule with homeowner/tenant and field staff.

5. Residential Code Compliance Audit Method

Residential energy code compliance was evaluated by focusing on 14 primary areas that are summarized by item numbers 4-15 (listed in parentheses) as shown on the first page of Form 1100A-08 (Figure 7), to include the Glass/Floor Area ratio and e-ratio.

a. (4.) Number of Bedrooms
b. (5.) Is this worst case?
c. (6.) Conditioned floor area (ft^2)
d. (7.) Windows
e. (8.) Floor types
f. (9.) Wall types
g. (10.) Ceiling Types
h. (11.) Ducts
i. (12.) Cooling systems
j. (13.) Heating systems
k. (14.) Hot water systems
l. (15.) Credits
m. Glass/Floor Area
n. e-ratio

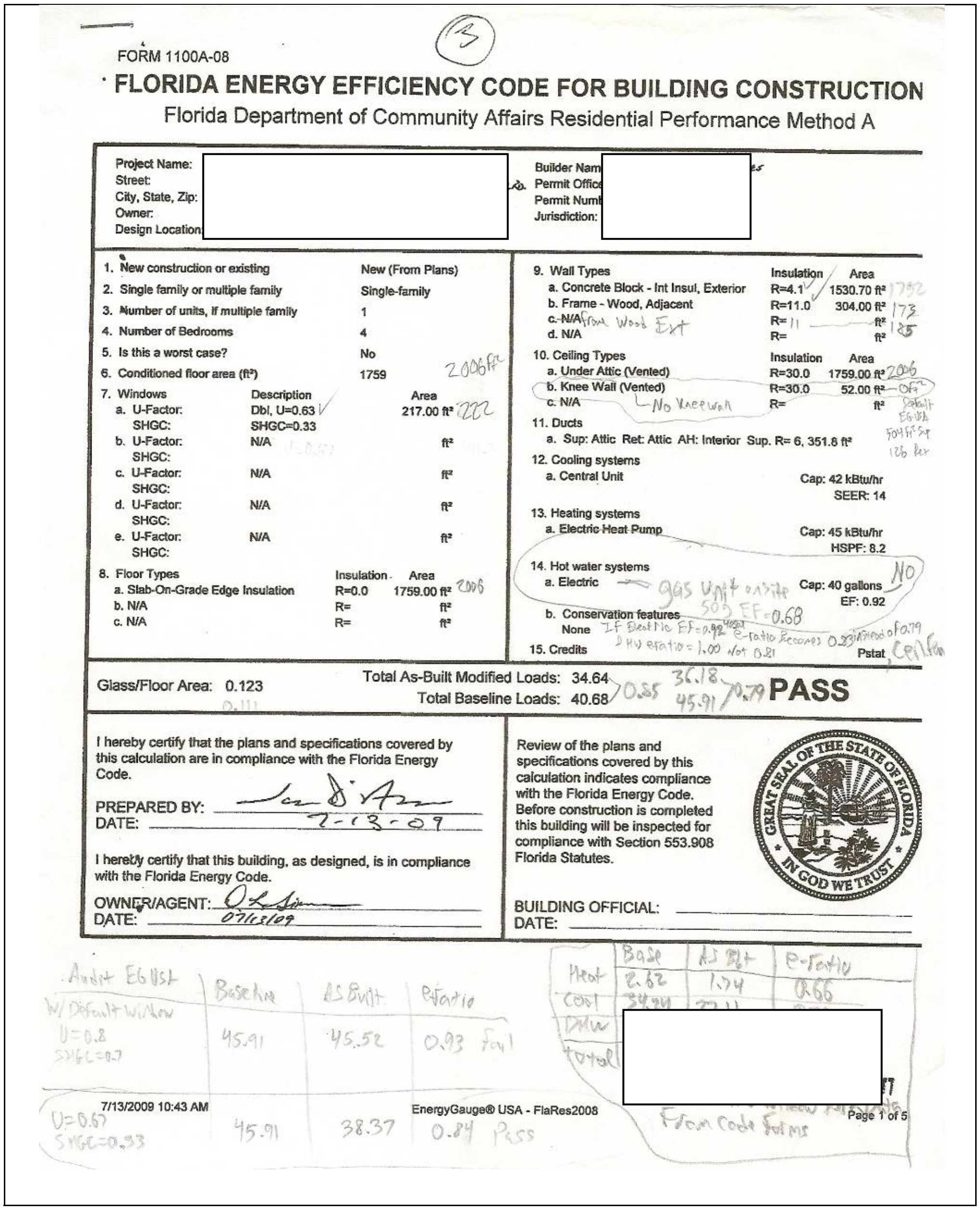
The general method of evaluation of each of these primary items is discussed in detail below.

1) <u>Correct Code Form</u>

Code form 1100A-08 is the correct code form for the performance evaluation method of energy code compliance. The code form requires a ratio of as-built modified loads to total baseline loads to be less than 0.85, or 15% better than the baseline for the 2007 code. This value is referred to as the e-ratio. The lower the e-ratio the more efficient the home is relative to the baseline.

2) <u>Number of Bedrooms</u>

This is a simple single value input regarding the number of bedrooms. If the code form differs from the built house, it is counted as non-compliance. A bedroom is a conditioned space of seventy square feet or more that has a door and a closet space. A “bedroom” used as an office or den space is considered a bedroom by Florida code. The number of bedrooms is used as a surrogate for occupants and effects the water heating gallons used per day in the simulation. As such the proportion of water heating relative to total will increase as bedrooms increase for a given sized home. Since many Florida homes are built with minimal efficiency water heating equipment, increasing bedrooms will often hurt the performance based code calculation (which needs to be 15% better that the baseline home), so omitting a bedroom could lead to a result of compliance when it should be non-compliant.



FORM 1100A-08

FLORIDA ENERGY EFFICIENCY CODE FOR BUILDING CONSTRUCTION

Florida Department of Community Affairs Residential Performance Method A

Project Name: / Street: / City, State, Zip: / Owner: / Design Location: [redacted]

Builder Name: / Permit Office: / Permit Number: / Jurisdiction: [redacted]

1. New construction or existing — New (From Plans)
2. Single family or multiple family — Single-family
3. Number of units, if multiple family — 1
4. Number of Bedrooms — 4
5. Is this a worst case? — No
6. Conditioned floor area (ft²) — 1759
7. Windows — Description — Area
   a. U-Factor: Dbl, U=0.63; SHGC: SHGC=0.33 — 217.00 ft²
   b. U-Factor: N/A; SHGC: — ft²
   c. U-Factor: N/A; SHGC: — ft²
   d. U-Factor: N/A; SHGC: — ft²
   e. U-Factor: N/A; SHGC: — ft²
8. Floor Types — Insulation — Area
   a. Slab-On-Grade Edge Insulation — R=0.0 — 1759.00 ft²
   b. N/A — R= — ft²
   c. N/A — R= — ft²
9. Wall Types — Insulation — Area
   a. Concrete Block - Int Insul, Exterior — R=4.1 — 1530.70 ft²
   b. Frame - Wood, Adjacent — R=11.0 — 304.00 ft²
   c. N/A — R= — ft²
   d. N/A — R= — ft²
10. Ceiling Types — Insulation — Area
   a. Under Attic (Vented) — R=30.0 — 1759.00 ft²
   b. Knee Wall (Vented) — R=30.0 — 52.00 ft²
   c. N/A — R= — ft²
11. Ducts
   a. Sup: Attic Ret: Attic AH: Interior Sup. R= 6, 351.8 ft²
12. Cooling systems
   a. Central Unit — Cap: 42 kBtu/hr, SEER: 14
13. Heating systems
   a. Electric Heat Pump — Cap: 45 kBtu/hr, HSPF: 8.2
14. Hot water systems
   a. Electric — Cap: 40 gallons, EF: 0.92
   b. Conservation features — None
15. Credits — Pstat

Glass/Floor Area: 0.123 — Total As-Built Modified Loads: 34.64 — Total Baseline Loads: 40.68 — PASS

I hereby certify that the plans and specifications covered by this calculation are in compliance with the Florida Energy Code.

PREPARED BY: ______ DATE: 7-13-09

I hereby certify that this building, as designed, is in compliance with the Florida Energy Code.

OWNER/AGENT: ______ DATE: 07/13/09

Review of the plans and specifications covered by this calculation indicates compliance with the Florida Energy Code. Before construction is completed this building will be inspected for compliance with Section 553.908 Florida Statutes.

BUILDING OFFICIAL: ______ DATE: ______

GREAT SEAL OF THE STATE OF FLORIDA — IN GOD WE TRUST

Audit EGUSA	Baseline	AS Built	E-ratio
W/ Default Window U=0.8 SHGC=0.7	45.91	45.52	0.93 Fail
U=0.67 SHGC=0.33	45.91	38.37	0.84 Pass

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Figure 7. Example of form 1100A-08 with notes written on it comparing it to actual house

3) Conditioned floor area (ft2)
This is the total of all conditioned areas in the house. Floor area on code form should be no more than 3% greater than the built house. Increasing the floor area as well as the associated ceiling and roof areas will typically can cause a decrease in the e-ratio.

4) Windows
The windows are evaluated by performance data. Performance inputs are the U-value and the solar heat gain coefficient (SHGC). The actual performance data is almost never available by the time the audit begins. When actual window performance data is not available, the code form values are assumed as long as the values claimed are reasonable. The glass area is evaluated as a separate item Glass/Floor Area.

Significant difference of window input values are qualified as:

i. Orientation is manipulated in a way to result in lower e-ratio, such as high % of glass on north and south sides instead of east and west.
ii. Shading input difference greater than 20% that favors lower e-ratio.

5) Floor types
The type of floor and the R value of floor are considered in this evaluation. Much of new Florida residential construction is slab on grade that usually does not have any added R value. Floor types may also be second story floors over unconditioned garage or cantilevered over outside space as well as raised floor over crawl space which do commonly have added insulation.

6) Wall types
The type of construction is considered as well as the cavity R value. Since the wall system is enclosed in completed, there is no way to observe actual insulation in finished walls. The code form wall R-value is assumed correct unless site measurements show the R-value claimed is not plausible. The built home wall insulation is estimated based on construction type and measured wall thickness. After subtracting the construction material from the total dimension, the space available for insulation can be known. Much of the new Florida exterior wall construction is eight inch concrete block. Consider the following example where a block wall was measured from interior finish surface to exterior stucco finish surface. If the construction material (interior gypsum board, concrete block and exterior stucco) add up to 9-3/8 inches and the measured wall thickness is 10 inches thick there is 5/8 inch space for insulation. Foil-faced Polyisocyanurate that is 5/8 inches thick can provide an R-value of 4.1.

7) Ceiling Types
The R value of insulation is the primary criteria for determining compliance. This applies to flat, vaulted ceiling areas, and on kneewalls. Areas of Ceiling Types are only noted as non-compliance if the difference from actual built house is great enough to result in a lower e-ratio.

8) Ducts

Duct compliance is primarily evaluated based on correct R value and location of supply, return and air handler. The duct area is only considered if it is clearly understated compared to the built house and the understatement is enough to result in a lower e-ratio. ASHRAE standard 152 uses a duct surface area default of 27% of conditioned floor area, however, well-designed layouts can be about half of this. Decreased duct surface area in attic spaces clearly results in lower calculated energy use in EG USA and can result in a lower e-ratio.

The field audit includes attic and duct inspection but does not make an actual measurement of duct surface area. This is because attics are very difficult to navigate through and a hostile environment to make physical measurements of duct surface dimensions. Care must also be taken not to compress and diminish the effectiveness of installed ceiling insulation. The number of supply and return registers is counted and location of these and the AHU are noted on a floor plan. The e-ratios of the actual built home is evaluated using the duct area on the code form, except when the code form uses a value that is not plausible. If a value is not plausible, the default surface area assumed by EG USA will be used.

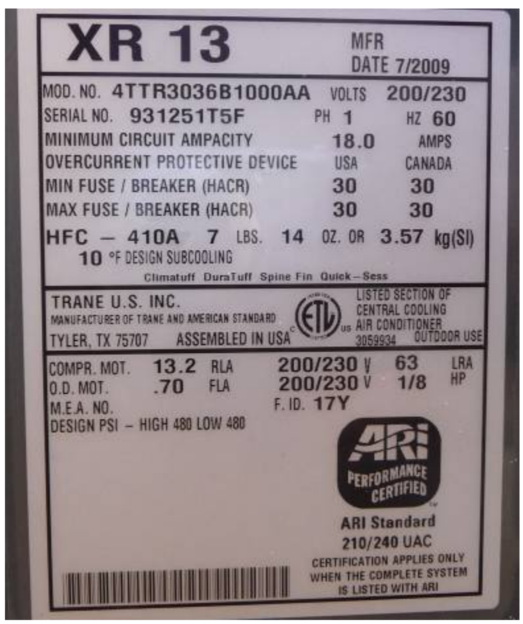

Figure 8. Photo of condensing unit tag, with model number listed at top of this 35.0 kbtu cooling system.

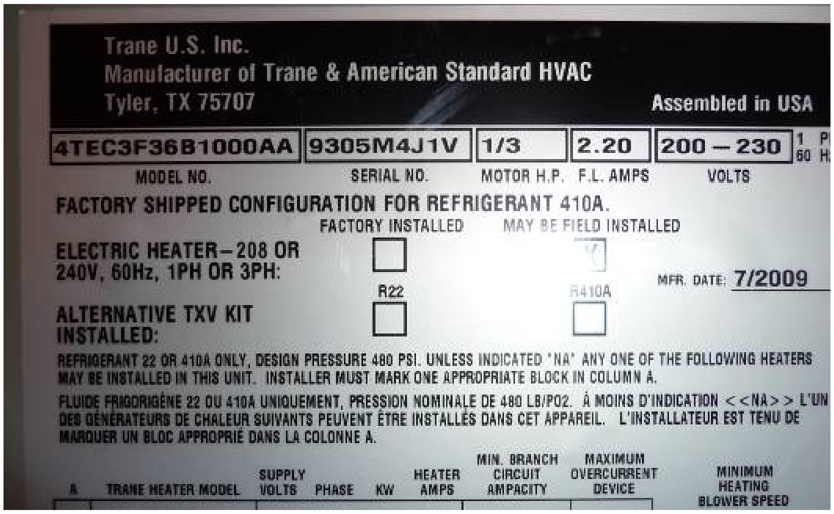

Figure 9. Photo of air handler unit tag with model number shown at the top left.

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Certificate of Product Ratings

AHRI Certified Reference Number: 1105474 Date: 4/2/2012

Product: Split System: Air-Cooled Condensing Unit, Coil with Blower
Outdoor Unit Model Number: 4TTR3036A1
Indoor Unit Model Number: 4TEC3F36B1
Manufacturer: TRANE
Trade/Brand name: XR13

Manufacturer responsible for the rating of this system combination is TRANE

Rated as follows in accordance with AHRI Standard 210/240-2008 for Unitary Air-Conditioning and Air-Source Heat Pump Equipment and subject to verification of rating accuracy by AHRI-sponsored, independent, third party testing:

Cooling Capacity (Btuh):	35000
EER Rating (Cooling):	11.00
SEER Rating (Cooling):	13.00

* Ratings followed by an asterisk (*) indicate a voluntary rerate of previously published data, unless accompanied with a WAS, which indicates an involuntary rerate.

DISCLAIMER
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Figure 10. Model numbers from the outdoor and indoor unit are looked up on the AHRI directory of efficiency ratings to determine the heating and cooling efficiency. This unit is a straight cool system with strip heat so only the cooling is rated. This air conditioner has a 13.0 SEER rated efficiency.

9) <u>Cooling systems</u>
The primary item evaluated under cooling systems is the cooling efficiency based on the seasonal energy efficiency ratio (SEER). The model information of the outside and inside unit is collected on site and the data used to look up the rated efficiency. Figures 8 and 9 show model nameplate data taken from each house that is used to look up the Air-Conditioning, Heating and Refrigeration Institute (AHRI) efficiency rating (Figure 10). This system at house 70 was a straight cool system with only SEER13 rating and electric strip heat (COP=1).

10) <u>Heating systems</u>
Heating system code compliance is evaluated by different named ratings depending on the type of equipment and fuel used. Electric heat pumps are evaluated by the heating seasonal performance factor (HSPF). Electric resistance heat rating is known as the coefficient of performance (COP). Gas fuel based system efficiency is known as annual fuel utilization efficiency (AFUE).

11) <u>Hot water systems</u>
Electric and gas hot water system energy compliance are evaluated by the efficiency factor (EF). Figure 11 shows model number data taken from an electric domestic hot water (DHW) tank that is used to look up the efficiency rating using AHRI. Figure 12 shows the AHRI certificate stating the 40 gallon electric water heater has an EF=0.92.

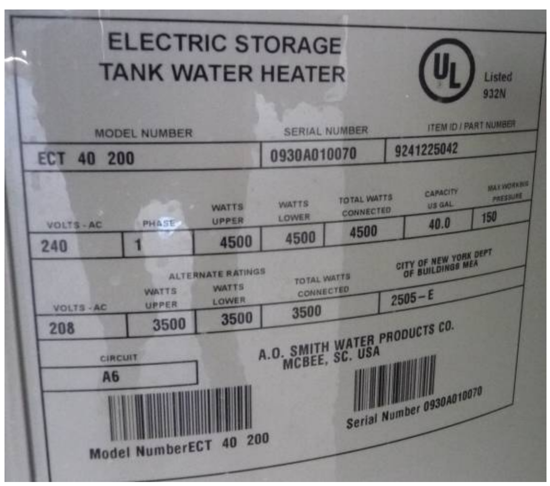

Figure 11. Photo taken of the 40 gallon electric storage domestic hot water heater nameplate. The model number and manufacturer are looked up using the AHRI rating directory to determine the efficiency. The rating certificate is shown below.


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Certificate of Product Ratings

AHRI Certified Reference Number: 2110411 Date: 4/2/2012 †Status: Active

Product: Residential Water Heaters
Model Number: ECT-40
Manufacturer: A.O. SMITH WATER PRODUCTS CO.
Trade/Brand name: A.O. SMITH

Rated as follows in accordance with Department of Energy (DOE) Water Heater test procedures as published in the latest edition of the Code of Federal Regulations, 10 CFR Part 430 and subject to verification of rating accuracy by AHRI-sponsored, independent, third party testing:

Energy Factor:	0.92
First Hour Rating:	54.0 Gallons per hour

The following data is for reference only and is not certified by AHRI:

Energy Source:	Electric Resistance
Water Heater Type:	Storage
Rated Storage Volume:	40 Gals
Input:	4.5 kWh
Recovery Efficiency:	98 %
Heat Traps:	Yes

FootNote 17 - Insulation supplied for Inlet & Outlet connections.

† Models with an 'Active' status are those that are currently in production. Models with a 'Discontinued' status are those that the manufacturer has elected to stop producing, yet stock is still available. Models with an 'Obsolete' status are those that the manufacturer is required to stop manufacturing due to an AHRI certification program test failure.

* Ratings followed by an asterisk (*) indicate a voluntary rerate of previously published data, unless accompanied with a WAS, which indicates an involuntary rerate.

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CERTIFICATE NO.: 129778732911696559

Figure 12. AHRI rating indicates the electric DHW heater has an efficiency rating EF=0.92.

There are also DHW conservation credits associated with insulated heat traps, tank insulation wrap, heat recovery unit, add-on dedicated heat pump and solar system.

12) <u>Credits</u>
There are several possible energy credits available. These are: programmable thermostat, ceiling fan cooling credit, whole house fan, and cross ventilation.Energy code compliance forms were been requested for each home that had agreed to participate in the research study. All residential code forms have been received so far for the new code homes that have already been visited and had as-built data collected. In total, 43 homes were audited as show in the 3rd column to the right with heading *Code Data Collection Completed* in Table 6.

13) <u>Glass/Floor Area</u>
The glass /floor area is calculated by the total area of glass per area of conditioned space.
The glass/floor area will be noted as non-compliance in cases where the glass/floor area on form is different enough to result in a lower e-ratio.

14) <u>e-ratio</u>
The e-ratio score is noted as non-compliance if the actual built home e-ratio is greater than 0.85.

B. State Residential Sample Set

The county location and number of homes suggested by the State Sample Generator are shown in Table 6 in the first two columns on the left. The last column on the right shows the final distribution of homes audited based on the associated county locations. Five additional counties not included in the original sample are listed in the bottom five rows and were used as replacements for some of the original sample counties where researchers had difficulty ascertaining code forms, assessing homes, etc.

Table 6. Residential building final distribution set

Location	Target Sample Size	Code Data Collection Completed
State Total	44	43
Climate Zone 1		
Miami-Dade County	3	0
Climate Zone 2		
Brevard County	1	4
Citrus County	3	0
Clay County	1	1
Duval County	3	6
Escambia County	1	0
Hillsborough County	2	4
Lake County	1	1
Lee County	2	1
Leon County	1	0
Manatee County	1	1
Marion County	1	3
Orange County	4	6
Osceola County	2	0
Pasco County	1	4
Polk County	4	1
Santa Rosa County	2	0
Sarasota County	2	2
Seminole County	1	2
St. Johns County	2	0
Sumter County	3	1
Suwannee County	2	0
Taylor County	1	0
Additional Counties Used		
Okaloosa County	-	1
Volusia County	-	1
Flagler County	-	1
Bay County	-	1
Walton County	-	2

C. Code Compliance Assessments

1. Level of Compliance

Non-compliance of all 43 houses was found to average 15.1% with a range from lowest at 0% to the highest at 54%.

Individual results are shown in Table 7 for each house according to twelve of the main individual evaluation criteria areas. Fourteen criteria items were considered overall, however, there was no non-compliance in the number of bedrooms claimed or in e-ratio categories. The summary percent compliance is shown in the far right column. Generally 14 criteria were considered. In a few cases where construction was not completed or there was not access to a specific item, the compliance % is based on the total number of items that were able to be evaluated. Therefore there can be differing % non-compliance for different homes having the same number of non-compliance items.

Using the data shown in Table 7, the number of times non-compliance occurred is shown in Figures 13 and 14 for each of the 12 categories. Non-compliance occurs most often in domestic hot water heating (37%), window (35%) and walls (30%) respectively. Cooling (21%) and heating (19%) efficiency follow in the order of occurrence.

The 12 non-compliance items shown in the top row of Table 7 are not weighted but are simply checked of if what auditor found during the building audit does not agree or match up with what is specified on the building's residential code form. Therefore, just because an item was found with a non-compliance (or found with a large frequency of occurrences with the 43 buildings) does not necessarily mean it is equal with another non-compliance item in the same house – regarding energy impact, etc. For example, while DHW leads the group in frequency, the actual impact on energy is likely modest since 81% (13/16) of the installed EF were within 0.02 of the claimed value.

In instances where an item called out in the code form no longer has the manufacture label or specs listed in the home the researchers focused on other areas of the specified item to quantify the item code form data with what was installed. Window non-compliance was related to window area/orientation errors – a called out code form item that could be compared with the home audit. Window U value and SHGC labels are removed when the home is completed however window performance data was available in about 6 houses. In those cases we did find that the installed performance data met or exceeded the claimed efficiency. The reason for wall non-compliance was usually (62%) related to significant wall area errors, the other 38% was related to overstated R value on code forms. The primary cause, 67% of the time, for non-compliance in cooling and heating was due to installation of lower efficiency equipment. Most of the time the SEER difference was about 1 SEER lower and HSPF about 0.3 lower. Heating and cooling non-compliance was noted for installation of significantly oversized equipment in 33% of all homes in these categories.

Table 7. Residential compliance summary table

	Wrong Code Form	Cond. Area ft²	Windows	Floor Types	Wall Types	Ceiling Type	Ducts	Cooling System	Heating System	DHW System	Credits	Glass/ Floor Area	Percent Non-Compliance
1R													0.0%
2R													0.0%
3R													7.1%
4R													14.3%
5R													7.1%
6R													0.0%
7R													7.1%
8R													7.1%
9R													14.3%
10R													42.9%
11R													21.4%
12R													0.0%
13R													0.0%
14R													7.1%
15R													14.3%
16R													7.1%
17R													7.1%
18R													7.1%
19R													0.0%
20R													21.4%
21R													7.1%
22R													0.0%
23R													28.6%
24R													42.9%
25R													28.6%
26R													14.3%
27R													28.6%
28R													14.3%
29R													7.1%
30R													0.0%
31R													0.0%
32R													28.6%
33R													7.1%
34R													42.9%
35R													42.9%
36R													28.6%
37R													53.8%
38R													42.9%
39R													14.3%
40R													7.1%
41R													7.1%
42R													9.1%
43R													8.3%
Total	**2**	**3**	**15**	**2**	**13**	**6**	**7**	**9**	**8**	**16**	**2**	**7**	
%	**4.7%**	**7.0%**	**34.9%**	**4.7%**	**30.2%**	**14.0%**	**16.3%**	**20.9%**	**18.6%**	**37.2%**	**4.7%**	**16.3%**	**15.1%**

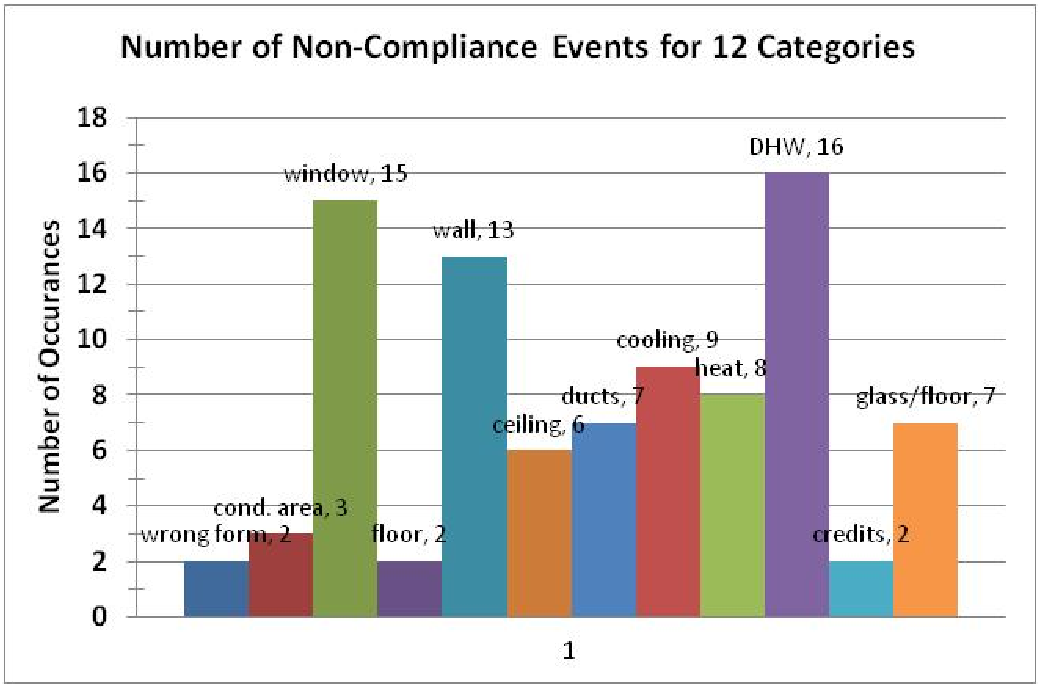

Figure 13. Number of homes where non-compliance was noted for each type of category.

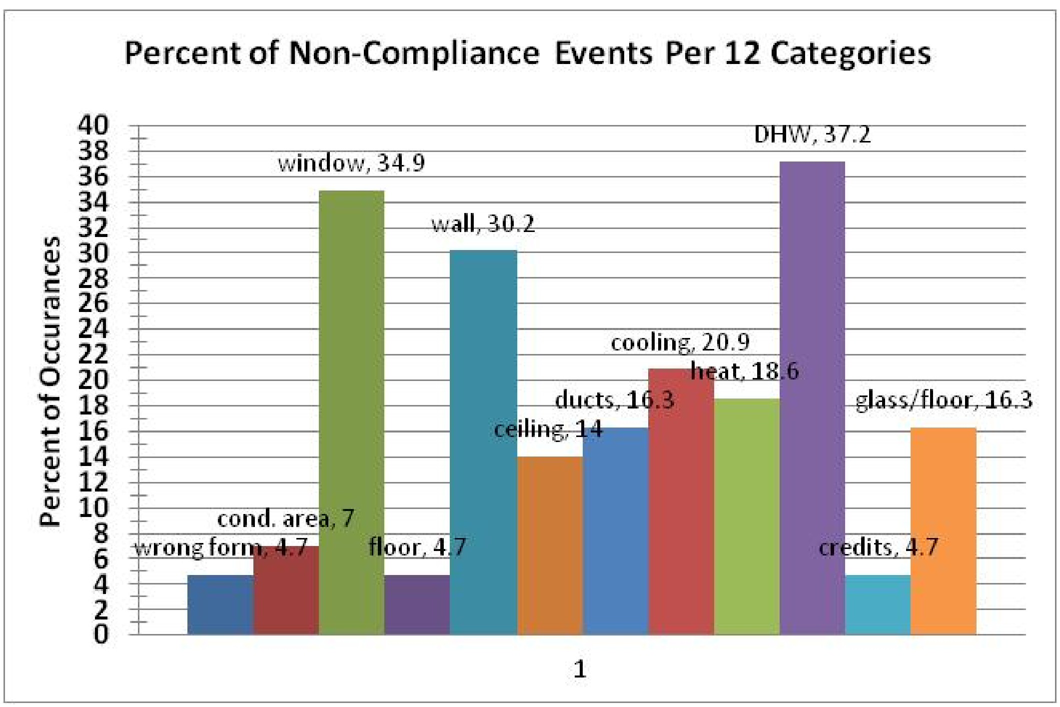

Figure 14. Amount of non-compliance (percent of homes) for each inspection category.

2. Comparison of e-ratio and Code Compliance

A total of 18 houses have had a comparison made between the calculated e-ratio on the as-submitted code forms and based on site collected data (as-built). Data from site audit was used to create an as-built EnergyGauge building file so that the as-built e-ratio could be calculated. Table 8 summarizes the as-submitted e-ratio, as-built e-ratio and the percent non-compliance for the 18 houses. These houses have been evaluated based on Performance Method A.

During the initial Method A code compliance comparisons, we have also observed that duct surface area can differ between code form and the assumed default using EnergyGauge USA code compliance software, however as mentioned earlier, field audit teams were not able to measure surface area of installed duct work. Further analysis on e-ratios will be included in the code effectiveness report later this year.

Seven out of eighteen houses had DHW EF values that were lower on site than on the code form. Most of the time they were within a couple points, but house 32 had EF values differing by 14 points and claimed an EF of 0.97 for a tankless gas water heater that was actually 0.83. This same house did not have the claimed wall R values and had code form data submitted on an old 600A-2004R form. In other homes, the second most common compliance error was incorrect insulation R value and significant window orientation/ area error on form. Heating and cooling efficiency non-compliance has only occurred in two of the eighteen homes so far.

Table 8. Preliminary Code Compliance Analysis

House ID # evaluated	As submitted E-ratio	As-Built E-Ratio
3	0.85	0.79
5	0.77	0.78
8	0.95	0.81
12	0.80	0.89
13	0.80	0.82
17	0.83	0.85
18	0.83	0.79
24	0.83	0.79
29	0.84	1.05
32	0.84	0.78
42	0.75	0.78
43	0.78	0.85
44	0.80	0.84
45	0.82	0.83
46	0.80	0.64
47	0.81	0.79
48	0.85	0.79
49	0.83	0.83

While most homes in this group are showing some degree of non-compliance, all but two are passing the E-ratio because the item(s) not in compliance is 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 e-ratio would have been 0.79 instead of 0.78. Eleven of the eighteen houses have e-ratios low enough to be able to pass with some relatively minor non-compliance items. 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 R38 attic insulation instead of R30 and radiant barrier system installed that was not claimed on code form.

Two homes had as-built e-ratios that are too high to meet minimum code. The worst example, house 29, had an as-built e-ratio of 1.05 due to the 43% of non-compliance. The causes for non-compliance here were due to lower heating and cooling efficiency, R15 wall claimed only R11, glass/floor ratio claimed 0.084 (21% lower than actual), significant window input errors on shading and orientation on code form made major shift of glass from east and west to north exposure. House 12 had DHW EF=0.91 instead of EF=0.92 claimed on form and the duct surface area input on code form was too small to be possible. The duct surface area was only 4% of floor area.

3. On-Site Enforcement Issues

Figures 13-15 visually represent non-compliance items in the 43 homes. Figure 13 summarizes the number of non-compliance occurrences. Figure 14 shows each non-compliance category item (e.g. windows, DHW, etc.) as a percentage of occurrence within each inspection category, while Figure 15 provides the frequency distribution at different ranges for the forty-three homes based on the twelve inspection categories of audited items.

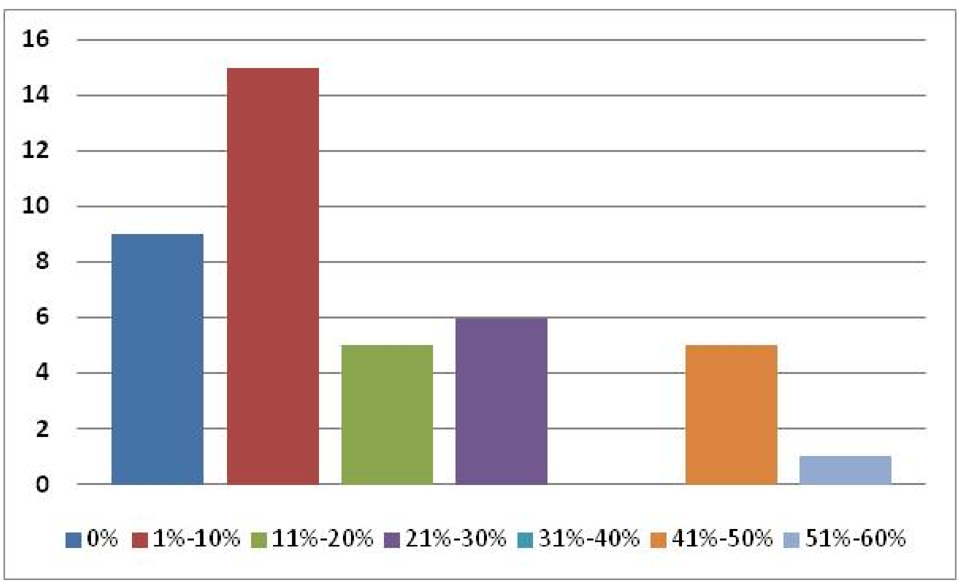

Figure 15. Frequency distribution at different ranges of non-compliance for 43 homes. The height of each bar is the number of homes that had the percentage of compliance issues shown on the x axis.

D. Residential Enforcement Recommendations

Residential energy code compliance had fewer code submittal issues than commercial buildings. Only two of the 43 homes sampled were submitted on the wrong form. However there were many violations found during the on-site inspections. The most prevalent of these violations are window orientation, hot water heater efficiency, wall R-value (as best as could be audited), cooling and heating equipment efficiencies, duct area and glass area. Of these, the cooling and heating efficiency and window orientation and area are items that can have major effects on compliance but are not terribly difficult to check. Some equipment efficiency may require an online search of matching air handler and outdoor equipment. Water heater efficiency violations, though frequent, were typically minor in magnitude of violation. Duct area violations are more difficult to ascertain, both for this study and for building inspectors.

Although the as-built home is often not in compliance with what was submitted (only 9 of the 43 homes passed all compliance check criteria), the magnitude of error is relatively small. A subsample of eighteen homes entered into the performance code software with the on-site data indicated only two would violate the code limit, although others were on the brink of failing the e-ratio test.

Improvements can be made in three areas: changes to the state's code, education, and local changes.

1. Code Changes

The submittal process seems to be working well. The correct counting of bedrooms shows that this not-so-obvious code information (Counting all rooms over 70 sq. feet with a closet counts as a bedroom) is correctly being implemented by people submitting and/or is being enforced. This is a good sign that junk isn't simply being submitted.

On the other hand, it does appear that code forms are being submitted with many items that differ from what is installed in the field. This is primarily an inspection issue. One item that was observed in this study is that duct surface area is hard to measure if not done pre-drywall and can play a role in code compliance. Some homes were claiming very small duct areas on their compliance forms. A code change that might default all duct area should be considered. This might penalize the rare house where a significant effort was made to consolidate duct area, and it will fail to penalize wasteful design that is entered correctly. Nevertheless, taking this element away from user entry in a simulation may result in one less way to cheat where inspection is difficult.

2. Education

Building officials need to be better trained on what to look for when inspecting a home 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. They need to fail homes and have them install the equipment submitted or equipment of equal or higher efficiency. For homes where window areas or orientations are incorrect, the builder should revise the code form and it may mean they need higher efficiency equipment to meet this changed design.

3. Local Changes

Building officials should verify that the entries on the code forms are consistent with those on the blueprints submitted. Two important parameters for Florida energy code compliance that may not be significant for other parts of the building code are the glass area and orientation. These should be examined in the office relative to the plans received. In order to comply with code, a cheating energy code submitter may falsely make the window size smaller or omit one or more windows. Sliding glass doors are entered as windows by Florida energy code and should be found as such on code submittal forms.

As building departments go more electronic, the ability to use the AHRI site in the field to match outside and inside component equipment for efficiency values will be very beneficial to obtaining energy code compliance verification. Hotlinks or any other time saving capabilities should be evoked to make it easy and quick for building officials to verify these key components.

IV. CONCLUSIONS

This report presents data on Florida energy code enforcement and makes recommendations for targeting areas to improve compliance.

This residential research study was focused on single-family, detached homes built to the 2007, with 2009 supplement, Florida energy code. Homes permitted after March 1, 2009 were selected by researching public records. A total of forty-three homes were audited and compared against energy code submissions. Non-compliance among the residential sample occurred most often in domestic hot water heating (37%), window (35%), and walls (30%), respectively. Cooling (21%) and heating (19%) efficiency followed in the order of occurrence.

While domestic hot water (DHW) leads the group in frequency, the actual impact on energy is likely modest since 81% (13/16) of the installed energy factors (EF) were within 0.02 of the claimed value. The reason for window non-compliance was related to window area/orientation errors. The reason for wall non-compliance was usually (62%) related to significant wall area errors, while the other 38% was related to overstated R-value on code forms. The primary cause, 67% of the time, for non-compliance in cooling and heating was due to installation of lower efficiency equipment. Usually, the seasonal energy efficiency ratio (SEER) difference was about 1 point lower, and the heating seasonal performance factor HSPF about 0.3 lower. Heating and cooling non-compliance was noted for installation of significantly oversized equipment in 33% of all homes in these categories.

Researchers studied the code enforcement of forty-four commercial buildings built to the 2007, with 2009 supplement, Florida energy code. Following a planned sample procedure, public records were used to select buildings permitted after March 1, 2009. Of the fifty buildings studied, 18 were small (≤ 25,000 ft^2), 18 medium (>25,000 ft^2 - ≤ 60,000 ft^2), and 14 large

(>60,000 ft^2 - ≤ 250,000 ft^2), meeting or exceeding the U.S. Department of Energy (DOE) target sample sizes.

Twenty-two of the commercial building energy code forms were the incorrect code form, were missing input data reports necessary to inspect the building, or had incomplete data reports. One building had no energy code form. Two other buildings used an alternate compliance method that made checking inputs difficult. Of the twenty-six buildings inspected, certain differences between the submitted energy code and the inspected buildings were found. The most common difference was incorrect window orientation (approximately 85% of the 26 buildings inspected). Other areas of concern are provided in the report.

In light of this study, it is recommended that the Florida Building Commission, the DBPR, the Building Officials Association of Florida (BOAF), and training organizations provide simple, energy code compliance information regarding what should be collected at the time of building permit. This information should also include what should be checked in the field. Perhaps an informative poster located in building departments/permit application areas for applicants and officials would be beneficial.

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