Demographic, Seasonal, and Housing Characteristics Associated with Residential Energy Consumption in Texas, 2010

Lila Valencia, Carlos Valenzuela, Jeff Jordan, Steve White, Lloyd Potter
Institute for Demographic and Socioeconomic Research, The University of Texas at San Antonio

Introduction

In 2008, the United States led the world's nations in electricity consumption, with a net electricity consumption of 3,906.44 billion kilowatt hours, and in 2009, only China had higher carbon dioxide (CO2) emissions than the U.S. (U.S. Energy Information Administration, 2010). In 2008, Texas ranked fifth among U.S. states in total per capita energy consumption, with an estimated 475 million Btu. Unfortunately, there is limited data on energy consumption at county and place levels.

Energy consumption comes at a high cost, both environmentally as well as fiscally. In 2007, Texas spent the most of any state in energy expenditures, totaling over $140 billion (U.S. Census Bureau, 2010). California ranked second at $121 billion even though California has a greater population than Texas. Texas had the fifth highest per capita energy expenditures in the country. In 2007, Texas residents spent $5,899 in per capita energy expenditures. During the same year, Texas residents paid $123.41 per 1,000 kilowatt hours, compared to the U.S. average of $106.52. Also in 2007, Texas residents paid $12 per 1,000 cubic feet of natural gas, which was lower than the national average of $13.04 per 1,000 cubic feet (U.S. Census Bureau, 2010).

Increasingly, energy efficiency is being identified as a means to improve the economy, national security, and technological innovation in the U.S. The American Recovery and Reinvestment Act (ARRA) of 2009 included the largest investment in energy efficiency in U.S. history. According to the American Council for an Energy Efficient Economy (ACEEE), more than $11 billion of ARRA was used by states to fund and create new energy saving programs in 2010 (Molina et al., 2010). Between 2007 and 2009, states increased their budgets for energy efficiency and almost doubled their spending, increasing from $2.5 billion to $4.3 billion. The period between 2007 and 2008 saw an increase of 8 percent in reported electricity savings across all states. However, the movement toward energy efficiency is not uniform across all states. The ACEEE's State Energy Efficiency Scorecard compiles data on six efficiency indicators: 1) utility and public benefits programs and policies, 2) transportation policies, 3) building energy codes, 4) combined heat and power, 5) state government initiatives, and 6) appliance efficiency standards and ranks states based on their performance on these measures (Molina, et al., 2010). In 2010 California ranked first in investment in energy efficiency in all sectors assessed by the ACEEE methodology. The remaining top ranking states are found mostly along the West and Northeast coasts of the U.S., with the exception of Minnesota. In this same report, Texas was ranked 32, with the lower ranking being mostly due to lower scores in transportation policies and appliance efficiency standards. However, the ACEEE report also highlighted that Texas has had a longstanding steady decline in residential natural gas consumption since 1980. While the decrease in residential natural gas consumption has historically been offset by increased residential electricity consumption, the electricity trend has begun to plateau in the last decade. Additionally, a number of energy efficiency related bills were passed in the 82nd Texas (most recent) legislative session, including a bill that requires additional energy efficiency analysis by counties, state agencies, and higher education institutions.

In a report produced by the Energy Systems Laboratory at Texas A&M University, it is estimated that if single-family, electric/gas residences located in Climate Zone 2, are compliant with the 2009 International Energy Conservation Code (IECC), relative to the 2001 and 2006 IECC, the annual energy and cost savings would range from 9.5 to 17.5 MMBtu per year and $432 to $462 per year (Kim, Baltazar, & Haberl, 2011).

Research Rationale

This study will focuses on residential energy (gas and electric) consumption in a Texas County, in 2010. The main research aim of this study is to investigate the relationship between energy consumption and its demographic, socioeconomic, and structural determinants. Understanding the determinants of energy consumption has implications for public policymakers that hope to influence household energy consumption and increase energy efficient behaviors. Additionally, understanding the influence of demographic and socioeconomic characteristics on energy consumption has implications for groups interested in influencing pro-environmental behaviors in other areas, such as water use, public transit, and recycling.

The unit of analysis for this study is the census tract. Data come from within a large urbanized area in Texas that contains over 600,000 housing units. A little over 38 percent of households included individuals who are under 18 years of age, and 21.1 percent were households with individuals 65 years and over. In 2010, the average household size was 2.75 individuals, and the average family size was 3.33 individuals.

The study uses data from three sources: 1) the county tax appraisal district (CAD), 2) a local energy company, and 3) the U.S. Census Bureau (both census and American Community Survey). CAD data serves as the foundation of the database with each housing unit being a record. Data from CAD on housing structural characteristics, such as type of household structure (e.g., apartment or house), year built, and number of bedrooms are used. The local energy company provided energy consumption data at the housing unit level for approximately 630,000 units. The Census Bureau's American Community Survey (ACS) 5-Year Estimates is used estimate demographic and socioeconomic characteristics shown to be associated with energy consumption. These data will are aggregated the census tract level.

Energy consumption is aggregated at the census tract level and electricity and natural gas consumption is converted into site kBTUs. The analytic sample for the census tract level analysis consists of 352 out of 354 tracts[1]. Two tracts consisted of areas with high concentration of businesses and, thus, not suitable for analysis[2]. Demographic variables were gathered from the

[1] Special population tracts were removed as well.
[2] In addition, those tracts consisted of less than 10 housing units from the individual sample.

U.S. Census 2010 Summary File 1. The following variables among owner occupied housing units in the Texas County were derived: average household size, proportion head of householders aged 65 years and older, proportion married, proportion work from home, median household income. Housing unit characteristics were aggregated from the merged dataset used in the individual level analyses, taking median housing unit size (in square footage) and proportions of housing units built with slab foundation, housing units built with masonry wall type, and housing units with pools. Descriptive statistics for dependent and independent variables are shown on Table 3.1.

Results

The average monthly kBTU consumption per housing unit in census tracts was highest during the winter, followed by, summer and non-seasonal months. On average, there were 3 persons per household; over 25% were led by head of householders aged 65 years and older, 56% were occupied by married households, 1% contained a person working from home, and the median household income was about $60,000 a year. The average housing unit size was about 1,600 square feet and the majority of housing units consisted of slab foundation and masonry wall types. On average, 6% of housing units in tracts had pools.

Bivariate scatterplots showed a non-linear association between median household income and kBTU consumption per housing unit. Log-transformations of kBTU consumption per housing unit and median household income provided suitable models given the nature of the data. Diagnostics of OLS models suggested that seven tracts had high leverage values, which could lead to biased results. Four models (for non-seasonal, summer, and winter months) were constructed in a nested fashion to ascertain the contribution of demographic and housing unit variables independently. The final model for each seasonal analysis controlled for the size of census tracts, specifically number of housing units taken from the census counts, and are the only models interpreted in the following paragraphs.

Estimates from robust regression models using the Huber weight function for non-seasonal, summer, and winter months were used. “The Huber weight function behaves like the mean and the least squares objective function associated with it (i.e. observations are given equal weight), but at the extremes it behaves like the median, and the least absolute values objective function associated with it, giving decreasing weight to observations as they get further out on the tails” (Andersen, 2008: 18). Regression results provided interesting insight as to the contribution that demographic and housing unit variables provided in estimating household energy consumption per housing unit in tracts, which depended on the type of season in question.

Table 1 Descriptive Statistics for Average Monthly kBTU Consumption per Housing Unit during Non-Seasonal, Summer, and Winter Months, Demographic and Housing Unit Variables

Variable	N	Mean	Median	S.D.
Non-Seasonal kBTU/HU	352	5,666.65	5,433.41	1,343.42
Log(Non-Seasonal kBTU/HU)	352	8.62	8.60	0.21
Summer kBTU/HU	352	6,941.73	6,517.31	1,371.96
Log(Summer kBTU/HU)	352	8.83	8.78	0.17
Winter kBTU/HU	352	9,487.04	9,089.47	3,230.97
Log(Winter kBTU/HU)	352	9.10	9.11	0.33
Average HH Size	352	2.89	2.94	0.37
Proportion HOH 65+ years	352	0.26	0.28	0.11
Proportion Married	352	0.57	0.56	0.11
Median Household Income	352	62,945.07	57,944.00	29,828.59
Log(Median Household Income)	352	10.95	10.97	0.46
Proportion Working from Home	352	0.01	0.01	0.01
Median Housing Unit Size (Square Feet)	352	1,688.30	1,542.25	584.17
Proportion Slab Foundation	352	0.76	0.99	0.35
Proportion Masonry Exterior Wall	352	0.68	0.76	0.27
Proportion Pool	352	0.06	0.03	0.08

Table 7: Descriptive Statistics for Average Monthly kBTU Consumption per Housing Unit during Non-Seasonal, Summer, and Winter Months, Demographic and Housing Unit Variables

The average household size significantly contributed to higher energy consumption per housing unit during the non-seasonal and summer months, but not during the winter months. Higher proportions of head of householders aged 65 years and older in census tracts resulted in higher energy consumption per housing unit in census tracts. Census tracts with higher proportions of married households significantly consumed more energy during the summer months, but not during the winter and non-seasonal months. Though census tracts with higher proportions of people working from home led to higher energy consumption per housing unit in the first model (for all seasonal analyses), the relationship was no longer significant once housing characteristics were input into the model. As one may expect, census tracts with higher median incomes, as well as census tracts with higher proportions of housing units with pools, led to more energy consumption per housing unit. Furthermore, as the median year built increased (i.e. younger housing units), energy consumption per housing units in census tracts decreased. Interestingly, census tracts with higher proportions of housing units built on top of slab foundations significantly consumed less energy during the non-seasonal and winter months, but not during the summer months. Finally, census tracts with higher proportions of housing units with masonry exterior walls resulted in higher average monthly energy consumption per housing unit.

The variation explained in the average monthly kBTU consumption per housing unit based on demographic and housing unit characteristics depended on the type of season. Essentially, opportunities exist to reduce energy consumption in census tracts based on household demographics during the non-seasonal and summer months, whereas housing unit characteristics play a larger role in energy consumption per housing unit in census tracts during the winter months.

Table 1 Robust Regression Models Estimating (the Log of) the Average Monthly kBTU Consumption per Housing Unit in Census Tracts based on Demographic and Housing Unit Characteristics in Census Tracts during Non-Seasonal Months

	Model 1		Model 2		Model3		Model 4	
Intercept	5.85	***	14.76	***	15.16	***	15.05	***
Average HH Size	0.09	***			0.08	***	0.08	***
Proportion HOH 65+ years	1.10	***			0.24	***	0.25	***
Proportion Married	0.21				0.19		0.11	
Log(Median Household Income)	0.19	***			0.11	***	0.11	***
Proportion Working from Home	5.57	***			-0.12		0.01	
Median Year Built			-0.00	***	-0.00	***	-0.00	***
Proportion Slab Foundation			-0.11	***	-0.09	***	-0.09	***
Proportion Masonry Exterior Wall			0.14	***	0.11	***	0.11	***
Proportion Pool			1.85	***	1.61	***	1.63	***
# of Housing Units							0.00	*
R2	0.41		0.58		0.62		0.62	
AIC	554.43		642.23		621.61		652.97	

Table 2 Robust Regression Models Estimating (the Log of) the Average Monthly kBTU Consumption per Housing Unit in Census Tracts based on Demographic and Housing Unit Characteristics in Census Tracts during Summer Months

	Model 1		Model 2		Model3		Model 4	
Intercept	6.35	***	7.40	***	9.78	***	9.75	***
Average HH Size	0.03				0.06	***	0.06	***
Proportion HOH 65+ years	0.52	***			0.07		0.07	
Proportion Married	0.60	***			0.28	***	0.28	***
Log(Median Household Income)	0.17	***			0.11	***	0.11	***
Proportion Working from Home	4.26	***			0.81		0.84	
Median Year Built			-0.00	**	-0.00	***	-0.00	***
Proportion Slab Foundation			-0.04	**	-0.01		-0.01	
Proportion Masonry Exterior Wall			0.11	***	0.06	***	0.06	***
Proportion Pool			1.56	***	1.21	***	1.22	***
# of Housing Units							0.00	
R2	0.64		0.69		0.76		0.76	
AIC	518.65		444.99		472.26		455.61	

Table 4 Robust Regression Models Estimating (the Log of) the Average Monthly kBTU Consumption per Housing Unit in Census Tracts based on Demographic and Housing Unit Characteristics in Census Tracts during Winter Months

	Model 1		Model 2		Model3		Model 4	
Intercept	5.83	***	23.43	***	21.92	***	21.83	***
Average HH Size	0.05				-0.01		0.00	
Proportion HOH 65+ years	1.69	***			0.37	**	0.38	**
Proportion Married	0.01				0.32		0.25	
Log(Median Household Income)	0.24	***			0.13	**	0.13	**
Proportion Working from Home	7.65	***			0.53		0.60	
Median Year Built			-0.01	***	-0.01	***	-0.01	***
Proportion Slab Foundation			-0.18	***	-0.18	***	-0.19	***
Proportion Masonry Exterior Wall			0.35	***	0.24	***	0.24	***
Proportion Pool			2.27	***	1.72	***	1.75	***
# of Housing Units							0.00	
R2	0.39		0.56		0.57		0.57	
AIC	440.62		608.58		606.24		591.98	

Kim, H., Baltazar, J. C., & Haberl, J. (2011). *Estimates of energy cost savings achieved from 2009 IECC code-compliant, single-family residences in Texas*. College Station: Texas A&M University Energy Systems Laboratory.

Molina, M., Neubar, M., Sciortino, M., Nowak, S., Vaidyanathan, S., Kaufman, N., et al. (2010). *The 2010 state energy efficiency scorecard* Washington, D.C.: American Council for an Energy-Efficient Economy.

U.S. Census Bureau. (2010). *State and Metropolitan Area Data Book: 2010*.

U.S. Energy Information Administration. (2010). International Energy Statistics. Retrieved June 6, 2011, from http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm