Building Code Impacts on Residential Electricity Usage

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ABSTRACT

Homes account for roughly 21% of energy consumption in the United States. However, most homeowners will not invest in energy efficiency, if there are not recognizable short term benefits. In an effort to reduce electrical consumption, municipalities have adopted increasingly stringent building codes, as it relates to home energy use. This study sought to explore the actual impact(s) of building code adoption on the consumption of electricity in homes, in Central Texas. Using smart meter data, collected over the last 20 years from the city of Georgetown, the following questions were addressed: 1) What is the a relationship between more stringent building codes and electrical consumption in homes? 2) Since the adoption of more stringent building codes, has electricity use been reduced? 3) Which building code caused the largest decrease in electrical consumption? The results of the study indicate that building code changes are related to significant electricity savings, with homes built under more recent codes using 35% less electricity than homes built in the early 1990s and 25% less than homes built in the 2000s.
Keywords: Sustainability, Electric Consumption, Electricity, Building Codes

INTRODUCTION

Energy is a commodity that is highly valued in most areas of the world. According to the United States Energy Information Administration, homes accounted for roughly 21% of the total national energy consumption in 2013. (United States Energy Information Administration [USEIA], 2014). So the implementation of energy conservation strategies in homes could lead to a substantial decrease of energy use. However, homeowners cannot be expected to make substantial investments if the benefits are not short-term (Meyers, Williams, & Matthews, 2009). Local governments on the other hand, can directly impact electricity consumption in homes through the adoption and enforcement of building codes. Through newer more stringent codes homebuilders are required to use materials and methods that use less electricity, which lead to long term electricity savings. Modeling has provided estimates of electricity saving through newer codes, so the researchers hypothesized that homes built to newer more stringent codes would demonstrate a lower usage of electricity. To quantify that hypothesis, the researchers sought to learn how much building codes reduced electricity consumption in actual homes. This study is significant as it provides a comparison of actual electric use based on a sample of homes constructed under different building codes. This information which could represent empirical support for municipalities to adopt newer more stringent codes and to better enforce existing codes as a measure to alleviate increasing electricity consumption. Further it could document money savings for home owners.

The specific research questions for this study were: 1) What is the relationship between more stringent building codes and electrical consumption in homes? 2) Since the adoption of newer building codes, what change in electrical use and thus cost has occurred in homes in Georgetown, Texas?

LITERATURE REVIEW

The literature regarding homes and the various approaches to examine their energy consumption are numerous, and help to display the evolution of energy use in homes. While some have simply considered the energy usage in homes, others have conducted research similar to this study where the impacts of codes on energy consumption were studied.

Improvements to the building envelope are important as the envelope is likely to be addressed by a building code. Cooperman, Dieckman, and Brodrick (2011) report that energy consumption can be reduced by 40% through window sealing, improved insulation, and roofing.   Another study by Zhai, Abarr, Al-Saadi, and Yate (2014) also considered the building envelope. They reported that 12% of energy use goes to space heating, 12% goes to air conditioning and refrigeration, and 29% goes to other electrical needs, so controlling the envelope is a key question for reduced energy consumption. While they considered more extreme improvements on the envelope these studies demonstrate the reduction in energy possible.

Research conducted by Suter and Shammin (2013) took a different approach to observe the rate of saving energy through people's reaction to energy saving methods. They tested how much energy was saved by bringing energy consumption to the attention of the homeowners through incentives and programmable thermostats. Homes were equipped with better roof insulation and programmable thermostats in different areas to isolate the separate factors. Some people were informed of the effort to save energy and ways to achieve energy conservation. Another group was not informed of the test, and the last group was informed and offered financial incentives to save energy. The largest saving was achieved though offering financial incentives. The group of informed individuals achieved substantial savings but not to the same degree as the incentives group (Suter & Shammin, 2013). This study supports the results of others that a few changes to a house could make a difference in energy use.

Extreme improvements to a building's performance likely carry a large price tag, but changes that are typically implemented in building codes tend to be smaller which reduce the potential cost. Sadineni, France, and Boehm (2011) investigated the economic feasibility of energy efficient measures in residential buildings. They applied some basic upgrades to homes in the Southwest United States and calculated the payback period. The basic energy upgrades included upgrading the wall's R-Value to 17, window's U-Value to .65, Door's R-Value to 7, reducing the effective leakage area to 54.9 F-hr-ft^2/BTU, using a 15 SEER air conditioner, and increasing the attic R-Value. From the research they determined that these basic energy efficiency upgrades had a payback period of less than 10 years (Sadineni, France, & Boehm, 2011).

In addition to the building envelope, home appliances are also a large contributor to energy consumption, and can carry a significant price tag. McNeil and Bojda (2012) looked at the effectiveness of high energy efficient appliances. The cost effectiveness was evaluated for different appliances, including: refrigerators, electrical water heaters, gas water heaters, central air conditioning, unit air conditioning, and electric cooktops. This study produced results indicating the following savings by using more efficient appliances: 27% for refrigerators, 17% for room air conditioning, 53% for electric water heaters, 23% for central air conditioning, and 11% for gas water heaters (McNeil & Bojda, 2012). While more efficient appliances are more expensive, they can relate to substantial savings in energy consumption. While heating, ventilation, and air conditioning systems have code based requirements, other household appliances do not, as such appliances represent an option for additional improvement in the building codes.

While many studies have looked at specific improvements to increase energy efficiency, others have looked at building codes holistically to evaluate their effects. These studies have used a variety of methodologies but are all consistent in identifying a decreased level of energy usage. Raheem, Issa, and Olbina (2012) studied the potential energy savings of the proposed 2012 International Energy Conservation Code (IECC) for residential construction. They compared the 2012 IECC to the Florida Energy Efficiency Building Code (FEEBC). They conducted this examination by using Building Information Modeling (BIM) and running computer simulations to analyze the energy consumption on a model of the home before and after the IECC changes. The results showed that a residence in Miami was capable of saving 13.6% of Kwh per year which amounted to between $250 and $430 in savings per year. A simulation can be argued to inaccurately portray accurate consumption, but other studies using actual homes have been completed.

Jacobsen and Kotchen (2013) conducted a study in which they focused on how energy code changes translate to actual energy consumption in Florida. They reported a 6.4% reduction in natural gas consumption and electricity reductions between four and eight percent during hotter months. The study identified three major changes in the building code that would have the most influence on energy use. First, the use of an electric heat pump instead of older electric resistance heaters. Second, air distribution system requirements were changed from "leak free" system to a "leaky" (allowing homes to gain points for a leak- free system). The last significant change was an increase in the minimum solar heat gain coefficient in windows from .61 to .4 (Jacobsen & Kotchen, 2013).

In a study that used IECC 2003 and IECC 2006 as a standard to base their experimentation. Koirala, Bohara, and Li (2013) estimated the effect of IECC 2003 and IECC 2006 on energy consumption using the American Community Survey 2007. They report that homes could save roughly 1.8% of electricity and 1.3% of natural gas. Aroonruengsawat, Auffhammer, and Sanstad (2012) went on to study what kind of impact state building codes could have on residential electricity use. They measured the savings of electricity per capita to range from 0.3% to 5% depending on which state was analyzed. They reported that the main problem was that even if states created energy saving building codes, enforcing the codes became a problem.

The actual cost of increasingly strict building codes has also been researched. Home Innovation Research Labs (Home Innovation Research Labs [HIRL], 2015) conducted a study to determine the change in construction cost for a homoe, after a new building code has been adopted. HIRL selected four baseline homes to use for their study. Those four model types were: One-story house with slab foundation, Two-story house with slab foundation, One-story house with basement foundation, and Two-story house with basement foundation. These four types of houses were constructed under the 2012 International Residential Building Code (IRC). The study reported that based on the average square footage of the homes (2,607) the cost to construct under the 2012 code was $246,453. In the 2015 International Residential Building Code, 49 building code changes were identified. While some of the changes from 2012 to 2015 reduced the cost of construction, the overall difference was an increase of about $10,838, on a 2,600 square foot home.

While these studies have reported and drawn conclusions about the effects of building processes and codes on energy consumption, or reductions thereof. This study is unique as it empirically compares the incremental improvements available from one code to subsequent versions that were adopted.

The city of Georgetown adopted four different building codes over the course of twenty years, and the chance an energy savings occurs is very likely.

METHODOLOGY

This study used a quantitative approach to empirically compare building codes and their effect on electricity use. Utilizing empirical data a sample of homes from each of the different building code periods were compared. ANOVA was used to make comparisons of the electrical consumption data, other appropriate statistical tests were conducted as well and are detailed in the analysis section.

Actual electricity consumption in Kilowatt hours for the year 2014 is the data used for comparison. Because the City of Georgetown has officially adopted four different building codes, since implementing smart-meter use, a sample of over 400 homes was identified. Those 400+ were then broken into groups of 100 homes based on the time period they were built and the building codes in effect at that time in Georgetown. The four building codes include: First was the 1985 Southern Standard Building Code (SSBC) which was adopted in January 1987. The second was the 1994 Southern Standard Building Code with appendix C that adopted the 1992 CABO One and Two-Family Dwelling Code, along with the 1993/94 Book of Amendments which was adopted in September 1995. The third was the Amendments to 1992 CABO One and Two-Family Dwelling Code to Adopt and add energy conservation standards that were adopted in April 1999. The fourth and current code in Georgetown is the 2000 International Residential Code that was adopted in February of 2012. Table 1 summarizes the codes adopted and their time periods.

Table 1. City of Georgetown Adopted Building Codes

Code	Years of Use
1985 Southern Standard Building Code (SSBC)	1987 – 1995
1994 Southern Standard Building Code with appendix C that adopted the 1992 CABO One and Two-Family Dwelling Code, along with the 1993/94 book of amendments	1995 – 1999
Amendments to the 1992 CABO One and Two-Family Dwelling Code to Adopt and add Energy Conservation Standards	1999-2012
2000 International Residential Code	2012-present

Homes were filtered by their respective building code based on the construction date. If a building code was adopted in 1999, only homes built in the following year were included in the sample to ensure the home was built under the intended building code. To further ensure that homes were categorized under the correct building code, the date used was the date in which the certificate of occupancy was obtained.

The study was designed to mitigate the effects of uncontrolled variables, and to ensure that the sample could appropriately be compared, certain delimitations were imposed. electricity consumption varies greatly based on homeowner habits and uses. To avoid a skewed analysis from individual homeowner habits, sample groups of 100 were used. As a result an average electric consumption for those 100 homes could be determined and used for comparison. To ensure the homes in each group were comparable, the study was delimited to electricity consumed at the sample homes in 2014. Only homes between 1600 – 2000 square feet that were constructed between 1991 and 2013 were included in the groups, and homes that had undergone a major renovation were disqualified.

Data from the city of Georgetown was used because the utility data was readily available, but also because the researchers considered it to be a more accurate representation of electrical consumption. The City of Georgetown has used smart electrical meters since the early 1990's, as a result actual electrical use at each home was available and considered highly accurate because it was not subject to error by meter readers or average use calculations used by some utility companies. The electrical consumption data was obtained from Georgetown Utility Systems. The data provided was already broken down into Kilowatt hours consumed per month, average monthly Kilowatt hour use, and average Kilowatt hour use per square foot.

Which homes were selected for use was a multistep process. First groups of 125 homes were identified using the website www.realtor.com. The website provided build dates that allowed the researchers to initially identify each group and which building code period homes were built under. Using realtor.com also allowed the researcher to verify that the homes selected were in areas of the city serviced by Georgetown Utility Systems (not all of the City of Georgetown is serviced by one utility company). When build dates and utility service were confirmed, data from the Williamson County Appraisal District was used to verify that the information gathered from www.realtor.com., Specifically that the square footage of each home chosen, met the delimitations of the project. Further the Williamson County Appraisal District allowed the researchers to verify that no major renovations had taken place in the selected homes. By using a group of 125 homes, the researchers were able to remove any homes that did not meet the requirements set forth or for which electrical consumption data was not available, and still have sample groups of 100 homes.

The Hypothesis tested was:

$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4$ $\qquad$ $H_a: \mu_1 \neq at\ least\ one\ other\ \mu$

Where μ is the average monthly electricity use for the homes in each of the building code periods. The tests were conducted with 95% certainty. ANOVA was used because it is robust in cases of unequal variance or non-normal data.

ANALYSIS AND RESULTS

To test the hypothesis an ANOVA test was conducted to compare the mean electrical consumption in Kwh for homes in the four separate groups (each building code period) in 2014. Figure 1 displays a box plot depicting the difference in the group averages. One way ANOVA Tests were performed to compare the mean electrical use per square foot in Kw for each period to allow for consideration of home sizes. ANOVA Tests were also performed comparing the electrical use in Kwh for each month in 2014 to explore if there was any relation to building code and electrical consumption in different seasons of the year. In addition to the ANOVA tests Tukey HSD tests were conducted to determine where the differences between the groups existed. Games-Howel post hoc tests were conducted in addition the Tukey HSD because the assumption of equal variances was violated (Morgan, Leech, Gloeckner, Barrett, 2007).

A statistically significant difference was found among the four building code periods on electrical consumption in Kw, F (3, 396) = 18.490, p = .000. Table 2 shows that the mean electrical consumption for the 1985 SSBC is 983.5 Kw, 854.2 Kw for the 1994 SSBC, 853.9 Kw for the Amended 1992 CABO, and 635.7 Kw for the 2000 IRC. Table 3 displays the ANOVA results. Post hoc Tukey HSD Tests indicate that the 1985 SSBC differed significantly from all other code periods (1994 SSBC p = .034, Amended 1992 CABO p = .033, and 2000 IRC p = .000). The 2000 IRB was also significantly different from all other code periods (1985 SSBC p = .000, 1994 SSBC p = .000, and Amended 1992 CABO p = .000). The 1994 SSBC however was not statistically different than the Amended 1992 CABO.

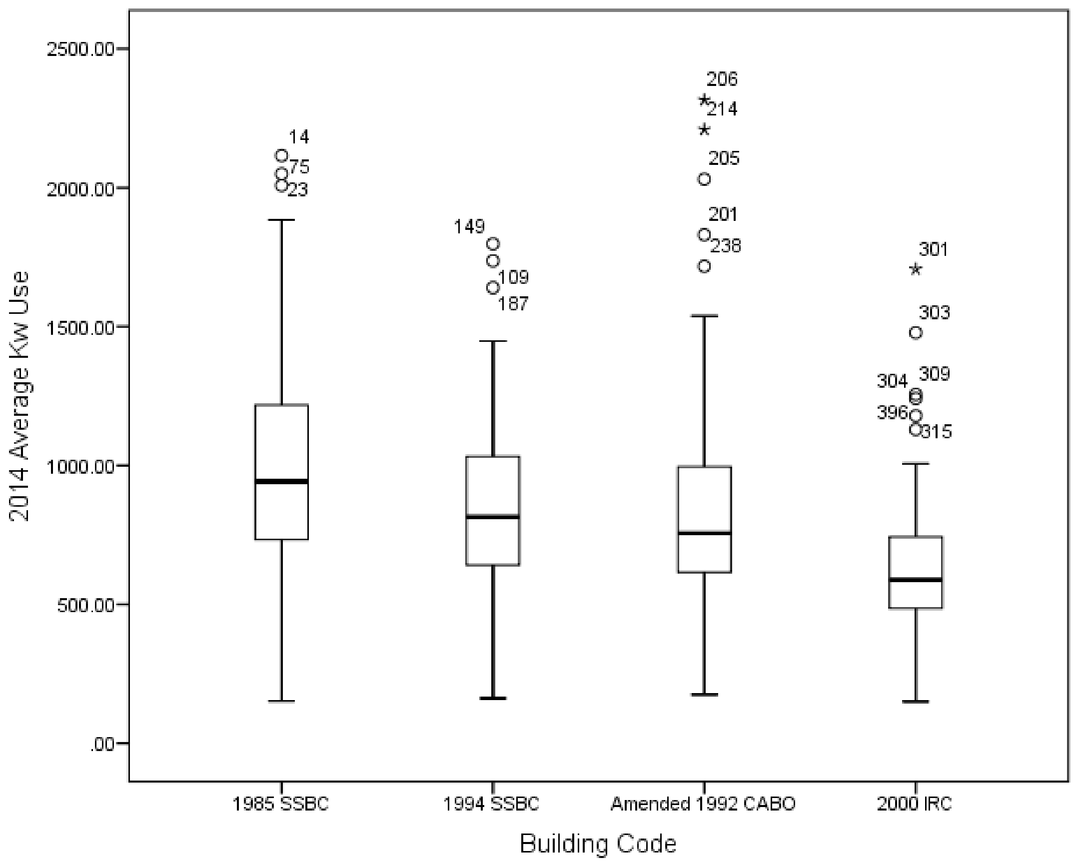

Figure 1. Boxplot of Electrical Consumption Data.

Table 2. Means and Standard Deviations Comparing Average Monthly Electrical Consumption in Different Code Periods and Monthly Electrical Consumption Per Square Foot.

Building Code	*n*	Average Kwh consumption		Average Kwh consumption Per Square Foot	
		M	*SD*	*M*	*SD*
1985 SSBC	100	983.54	368.63	0.56	0.22
1994 SSBC	100	854.17	313.98	0.48	0.18
Amended 1992 CABO	100	853.86	388.38	0.48	0.21
2000 IRC	100	635.68	255.36	0.36	0.20
Total	400	831.81	356.99	0.47	0.20

Table 3. One-Way Analysis of Variance Summary Table Comparing Building Code Periods on Average Monthly Kwh Consumption and Monthly Kwh Consumption Per Square Foot.

Source	*df*	SS	*MS*	*F*	*p*
2014 Average Kwh consumption					
Between groups	3	6247514.19	2082504.73	18.49	.000
Within groups	396	44600902.75	112628.54		
Total	399	50848416.93			
2014 Kwh consumption/SqFt					
Between groups	3	2.04	.68	19.18	.000
Within groups	396	14.04	.04		
Total	399	16.08			

A Games-Howell post hoc comparison showed slightly different results than the Tukey HSD. The 2000 IRC remained significantly different than all other code periods (1985 SSBC *p*=.000, 1994 SSBC *p* = .000, and Amended 1992 CABO *p* = .000), and the 1994 SSBC and the Amended 1992 CABO had no significant difference. However, using the Games-Howell, the 1985 SSBC was significantly different from the 1994 SSBC (*p* = .041), and 2000 IRC (*p* = .000), but not from the Amended 1992 CABO (*p* = .076).

A statistically significant difference was also found among the four building code periods on average monthly Kwh consumption per square foot F(3,396) = 19.182, p = .000. Table 2 shows that the mean Kwh consumption square foot for the 1985 SSBC is 0.56 Kwh, 0.48 Kwh for the 1994 SSBC, 0.48 Kwh for the Amended 1992 CABO, and 0.36 Kwh for the 2000 IRC. Table 3 displays the ANOVA results. Post hoc Tukey HSD Tests indicated the same building codes had statistically significant differences as in the comparison of Kwh use. The 1985 SSBC differed significantly from all other code periods (1994 SSBC *p* = .021, Amended 1992 CABO *p* = .026, and 2000 IRC *p* = .000). The 2000 IRB was also significantly different from all other code periods (1985 SSBC *p* = .000, 1994 SSBC *p* = .000, and Amended 1992 CABO *p* = .000). The 1994 SSBC again, was not statistically different than the Amended 1992 CABO.

A Games-Howell post hoc comparison was also conducted, because of unequal variance, and showed slightly different results than the Tukey HSD. The 2000 IRC remained significantly different than all other code periods (1985 SSBC *p*=.000, 1994 SSBC *p* = .000, and Amended 1992 CABO *p* = .000), and the 1994 SSBC and the Amended 1992 CABO had no significant difference. However, using the Games-Howell, the 1985 SSBC was significantly from the 1994 SSBC, but not from the Amended 1992 CABO (1994 SSBC *p* = .036, Amended 1992 CABO *p* = .062, and 2000 IRC *p* = .000).

These comparisons indicate a substantial average reduction in Kwh consumption through the adoption of the 1994 SSBC and 2000 IRC building codes, but no significant change in the adoption of the Amended 1992 CABO (from the 1994 SSBC). While the adoption of the Amended 1992 CABO resulted in no significant difference in electricity consumed (compared to the 1994 SSBC), the 1994 SSBC is related to an average reduction of 14% in electrical use, over the 1985 SSBC. An even larger reduction (25%) in electrical use is seen from the adoption of the 2000 IRC over the 1994 SSBC or Amended 1992 CABO.

The previous tests compared the average electrical consumption for one year. To explore the effects of the codes on electrical consumption in different times of the year, the monthly data was also tested using ANOVA. Analysis of the monthly data was performed to look for any significant differences in use related to seasons. Table 4 displays the means and standard deviations for each month under each building code in 2014. The results of the ANOVA are shown in table 5.

Table 4. Means and Standard Deviations Comparing Monthly Electrical Consumption in Different Code Periods.

		1985 SSBC		1994 SSBC		Amended 1992 CABO		2000 IRC	
Month	*n*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Jan	400	741.18	377.38	567.21	266.02	628.08	380.87	486.29	252.64
Feb	400	743.54	348.30	703.63	292.53	744.59	376.99	629.28	256.96
Mar	400	1057.07	416.68	1011.54	336.03	959.05	437.66	792.84	315.12
Apr	400	1538.18	538.89	1463.56	484.49	1347.72	571.39	1094.22	353.00
May	400	1477.09	538.05	1351.09	505.01	1237.82	544.97	981.66	425.43
Jun	400	1390.63	565.86	1190.56	471.66	1074.62	519.20	821.86	364.92
Jul	400	1093.62	448.29	915.20	419.95	863.93	475.03	601.50	306.113
Aug	400	784.60	359.38	659.13	324.50	660.21	393.19	471.59	243.51
Sep	400	644.92	311.24	535.99	277.85	576.19	331.04	415.69	221.21
Oct	400	683.40	392.33	542.62	278.42	615.26	377.00	414.47	270.41
Nov	400	807.25	573.03	631.43	367.38	769.32	517.19	461.85	329.51
Dec	400	867.18	582.04	677.15	417.06	769.27	526.06	456.46	365.02
Total		11829		10249		10246		7628	

Table 5. One-Way Analysis of Variance Summary Table Comparing Building Code Periods on Monthly Kwh Consumption.

Source	*df*	SS	*MS*	*F*	*p*
January					
Between groups	3	2782621.26	927540.42	8.79	.000
Within groups	396	41784441.30	105516.27		
Total	399	44567062.56			
February					
Between groups	3	878782.460	292927.49	2.82	.039
Within groups	396	41089010.50	103760.13		
Total	399	41967792.96			
March					
Between groups	3	3992726.21	1330908.74	9.22	.000
Within groups	396	57160599.54	144344.95		
Total	399	61153325.75			
April					
Between groups	3	11325920.72	3775306.91	15.47	.000
Within groups	396	96646152.72	244055.94		
Total	399	1.080E8			
May					
Between groups	3	13337589.53	44445863.18	17.39	.000
Within groups	396	1.012E8	255626.28		
Total	399	1.146E8			
June					
Between groups	3	16916475.72	5638825.24	23.86	.000
Within groups	396	93594053.55	236348.62		
Total	399	1.1.5E8			
July					
Between groups	3	12416977.36	4138992.456	23.76	.000
Within groups	396	68971401.07	174170.21		
Total	399	81388378.43			
August					
Between groups	3	4998519.39	1666173.13	14.87	.000
Within groups	396	44387038.09	112088.48		
Total	399	49385557.47			
September					
Between groups	3	2774608.27	924869.42	11.12	.000
Within groups	396	32926527.13	83147.80		
Total	399	35701135.39			
October					
Between groups	3	3970025.73	1323341.91	11.85	.000
Within groups	396	44222089.71	111671.94		
Total	399	48192115.43			
November					
Between groups	3	7349033.67	2449677.90	11.67	.000
Within groups	396	83099003.77	209845.97		
Total	399	90448037.43			
December					
Between groups	3	923723.85	3078574.62	13.35	.000
Within groups	396	91346072.06	230671.90		
Total	399	1.006E8			

A statistically significant difference was found among the four building code periods on Kwh consumption in every month (See Table 5), so a Tukey HSD was performed to explore the interactions in each month. Subsequently, because the assumption of equal variance was violated Games-Howell tests were also performed. The researchers point out however that while 11 or the 12 months were significantly different at $p = .000$, February did not show the same strong p value [F(3,396) = 2.82, p = .039]. As a result the researchers anticipated differences in February.

The Games-Howell and Tukey HSD generally agreed with each other in the month to month statistically significant differences. The Games-Howell indicated a statistically significant difference between the 1985 SSBC and the 2000 IRC ($p = .044$) in February, but the Tukey HSD did not produce a statistically significant difference ($p = .060$). Because the data violated the assumption of equal variance, the Games-Howel is the more reliable statistic. Not surprisingly, the 1985 SSBC had a statistically significant difference from the 2000 IRC every month.

The electrical consumption by month had statistically significant differences between the building codes in most months over the course of a year. And while a comparison between the 1985 SSBC and the 2000 IRC has value, differences between the 1994 SSBC and the amended 1992 CABO when compared to the 2000 IRC have even greater value. For the 1994 SSBC and the Amended 1992 CABO, there was a statistically significant difference from the 2000 IRC in all but the coldest months. The 1994 SSBC had no statistically significant difference in electrical use from the 2000 IRB in January ($p = .125$) or February ($p = .227$) of 2014. The Amended 1992 CABO had no statistically significant difference in electrical use from the 2000 IRB in February ($p = .059$), but did have a statistically significant difference in January ($p = .012$). In 2014, February was the coldest month of the year in Georgetown, TX. As a result it is likely that the cold is related to the lack of a significant difference between the electrical use from each code period to the next.

Table 6. Games-Howell & Tukey significance to the 2000 IRB.

Month	1985 SSBC			1994 SSBC			Amended 1992 CABO		
	Mean Δ	*G-H p*	Tukey *p*	Mean Δ	*G-H p*	Tukey *p*	Mean Δ	*G-H p*	Tukey *p*
January	-277.9	.000	.000	-80.9	.125	.294	-141.8	.012	.012
February	-114.3	.044	.060	-74.4	.227	.362	-115.3	.059	.057
March	-264.2	.000	.000	-218.7	.000	.000	-166.2	.013	.011
April	-434.0	.000	.000	-369.3	.000	.000	-253.5	.001	.002
May	-495.4	.000	.000	-369.4	.000	.000	-256.2	.002	.002
June	-568.8	.000	.000	-368.7	.000	.000	-252.8	.001	.000
July	-492.1	.000	.000	-313.7	.000	.000	-262.4	.000	.000
August	-313.0	.000	.000	-187.5	.000	.001	-188.6	.000	.000
September	-229.2	.000	.000	-120.3	.005	.018	-160.5	.000	.001
October	-268.9	.000	.000	-128.1	.006	.035	-200.8	.000	.000
November	-345.4	.000	.000	-169.6	.004	.045	-307.5	.000	.000
December	-410.7	.000	.000	-220.7	.000	.007	-218.8	.000	.000

On homes in the central Texas town of Georgetown, in 2014, statistically significant differences exist between average yearly Kwh consumption, average yearly Kwh consumption per square foot, and average Kwh consumption in most months when comparing one building code period to another. The study showed that there was a reduction in electrical use by homes built under newer building codes in The City of Georgetown. There was only one change in building code that did not result in a significant savings of electricity use in Georgetown homes. The 1994 Southern Standard Building Code containing appendix C with the 1992 CABO one and two family dwelling code did not have a significant savings after the adoption of amendments to 1992 CABO to add energy conservation standards. As should be expected, the savings were most substantial when comparing the oldest building code (1985 SSBC) to the newest building code (2000 IRC). The potential impacts of these differences are discussed in the conclusions.

CONCLUSIONS

This results of this study indicate that adoption of new building codes are an effective method to significantly reduce electrical consumption. However it also indicates that the differences between codes can be insignificant. While the 1985 SSBC and 2000 IRC were significantly different from the 1994 SSBC and the Amended 1992 CABO, The 1994 SSBC and the 1992 CABO were not significantly different in the electricity consumed by homes built under those code periods. The lack of a significant difference between the 1994 SSBC and the Amended 1992 CABO relating to electrical consumption is particularly interesting because the Amended 1992 CABO specifically included energy conservation standards. Never the less, average annual Kwh consumption in 2014, was less than one Kwh different from the 1994 SSBC to the Amended 1992 CABO. In comparing the average monthly usage data there was again no statistically significant difference, but there was some practical significance from one month to the next. In 2014 homes built under these two codes averaged a 75 Kwh difference per month. However that difference was split with homes built under the 1994 SSBC using less electricity in six months, homes built under the Amended 1992 CABO using less electricity in five months, and one month where the consumption was essentially the same. The interesting finding here is that the months where homes under each code used less than the other were not random, rather the 1994 SSBC homes performed better in the colder months, while the Amended 1992 CABO homes performed better in hotter months. Because Georgetown is a cooling dominated climate, a decision to adopt the Amended 1992 CABO with energy conservation standards is understandable as refrigerated air conditioning makes up a considerable chunk of home electricity consumption. However the data indicates that decision to change from the 1994 SSBC to the Amended 1992 CABO, and the related costs did not net the city a reduction in electricity consumption.

Electrical usage in February of 2014 was not significantly different between the 2000 IRC and the 1994 SSBC and the Amended 1992 CABO. And the mean difference between the 2000 IRC and 1985 SSBC only amounted to a difference of 114 Kwh, that was just barely statistically significant (p = .044). Normally January is the coldest month of the year in Georgetown, however in 2014, February was the coldest month. These findings indicate that while the changes in the 2000 IRC have had a positive impact in reducing the electrical consumption in warmer months, in colder months the code changes have little impact in reducing the electrical usage. As previously indicated, Georgetown has a cooling dominated climate, where more days each year requiring space cooling than space heating, so the consumption and use of electricity is lowest in winter months. As a result, adopting a code that provides a greater reduction in electrical use in warmer months is an appropriate strategy for this region. However, it is important to note that the building codes as implemented in Georgetown would likely be ineffective in reducing electrical consumption in a heating dominated climate.

This study did not consider the specific differences from one code to the next. However based on these findings the authors assert that the changes implemented between these codes have probably done little to affect the building envelope. In Georgetown space heating is predominantly accomplished via a natural gas fired furnace. Lighting, and appliance usage does not change significantly with seasonal temperature change, so the fundamental change from warmer months to cooler months is the energy source used for space cooling and heating, electricity is used in the summer for air conditioning and natural gas in winter for heating. As a result the authors believe that the primary cause of reduced electrical consumption has resulted from the installation of air conditioning systems with higher SEER (Seasonal Energy Efficiency Rating). So in seasons when the air conditioner is in use, a reduction in electrical usage in Kwh is seen, but in seasons when the air conditioner is not in use or used only minimally little change in electrical consumption is observed.

The City of Georgetown adopted the 2012 IRC in January of 2015, so at the time of this study, there was not electrical consumption data for homes built under that version of the code that could be compared to homes built under previous building codes. The authors intend to revisit this research in 2017 when a year's worth of electrical consumption data can be collected from homes built under the 2012 IRC and compared to homes built under the previous codes. Based on the percentage decreases in electrical consumption from the 1985 SSBC to the 1994 SSBC and Amended 1992 CABO (14%) and from the 1994 SSBC and Amended 1992 CABO to the 2000 IRC (25%) it is expected that the 2012 IRC could achieve a statistically significant reduction in electricity consumption from the 2000 IRC.

Without a return on investment increases in energy efficiency are challenging to implement. To consider the effects of reduced electricity use from building code in Georgetown some basic calculations were performed based on current residential electricity rates. In Georgetown the rate for residential electricity is $0.094/Kwh. So in the average home built under the 2000 IRC a home owner could expect to spend $246 less each year than owners of homes built under the 1994 SSBC or Amended CABO, and $395 less each year than owners of homes built under the 1985 SSBC.

Because of the variance in building code performance in colder and warmer months, the difference ranges from $10/month to $53/month, and averages to about $33 a month over a year. If homes built under the 2012 IRC have a reduction of 15% the difference in utility cost could equal over $40/month when compared to homes built under the 1985 SSBC. If an average reduction in electrical use like that seen from the 1994 SSBC and Amended 1992 CABO to the 2000 IRC (25%) occurred from the adoption of the 2012 IRC it could equate to $575 a year in savings to the homeowner. Table 7 displays these rates and projections.

Table 7. Actual and Projected Electricity Costs from one Building Code to another in 2014.

Month	1985 SSBC	1994 SSBC	Amended 1992 CABO	2000 IRC	2012 IRC 15% Reduction	2012 IRC 25% Reduction
Jan	$69.97	$53.21	$59.04	$45.71	$38.85	$34.28
Feb	$69.89	$66.14	$69.99	$59.15	$50.28	$44.36
Mar	$99.36	$95.08	$90.15	$74.53	$63.35	$55.90
Apr	$144.59	$137.57	$126.69	$102.86	$87.43	$77.14
May	$138.85	$127	$116.36	$92.28	$78.43	$69.21
Jun	$130.72	$111.91	$101.01	$77.25	$65.67	$57.94
Jul	$102.80	$86.03	$81.21	$56.54	$48.06	$42.41
Aug	$73.75	$61.96	$62.06	$44.33	$37.68	$33.25
Sep	$60.62	$50.38	$54.16	$39.07	$33.21	$29.22
Oct	$64.24	$51.01	$57.83	$38.96	$33.12	$29.22
Nov	$75.88	$59.35	$72.32	$43.41	$36.90	$32.56
Dec	$81.51	$63.65	$72.31	$42.91	$36.47	$32.18
Total	$1,111.89	$963.42	$963.13	$717.00	$609.45	$537.75

Beyond the value of $30 or $40 monthly in a home owner's pocket, these savings in electrical utility expenses are important as they can serve as an argument for buyers of newer homes, built to more stringent codes, being able to qualify for a larger mortgage as they have more money available. By through decreased monthly utility costs homeowners would have more money available for a mortgage payment. These results represent averaged electrical usage numbers because the individual behaviors of occupants cannot be controlled, but nonetheless these results provide an empirically supported baseline.

Beyond the cost savings to the homeowner, for a utility provider that is directly tied to the municipality, like in Georgetown, these results provide empirical evidence supporting the adoption of the most up to date building codes. A statistically significant reduction in electrical usage related to a building code is data a municipality should consider in considering the adoption of building codes. Further this information has value as utility providers can better estimate electrical demand and cater generation to meet the demand.

This study represents a primary foray into electrical consumption in central Texas as it relates to building codes. As a result there are many areas that should be further researched. A few of those topics include: The comparison of these results to similar data from other climate zones. Analysis of homes built to the 2012 IRC and their electricity consumption. An analysis of the building code changes to define the changes that have led to reduced energy consumption. An understanding of the factors that lead municipalities to adoption, or not, new building codes. An evaluation of water and natural gas consumption in the same code periods to explore overall effects on energy consumption in homes.

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