FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

Why Doesn't 25 Years of an Evolving Energy Code Make More of a Difference?

FSEC-CR-2017-15

Final Report
October 07, 2015

Author

Charles R. Withers, Jr.
Robin Vieira

1679 Clearlake Road
Cocoa, Florida 32922, USA
(321) 638-1000

www.floridaenergycenter.org

Disclaimer

Title:
Why Doesn't 25 Years of an Evolving Energy Code Make More of a Difference?

Author:
Withers, Charles R. Jr., University of Central Florida
Vieira, Robin, University of Central Florida

Publication Date:
October 7, 2015

Series:
2015 Conference Proceedings

Permalink:
https://escholarship.org/uc/item/1128g46s

Keywords:
Energy Consumption, Energy Efficiency, Florida Energy Code, Energy Code Effectiveness

Abstract:
New and more stringent building energy codes are implemented with the assumption and expectation that significant energy conservation will occur. While simulation and various analysis methodologies may be reasonably sound at estimating the energy impact, the actual impact is largely dependent upon new code enforcement and occupant behavior. This work is based upon the research question: Do homes built to a newer energy code deliver measurable energy savings compared to homes built to a much earlier energy code? This residential research study was focused on comparing measured energy use of new code to old code homes. The new code group represented homes built to the 2007 Florida energy code, with 2009 supplement. The old code group were built to the code in effect from June 1, 1984 to Dec. 31, 1985. Energy monitoring equipment was installed to measure whole house, space heating/cooling, and domestic hot water energy use. Interior temperature and relative humidity were also monitored. Using utility bill and end-use monitored data, savings for the new code homes were determined to be 13% for cooling energy, 39% for heating energy, and 5% for domestic hot water energy. The overall annual energy savings of space heating, cooling and domestic hot water were 13%. This paper presents the methodology of the research along with reasons why the measured savings are far less than predicted by simulations of homes built to the two codes. The results may be useful in policy decisions or evaluating the long-term implications of residential building energy codes.

Why Doesn't 25 Years of an Evolving Energy Code Make More of a Difference?

Charles R. Withers Jr.; Florida Solar Energy Center, Cocoa, Florida
Rob Vieira; Division Director Florida Solar Energy Center, Cocoa, Florida

ABSTRACT

New and more stringent building energy codes are implemented with the assumption and expectation that significant energy conservation will occur. While simulation and various analysis methodologies may be reasonably sound at estimating the energy impact, the actual impact is largely dependent upon new code enforcement and occupant behavior. This work is based upon the research question: Do homes built to a newer energy code deliver measurable energy savings compared to homes built to a much earlier energy code? This residential research study was focused on comparing measured energy use of new code to old code homes. The new code group represented homes built to the 2007 Florida energy code, with 2009 supplement. The old code group were built to the code in effect from June 1, 1984 to Dec. 31, 1985.
Energy monitoring equipment was installed to measure whole house, space heating/cooling, and domestic hot water energy use. Interior temperature and relative humidity were also monitored. Using utility bill and end-use monitored data, savings for the new code homes were determined to be 13% for cooling energy, 39% for heating energy, and 5% for domestic hot water energy. The overall annual energy savings of space heating, cooling and domestic hot water were 13%. This paper presents the methodology of the research along with reasons why the measured savings are far less than predicted by simulations of homes built to the two codes. The results may be useful in policy decisions or evaluating the long-term implications of residential building energy codes.

Background

The title of this paper, "Why doesn't 25 years of an evolving energy code make more of a difference?" poses a question that could perhaps insinuate that energy codes have had a limited impact on energy use. In the background of this question is the basis of measured energy of an older code era compared to a newer code era. This should not be inferred to suggest that a quarter century of energy codes has not had a significant impact on the residential built environment. This paper will explain the basis for a study that focused on measured energy, and arrive at explanations for the differences between potential expectations and measured data.

This paper is based upon a study (Withers et. al, 2012 a) conducted to determine if Florida homes built to the newer code delivered measureable energy savings compared to homes built to a much earlier energy code. The study came on the heels of a modeling study (Fairey, 2009) designed to determine the impacts of Florida's Energy Code over a period of 30 years. Fairey (2009) claimed efficiency requirements that had advanced by more than 65%, had cumulative savings over 39 billion kWh of electricity, and that the homes of 2009 code would save $1880 annually compared to a home built 30 years prior in 1979. Two other important findings were illuminated from this report. Florida and most energy codes only consider heating, cooling and hot water energy use. One finding was that residential energy uses not considered had significantly increased from 28% of total home use up to 55%. The second trend was that home size had increased from a median of 1736 ft^2 to 2344 ft^2 which was claimed to have taken back about 20% of the whole house energy savings that would have otherwise been achieved. Since this was based on modeling, it was of interest to implement a new study that could make a direct measurement of energy use in real homes from two different code eras, and also evaluate code compliance enforcement in the new code homes.

The Florida Solar Energy Center (FSEC) conducted research into the effectiveness of the Florida energy code to reduce energy use in residential buildings. FSEC examined two groups of homes: those built to the 1984 energy code (June 1, 1984- Dec. 31, 1985) and those built to the 2007 with 2009 supplement energy code (March 1, 2009- March 14, 2012). The earlier code era will be referred to as the "old" code and later code era as the "new" code in this report. Florida has had the option to comply by either a prescriptive method or performance-based method. All builders of the new code sample chose to use the performance-based method. This method allows some trade-off (flexibility) in specific efficiency measures, but a minimum energy performance must be met. The energy performance-based code compliance was based upon house qualities that impact space heating, space cooling, and domestic hot water.

Study Method

The code effectiveness study (Withers et. al, 2012 a) was developed using US Department of Energy (DOE) Building Technology Program resources (DOE 2010) on code enforcement evaluation. The 2010 DOE report was used to establish a target number of homes for the study as well as guidance on determining code enforcement levels. An equal sample of 44 homes of each code group was desired. A sample of 47 old code and 31 new code homes was obtained. The target sample of new code homes was more difficult to obtain given the severe economic recession that resulted in a drastic reduction in home construction around the period of time the new code homes would have been built.

In order to reduce climate-related factors and project costs, the energy-effectiveness study was limited to homes located across the central Florida region. Homes were selected by starting with public databases to find potential houses meeting primary study criteria. In order to keep sufficiently sized comparative samples, only single-family detached homes within the range of 1,500 to 2,300 square feet were used. The home had to be occupied by the owner with no intent to move or rent the home within the study period. Florida home space heat and domestic hot water use are dominantly electric. All electric homes were sought after in the study, however a few homes had some gas heat and gas domestic hot water.

Following development of an initial list of potential homes, a postcard was sent to homeowners to invite them to participate in the study. Homes were located in several different code jurisdictions and built by various builders. Copies of Energy Code forms for each study home were obtained and used to compare to the house as it was built (as-built). An extensive energy audit was completed on each home and the level of code compliance of the new code group was determined by comparing the claimed code form efficiency to the as-built efficiency. Details on audit methods and enforcement rate analysis can be found in (Withers et. al, 2012 a), and also in another code enforcement rate study in residential and commercial buildings (Withers et. al, 2012 b).

During the energy audit visit, monitoring equipment was installed in each home to measure:

- Outdoor compressor electrical use (space cooling, and space heating if heat pump)

- Air handler electrical use (and electric strip heat)
- Hot water electrical use
- Total home electrical use
- Indoor air temperature
- Indoor relative humidity

Measurement of indoor temperature and relative humidity in addition to local weather data provided a means to normalize space cooling and heating.

Ideally one full year of data would have been collected for each home. However, the difficulty in obtaining houses, combined with some data logging issues, did not allow a full year of submetered data for most homes before the project deadline. At least two years of utility billing data was also obtained to allow longer-term comparisons between the two code groups. A least-squares best-fit regression analysis method was used based on measured data to develop a means to predict energy use for parts of the year when submetered measurements were not available. Heating and cooling energy use was normalized by house size, and domestic hot water use was normalized by number of occupants. Specific details on the energy analysis method can be found in (Withers et. al 2012 a).

Results

House Characteristics

The characteristics of each group of homes are presented in Tables 1 - 3. The differences in equipment efficiency are small as most of the older homes replaced their heating, cooling and hot water equipment over the years. This helps explain why measured energy differences are less than expected. Although most old code homes may have had electric resistance heaters at the time of construction, we found heat pumps present in 81% of the old code group (Table1), and average HSPF of 7.6 compared to 90% heat pump with an average HSPF of 8.3 in the new code group (Table 3). The rated cooling efficiency has a big impact on annual energy use in Florida and the average difference is not as great as one might expect. The new code homes had an average SEER 14 compared to an average SEER 13 for the old code homes (Table 3). Also notable is that both groups have the same rated electric hot water efficiency of 0.92 on average (Table 3).

While the Fairey (2009) study indicated a 35% increase in median home size from 1979 to 2009, the restricted Withers et. al, (2012a) energy study had a mean floor area approximately 1830 ft^2 (Table 2) for both the old and new code home groups, although the new code volume was about 5.4% greater.

Table 1. Comparison of Key Home Characteristic for Each Code Study Group

	New Homes	Old Homes
Number of Homes	31	42
	Construction Type*	
% Wood Frame Homes	0%	23.4%
% Concrete Block Homes	100%	76.6%
Average Wood Frame Insulation Value [R]	--	11.2
Average Concrete Block Insulation Value [R]	4.73	4.74
	Heating System	
% Electric Heat Pump	90.3%	80.9%
% Electric Strip Heat	6.5%	12.8%
% Natural Gas Furnace	3.2%	4.3%
Average HSPF for Electric Heat Pumps	8.3	7.6
	Supply Duct Location	
% Attic	96.8%	91.5%
% Interior	3.2%	8.5%
	Air Handler Location	
% Garage	38.7%	38.3%
% Interior	58.1%	29.8%
% Attic	3.2%	27.7%
	Hot Water System	
% Electric (no HRU or ICS System)	83.9%	76.6%
% Propane or Natural Gas (no ICS System)	12.9%	10.6%
% Electric with Heat Recovery	0.0%	8.5%
% ICS Solar System	0.0%	2.1%
% Instantaneous (Gas or Electric)	5.3%	5.0%
	% of Homes with Select Appliances	
Programmable Thermostat	84%	26%
Pool Pump	6%	55%
Well Pump	0%	11%

* Construction type represents the dominant type of wall found in each home.

Table 2. Home Envelope Averages and Ranges for Each Code Study Group

	Averages		Ranges	
	New Home	**Old Home**	**New Home**	**Old Home**
Occupants	2.7	2.2	1 to 5	1 to 4
Bedrooms	3.5	3.1	3 to 5	2 to 4
Stories	1.1	1.1	1 to 2	1 to 3
Floor Area [ft^2]	1829	1833	1350 to 2360	1067 to 2400
Wall Height [ft]	8.82	8.35	8 to 10	8 to 10
Volume [ft^3]	16137	15305	10800 to 22019	8536 to 20511
Attic Insulation [R]	31	24	30 to 38	11 to 48
Knee Wall Area [ft^2]	39	67	0 to 189	0 to 872
Knee Wall Insulation [R]	27	19	0 to 30	0 to 30
Roof Solar Absorptance	0.86	0.82	0.75 to 0.92	0.30 to 0.92
Wall Solar Absorptance	0.61	0.68	0.50 to 0.80	0.30 to 0.75
Window U-Value	0.66	1.02	0.37 to 1.20	0.29 to 1.20
Solar Heat Gain Coefficient	0.44	0.72	0.29 to 0.80	0.21 to 0.80
Single Pane Window Area [ft^2]	29	197	0 to 281	0 to 488
Double Pane Window Area [ft^2]	182	59	0 to 316	0 to 388
Total Window Area [ft^2]	213	261	127 to 319	111 to 488
Infiltration (ACH50)	5.6	9.1	3 to 11	4 to 18

Table 3. Home Equipment Averages and Ranges for Each Code Study Group

	Averages		Ranges	
	New Home	**Old Home**	**New Home**	**Old Home**
A/C Efficiency [SEER]	14.1	12.9	13.0 to 15.3	10.0 to 15.8
Electric Heat Pump [HSPF]	8.3	7.6	7.7 to 8.8	6.5 to 9.0
Electric Water Heater Efficiency	0.92	0.92	0.86 to 0.93	0.88 to 0.93
Gas Water Heater Efficiency	0.66	0.64	0.59 to 0.83	0.59 to 0.82
Number of Ceiling Fans	3.3	4.1	0 to 8	0 to 7
% Fluorescent Bulbs	26	13	10 to 90	10 to 50

Interior Temperature and Relative Humidity

Interior temperature and relative humidity were measured and stored for each hour of the day at each home. The hourly data from each home has been assembled to represent a daily 24 hour composite for each month.

Temperatures in old code homes averaged about 1 degree F higher during the summer and about 0.6 degrees colder during the winter. Relative humidity in old homes averaged 2%-5% higher than the new code homes. Figure 1 shows the monthly average indoor temperatures of the two code periods while Figure 2 shows average monthly outdoor temperatures matched closely.

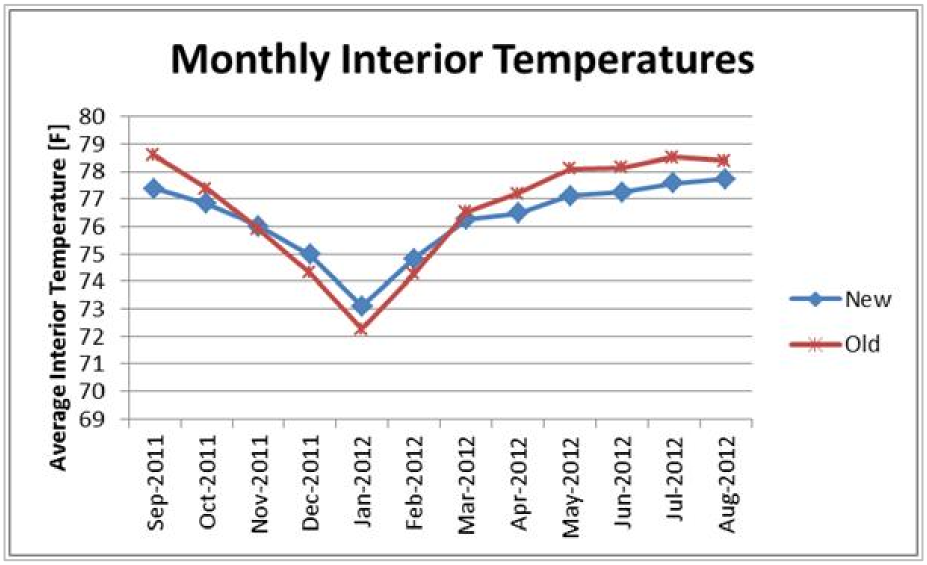

Figure 1. Average monthly indoor temperatures.

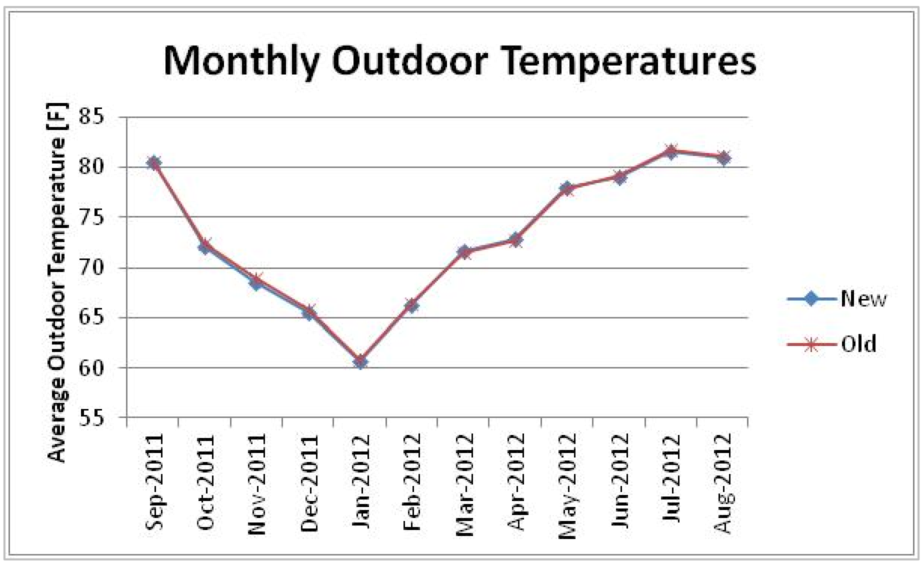

Figure 2. Average monthly outdoor temperatures.

Energy Use

Monitored data indicates homes built to the 2009 Florida Energy Code are using 4.4% less energy for cooling than homes built to the 1984 code. They are using about 9% less for water heating. Space heating data size was smaller and, due to a mild winter, less reliable, however the newer homes that were monitored used 37% less energy for heating. Overall the combined heating, cooling and hot water energy use was 7% less for the new code homes using the available monitored data. Due to the smaller sample that had monitored data available for all seasons (monitored equipment had to be retrieved before project deadline), the possible error of solely relying on monitored data is large. However, looking at individual summer and winter months for monitored sites, the results are rather consistent for cooling and heating.

In order to further explore annual savings, two methods were employed. The first method used monitored energy data to project missing data periods: heating and cooling projections were based on inside and outside temperatures and hot water projections were based on established monthly adjustment factors of water use and cold water temperature. The second method used utility bill data along with monitored data to estimate annual heating and cooling energy use of the participants.

Projections of missing months for cooling show a larger savings of 12.3% while space and water heating show lower savings at 20.5% and 5.2%, respectively. Overall, heating, cooling, and hot water energy use is 11.2% lower in new homes compared to old homes using monitored projections to create annual data.

Using utility bill analysis along with the monitored data, cooling savings for the new code homes are estimated at 12.8%, while for heating 38.9%, and water heating 5.2%, for an overall estimate of 13.0%. Because more homes are included with full annual billing energy data, the statistical confidence is higher than solely relying on monitored data. Figures 3 -5 show the monthly energy use for cooling, heating and water heating, respectively.

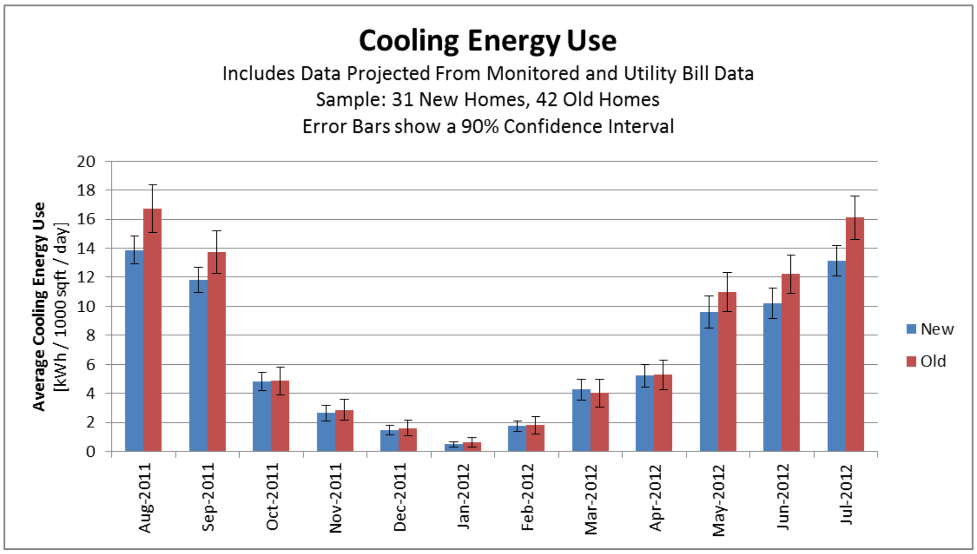

Figure 3. Monthly Cooling Energy Use Results, Utilizing Monitored and Utility Bill Data Projections.

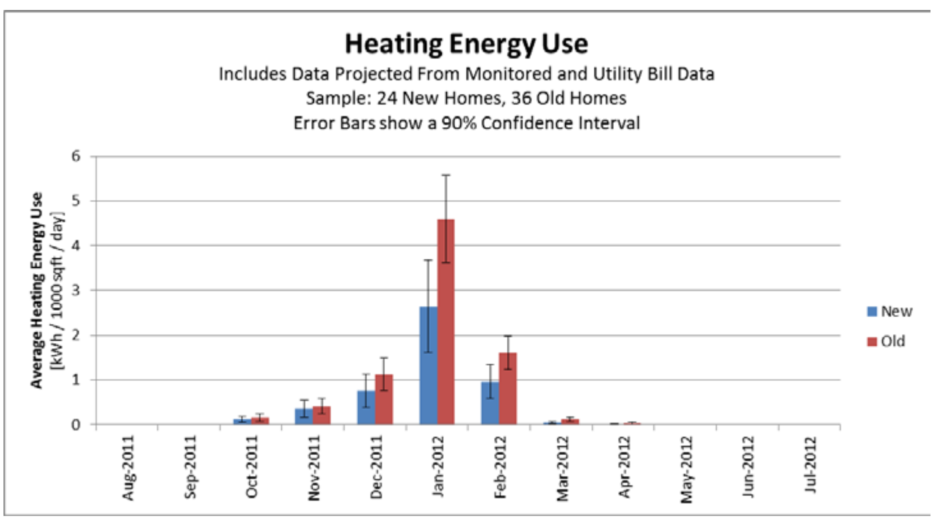

Figure 4. Monthly Heating Energy Use Results, Utilizing Monitored and Utility Bill Data Projections

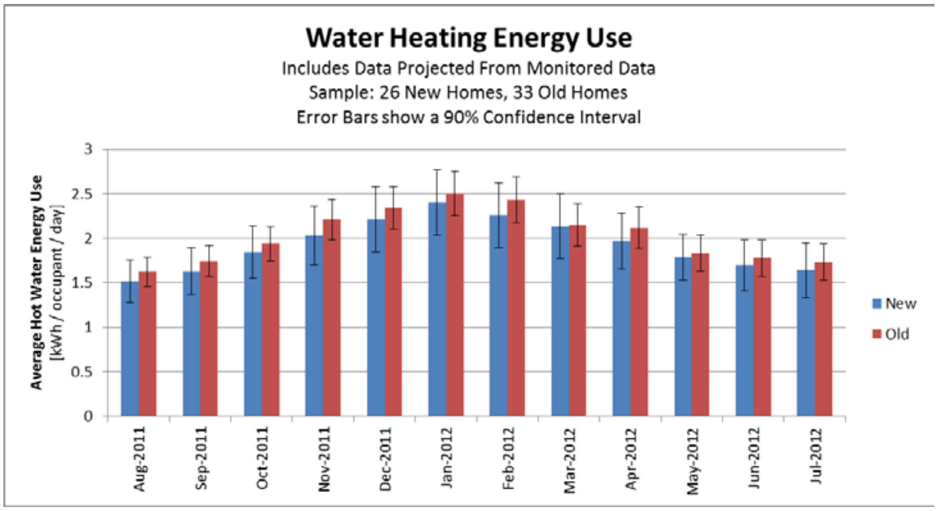

Figure 5. Monthly Hot Water Energy Use Results, Utilizing Monitored and Utility Bill Data Projections.

Although the energy code does not address whole house energy use, the new code homes used 17.5% less annual energy than the old code group. Interestingly new homes used about 10% more baseline electricity than old code homes (groups without swimming pools).

Adjusted Simulation Results

Simulation results (Fairey, 2009) indicated savings of about 50% of combined heating, hot water and cooling between the 1984 and 2009 energy code. Savings of the three primary energy uses were only 7%, based solely on the submetered data, and were 13% based on a combination of submetered and utility billing data for the last year. Some contributing factors to the difference between monitored and simulated results are as follows: the unusually mild winter of 2011-2012 that occurred during monitoring; a notable interior temperature difference between new and old constructions, different internal loads, and the replacement of heating, cooling, and water heating equipment in the older code homes. In order to account for the currently installed equipment in older homes, simulations were repeated with the average equipment efficiency as-found. For example, starting with the Tampa modeled 1984 code home (Fairey, 2009) modifications were made to include the typical equipment specifications for old homes: a 12.9 SEER/7.6 HSPF heat pump and a 0.92 EF electric resistance water heater. This brought the expected simulated savings down from 50% to 27.1%.

The next adjustment reduced the winter season heating-degree days from TMY3 Tampa (typical meteorological year weather data used in building energy simulation software) of 647 to 359 to account for the mild winter during the monitoring study. This adjustment resulted in a small reduction in simulated savings from 27.1% down to 26.5%.

The original model also used a less efficient refrigerator and other appliance loads for the 1984 baseline (non-cooling, heating and hot water energy use). The original model was based on 18.7 kWh/day for 1984 and 17.2 kWh/day for 2009. However, the monitoring study found that the old homes without pools used 15.0 kWh/day and the new homes used 16.5 kWh/day (fairly close to the new code model). Simulation runs using 17.2 kWH/day were made for both code period homes as a moderate adjustment to older code baseline energy. Finally the 2009 home which had been modeled with a programmable thermostat and 78°/80° F summer temperatures was changed to a constant 77° F while the 1984 home remained at a constant 78°F. Table 4 shows the summary of various progressive simulated savings that resulted in 9.4% savings that are much more comparable to the measured savings results.

Table 4. Simulated Energy Savings of Tampa Modeled Home Used in Code Study

Modification	Combined Heating, Cooling and Water Heating Electrical Use kWh/yr		2009 Simulated Savings from 1984
Simulated Home	**1984**	**2009**	**kWh/yr (%)**
Original Code-level (no adjustments)	12109	6061	6048 (49.9%)
1984 Equipment	8318	6061	2257 (27.1%)
Reduce Heating Season	8155	5991	2164 (26.5%)
Reduce 1984 Internal Loads to Match 2009	8065	5991	2074 (25.7%)
Change 2009 Cooling Thermostat from 78/80 F to Constant 77 F	8065	7309	756 (9.4%)

Discussion and Conclusions

Improvement in existing building stock explains most of the measured limitations of energy savings between old and new code homes. The study did not statistically determine the extent that homes were upgraded (or downgraded) with respect to energy over time. That information likely varied by effort provided through utility and other outreach programs, and may also have been dependent on demographic factors such as income. Thus, the length of time that a code-level home stays at that level was not analyzed. The measured values in this study showed savings in new homes due to national equipment standard changes will be reduced with change-outs, and that occupants of newer, more efficient homes may keep thermostats at slightly more comfortable levels while using more “plug-load” energy. It was not explored if this behavior varies due to demographics of new vs. older home occupants or because newer home owners believe that they can set their thermostats lower and afford the utility bill because the house is more efficient.

Another important factor is how well new energy codes are enforced. New code enforcement is critical to realizing the full potential savings and conservation goals of society. A low enforcement rate would diminish savings potential. In Florida’s case, a complement energy code compliance enforcement study (Withers et. al, 2012 b) to the energy study (Withers et. al, 2012 a) found that compliance by the performance method was 90%, and the specific items accounting for the non-compliance could be improved with simple enforcement education and an updated checklist. While the code enforcement in new homes could be better, it met the DOE minimum goal of 90% compliance enforcement, and the types of non-compliance found in the compliance study would typically only have a modest impact on annual energy use of 1% or less.

The title of this paper, “Why doesn't 25 years of an evolving energy code make more of a difference?” poses a question that could perhaps insinuate that energy codes have had a limited impact on energy use. The response to this question is, “It really has made a significant difference, but measured savings compared to older homes 25 years after construction are decreased by years of home improvement efforts”. Many older homes have gradually evolved incorporating energy conservation measures in light of the “home improvement” era. New homes are larger on average and internal plug loads have increased over the last few decades.

Energy codes really have made a difference relative to "as-built" efficiency of an older era compared to a newer era, but measureable differences after two decades are likely to be significantly diminished. Specific reasons for this can be related to:

1) Primary energy consuming appliances such as furnaces, air conditioners, and hot water heaters wear out and have to be replaced. The base efficiency decades later is more efficient than original equipment.
2) Consumer energy conservation education and access to conservation measures at home improvement stores has increased.
3) Increased energy costs encourage consumer purchases of home efficiency improvements.
4) Utility conservation program and tax incentives.
5) Increased Federal mandated minimum efficiency standards over the last decade along with technological advances in efficiency have created opportunities for cost-effective appliance replacement at modern minimum and lower efficiency levels that are much more efficient than base efficiency decades prior.
6) Incomplete energy code enforcement in new code standards.
7) Newer Florida home (2009) median size has increased 35% relative to 1979. The simulated impact of this was that 20% of whole-house energy savings have been diminished from this single attribute.
8) Increased plug loads over time. Increased energy of plug load adds more cooling load during cooling season.

The issue of increased home size as well as energy use beyond the scope of energy codes are important considerations. It demonstrates a significant impact in total energy use that is currently not impacted by energy code with good potential for further decreasing home energy use. It may well be worth considering some measures of whole-house energy in future codes, however acceptance and implementation could be very difficult. One example could be a requirement for larger homes to implement a higher level of efficiency. Impacting energy use of specific appliances is likely best done through national standards that keep up with advances in technology.

References

DOE 2010, "Measuring State Energy Code Compliance," U.S. Department Of Energy, Buildings Technology Program March 2010.

Fairey, P. 2009. "Effectiveness of Florida's Residential Energy Code: 1979 -2009," FSEC-CR-1806-09, Final Report, June 15, 2009.

Withers, C.R., Jr., J. Cummings, J. Nelson, and R. Vieira. 2012 a. "A Comparison of Homes Built to the 2009 and 1984 Florida Energy Codes". FSEC-CR-1934-12, Florida Solar Energy Center, Cocoa, FL October 10, 2012.

Withers, C.R., Jr., J. Montemurno, and R. Vieira. 2012 b. "Final Report of Task 8 ARRA: Energy Code Compliance and Effectiveness Measurement Project". FSEC-CR-1922-12, Florida Solar Energy Center, Cocoa, FL June 15, 2012.