Household Energy Consumption in the United States

by

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Abstract

Residential energy consumption is a major component of the American national energy profile. When addressing issues of greenhouse gas emissions, understanding what factors contribute to residential energy consumption becomes crucial. This thesis uses regression analysis to determine what these factors are and isolate for their relative impacts on the amount of energy consumed. The data comes from the 2009 Residential Energy Consumption Survey.

Geographic region, weather, dwelling characteristics, appliance characteristics, behavioral characteristics, and input prices are found to significantly contribute to household energy consumption. Dwelling characteristics, behavioral characteristics, and demographic characteristics have the greatest relative impacts on energy consumed. The effect of appliance efficiency on energy consumption is examined. Results indicate that the energy efficiency of appliances do not significantly impact the energy consumed by the household. This lays the groundwork for further research to test Jevon's Paradox using efficiency measures that go beyond appliance efficiency. Moreover, results indicate that in landlord-tenant utility agreements tenants consume more energy when they are not directly responsible for payment. This provides evidence of a principal-agent issue in landlord-tenant energy bill payment agreements.

Chapter 1: Introduction

In 2008 the American residential sector produced 1.220 billion metric tons of carbon dioxide emissions through its energy consumption (EIA, 2009). The residential sector is a major consumer of energy in the economy, and the potential for reducing emissions depends on understanding the demand for energy. In understanding what factors drive residential consumption, government officials can create the most meaningful policies.

Using regression analysis, the significant determinants of energy consumption in households are identified as geographical region, weather, dwelling characteristics, appliance characteristics, behavioral characteristics, demographic characteristics, and input prices. Within these categories important variables include the type of structure, the year of construction, the number of windows, the presence of a washer and dryer, the temperature preferences of residents in the home, the use of central air conditioning, the number of household members, income, and the price of natural gas. This thesis also concludes that, all else being equal, residence in a colder climate will cause energy consumption to be higher than residence in a warmer region.

Hypothesis testing included a preliminary examination for the presence of Jevon's Paradox in the context of appliance efficiency.[1] This thesis concludes that energy efficient fridges do not reduce energy consumption. Furthermore, the age of a refrigerator does not contribute to energy consumption. Conversely, the age of main space heating equipment does increase energy consumption on average when

[1] Jevon's Paradox theorizes that consumers substitute gains in energy efficiency for increased consumption.

the equipment is more than 5 years old. Overall, this test is conclusive about the efficiency of refrigerators being insignificant to energy consumption and lays the groundwork for further empirical testing of Jevon's Paradox.

A second test in this thesis examines the consumption decisions of those who are directly responsible for utility payments and those who have these payments included in rental agreements. This is a partial analysis of the principal-agent issue that states that without direct responsibility for energy payments, tenants have no incentive to minimize energy consumption. Hypothesis testing indicates that the principal-agent issue does exist. Further research on rental agreements is required to conclude that the entire principal-agent issue occurs.

Chapter 2 of this thesis provides the context for residential energy consumption. Chapter 3 reviews the literature and presents the policy implications for this analysis. Chapter 4 presents the methodology and data. Chapter 5 consists of empirical results obtained from regression analysis and the hypotheses tests conducted. Chapter 6 presents the conclusions of this thesis and implications for further research.

Chapter 2: Context

2.1 Importance of Emissions

Greenhouse gas emissions have become an increasingly important policy concern internationally. Emission targets are being established at conferences such as Kyoto (1997), Durban (2011), and Rio Earth Summit (2012). The United States is committed to reducing its emissions. As a signatory of the Copenhagen Accord, the US has agreed to reduce its greenhouse gas emissions by 4 per cent from 1990 levels by 2020 (Scientific American, January 29 2010). As a secondary energy consumer, the residential sector contributes to greenhouse gas emissions through consumption. The Energy Information Administration (EIA) estimates that the residential sector claimed 22% of total energy consumed in the United States, amounting to 21,619 trillion BTUs in 2011 (Figure 1). The household has a large environmental impact, and by understanding the actions of the household, emission and conservation initiatives can be better designed.

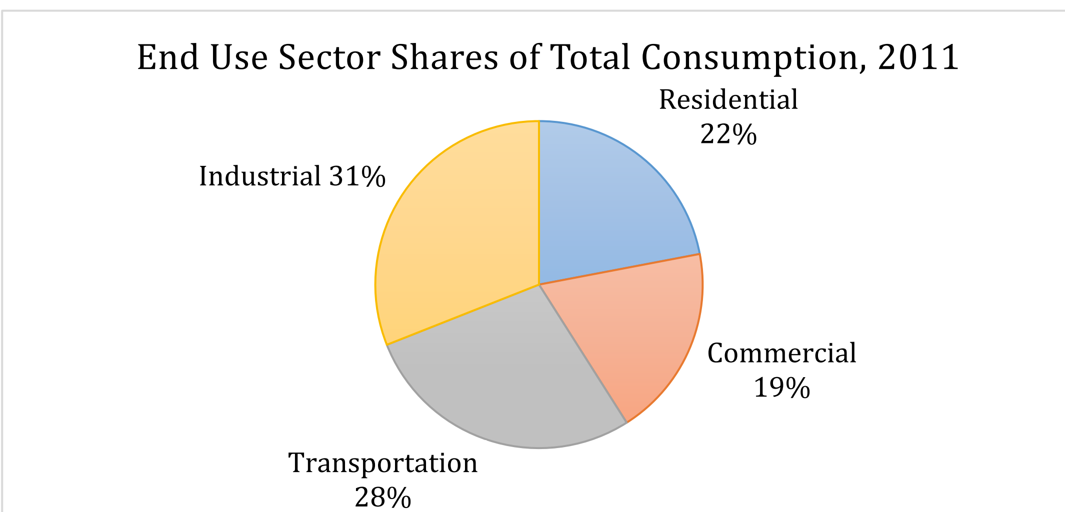

Figure 1: End-Use Sector Shares of Total Consumption, EIA (2011)

2.2 Importance of Energy Analysis

The study of energy consumption is a particularly important avenue of research as it has implications on quality of life, markets, and government. By observing what factors determine consumption, it is possible to target conservation measures, insulate consumers against price and quantity volatility, and promote sustainable practices. By understanding what factors drive consumption, it is possible to determine demand. Recent trends in “deregulation, record cold winter temperatures, unstable oil prices, and continued global warming concerns have rekindled interest in understanding the demand for electricity” (Espey and Espey, 2004). Through energy analysis, it is possible to identify the most effective and efficient avenues for policy intervention. This demonstrates the important role that the activities and preferences of the energy consumer play in understanding modern societies.

2.3 Importance of the Domestic Sector

The American residential sector is the third largest consumer of secondary energy in the economy. Between 2001 and 2011, the total amount of energy consumed by the residential consumption increased by 1,577 trillion BTU, and in 2011, it accounted for 22 percent of energy consumption (EIA, 2012a). This is significant as certain lifestyle trends, such as technology use, seem to be permanent. This indicates that greater energy consumption is a characteristic of modern societies. The American Energy Outlook (2012b) projects best and worst case scenarios until 2035 for energy use, and identifies three lifestyle trends that have contributed to the increase in household energy consumption. First, the average size of living spaces has increased. Second, the popularity of minor appliances such as computers offsets the gains in efficiency of major appliances such as furnaces. Finally, the adoption of air conditioning has made home cooling widespread. In this sense, changing lifestyles are changing traditional residential energy allocations.

Energy intensity, or household inefficiency, is projected to decrease by 19.8 percent by 2035 (EIA, 2009). This increase in efficiency is predicted to be done predominantly through the development of energy efficient space heating technologies. This demonstrates the significant potential for technological improvements to be made through dwelling upgrades. For Cheng and Steemers (2011), "the residential sector represents great potential for $C0_2$ reductions through the implementation of energy efficiency measures" (Cheng and Steemers, 2011, p.1). The domestic sector can be considered the most crucial sector, as the "wide range of lifestyles and their dynamic features influence, directly and indirectly, the throughput of energy and material cycles through[out] the entire economy" (Biesot and Noorman, 1999, p.3). Biesot and Noorman are referring to the idea that the consumption habits of the individual in the household will strongly influence their consumption habits in the workplace and the transportation sector. For these reasons, the study of household energy consumption in the United States is crucial to understanding energy demand, implementing emission targets, and explaining the energy preferences of Americans.

Chapter 3: Literature Review

This section presents research and the dominant conclusions regarding household energy use. In particular, an overall discussion of the literature and of the main determinants of household energy consumption will be provided. First, the historic developments in the study of domestic energy use and the interdisciplinary contributions to this literature are presented. Next, modelling approaches and the benefits and drawbacks of each method are explored. Finally, the broader implications of residential energy use and the most beneficial avenues for policy intervention are presented.

3.1 Traditional Efforts

Traditional efforts in energy consumption concentrated primarily on variations in dwelling structure. Parti and Parti (1980) present a conditional demand analysis where end use consumption is determined through the specific appliance demands. This type of analysis assumes the major determinants of household consumption to be technical, and considers residents to be homogeneous. Parti and Parti (1980) primarily concentrated on decomposing total energy use by appliance and physical dwelling characteristics. The demographics, behaviors, and preferences of residents were not incorporated into traditional estimates of household consumption. Parti and Parti (1980), for example, use a list of appliances, proxies for dwelling efficiency, and climate as explanatory variables, and yet include only household income and the number of household members as 'resident' characteristics. The development of experimental and empirical studies, however, showed the role that other factors play in determining variations in household consumption.

After the energy crisis of 1973, the lack of detailed research regarding the consumption habits of the American household became a serious concern. Newman and Day undertook a comprehensive study in which 1,500 households and their utility companies were surveyed. As the pioneering literature to undertake such a large-scale analysis, the aims of the study were relatively modest, and "wanted to put numbers on the variations in energy use and the cost among households of differing income and other characteristics" (Newman and Day, 1975, p.xii). Without previous empirical analysis, Newman and Day work is the standard from which most research on household energy consumption was developed. The results provide a "description of what is true about energy consumption in households; and second, a basis for answering some key policy questions" (Newman and Day, 1975, p.xxiii). The major conclusion of this study was that income is the overwhelming determining factor in energy consumption. Furthermore, writing in such an uncertain energy climate, Newman and Day (1975) make the important conclusion that households often lack alternatives for their highest energy consuming needs, such as appliances for space heating and cooking. This could make households especially vulnerable to price volatility. It is from this study that researchers began including sociodemographic factors in the study of household energy consumption.

3.2 Behavioral Studies

Behavioural studies emerged as a response to traditional measurements of household energy consumption. One such study, the Twin Rivers program on energy efficiency, was a 5 year experiment undertaken by a multidisciplinary group from Princeton University that began in 1972. This study focused on determining two consumption effects: 1) to what degree consumption would fall when retrofits are made to the dwelling, and 2) to what extent consumption would fall when feedback is reported to residents on their energy use (Socolow, 1978, p.1). In identical townhomes, the study found that variation in consumption was primarily determined by the residents, rather than the structure of the home or appliances (Socolow, 1978, p.11). Furthermore, the attitudes towards conservation, especially in the decision to cool the home, had a large impact on resident consumption. Finally, the study found that providing feedback to residents, both on their past and their peer's consumption, was a significant factor in determining energy use. Interestingly, this study was able to directly observe respondent reactions to the 1973 energy crisis. When the price of gas increased 50%, all consumers decreased their energy consumption by 10%, primarily through conservation of interior temperature (Socolow, 1978, p.12). What this early study proved was that resident behavior has an overwhelming effect on residential energy consumption, and that significant factors besides dwelling characteristics ought to be included in model construction.

Ayers, Raseman, and Shih (2009) expand these preliminary conclusions in an experiment on billing data for 75,000 households in Sacramento and the Puget

Sound area that was undertaken in 2008. The treatment group received periodic feedback on consumption, and utility bills were personalized with current period comparisons, including comparisons to efficient neighbors, personal historical comparison, and targeted energy efficiency advice. This feedback was selected based on the household's energy use pattern, housing characteristics, and household demographics (Ayers et al., 2009). The empirical strengths of this study are threefold. As a large scale study, this feedback had larger sample sizes than previous experiments. In addition, Ayers et al. (2009) had access to many demographic characteristics, as they had voter (political beliefs) information, which have been theorized as highly significant.[2] Finally, as an experimental study, it covers a fairly long time period, which allowed the authors to see to what extent changes in consumption are permanent as a result of feedback. The study concludes that peer comparison and feedback is significant in reducing energy consumption. Households were more likely to make behavioral rather than durable changes in consumption. This indicates that household behavior is easier to modify than promoting dwelling retrofits. Finally, this research found that higher income households were less likely to reduce consumption, indicating that governments ought to mandate or provide incentives to households to promote conservation (Ayers et al. 2009).

What these behavioral studies suggest is the need for expanded models to include a greater scope of characteristics and the important role that occupant behavior plays in residential energy consumption.

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[2] Costa and Kahn (2009) theorize that environmentalists are likely to live in like-minded communities. Voter information is a revealed preference as donating to environmental groups would demonstrate a household's level of environmentalism.

3.3 Social Models

As empirical studies have developed, the study of energy consumption has expanded to include more demographic and behavioral variables. Van Raaij and Verhallen (1982) developed a behavioural model that includes numerous potential behavioral factors that impact household energy consumption. The complex relationships between factors that affect domestic consumption and how they interrelate are illustrated in Figure 2. This model presents comprehensive evidence from empirical cases for why certain variables are crucial to determining residential consumption. Household behaviour is divided into three categories: purchase related behaviours, usage related behaviours, and maintenance related behaviours. These categories distinguish between various types of influences on behaviour, and allow energy analysis to occur from a different perspective than one that considers only appliance efficiency. The authors further identify broad category variables that influence consumption. These include lifestyles, characteristics of the home and appliances, sociodemographic factors, energy related attitudes, responsibility effectiveness and knowledge, cost benefit tradeoff, energy prices, price rates, feedback information, social reference, and community approach. The main advantage of categorization is the inclusion of broad variables that demonstrate the far reaching nature of household consumption. This approach has contributed to the literature on household energy consumption by expanding the modeling of household behavior to include socio-demographic factors in analysis. The major drawback to this approach is the lack of tractability in empirical analysis. Many of these factors cannot be measured nor standardized, which makes comparison across studies difficult. Therefore, the relative impact and causality of each variable are difficult to discern. Regardless, Van Raaij and Verhallen (1982) provide a theoretical justification for including behavioural and social variables in empirical models and demonstrate the expanded nature of household consumption.

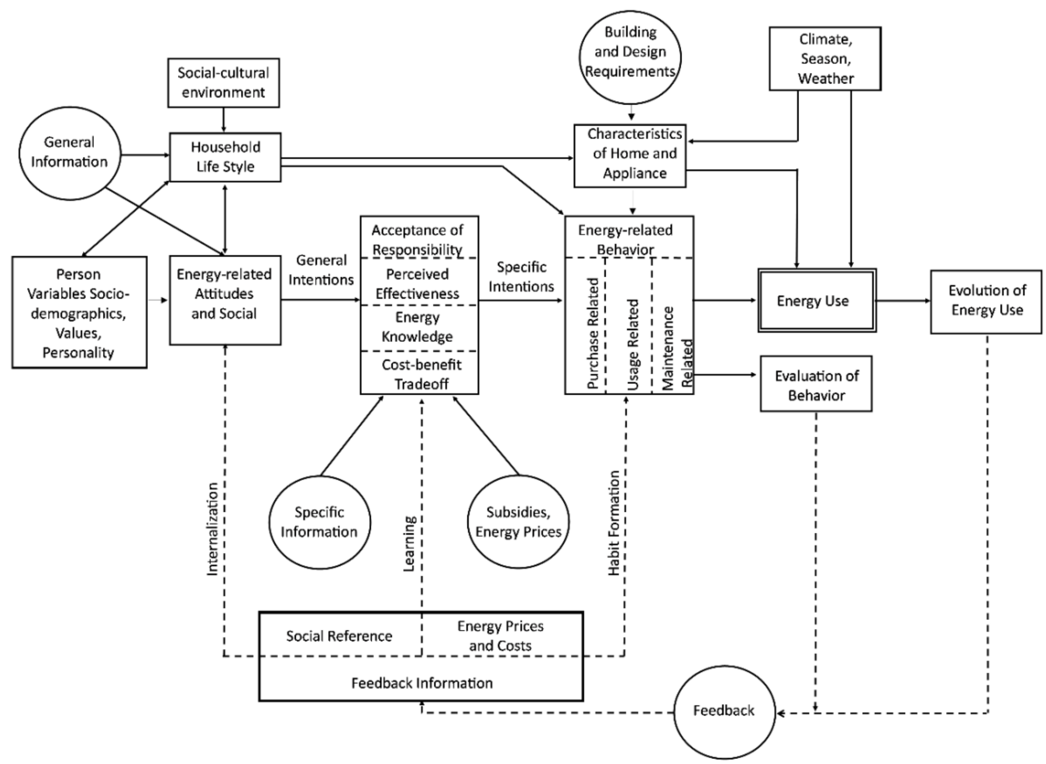

Figure 2: A behavioral model of residential energy use, Van Raaij and Verhallen (1982)

3.4 Alternative Social Models

The explanatory factors provided by Van Raaij and Verhallen (1982) are neither exhaustive nor complete. The criticism social scientists may have of this type of analysis is the inherent assumption that the household is the main unit of analysis for energy consumption. Lutzenhiser (1993) presents the sociological and anthropological arguments for why theoretical analysis in this field has its controversies. Social dynamics, for example, can have a significant effect on the consumption habits of an individual. In certain cases, the apartment building, the neighborhood, or the small town may be more appropriate perspectives for understanding consumption. When addressing variations in habitual consumption, household life-cycle, age related differences, and cultural practices may be important determining factors. However, measurement of these factors is difficult and the models that account for these perspectives are difficult to construct. The purpose in presenting the perspectives of Lutzenhiser (1993) in this literature review is to demonstrate that there does exist an alternate theory of energy consumption. Secondly, these factors and perspectives may account for unexplained variation in the empirical household model used in this thesis. Finally, these factors demonstrate where future research is needed.

3.5 Modelling Approaches

In addition to the choice of variables, empirical models vary greatly in their methodology, scope, and theoretical framework. In their review of building stock models, Kavgic, Mavrogianni, Mumovic, Summerfield, Stevanovic, and Djurovic-Petrovic (2010) identify three modelling approaches through which consumption is estimated in the residential sector. These include the top-down approach, which begins with aggregate energy consumption, the bottom-up physics macro approach, which uses building characteristics to estimate energy consumption, and the bottom-up statistical method, which uses regression analysis. Kavgic et al. (2010)

summarize the benefits and drawbacks of these three methods in Table 1. These models and their conclusions are presented below:

Characteristics	Top-down	Bottom-up statistical	Bottom-up building physics
Benefits	- Focus on the interaction between the energy sector and the economy at large	- Include macroeconomic and socioeconomic effects	- Describe current and prospective technologies in detail
	- Capable of modelling the relationships between different economic variables and energy demand	- Able to determine a typical end-use energy consumption	- Use physically measurable data
	- Avoid detailed technology descriptions	- Easier to develop and use	- Enable policy to be more effectively targeted at consumption
	- Able to model the impact of different social cost-benefit energy and emission policies and scenarios	- Do not require detailed data (only billing data and simple survey information)	- Assess and quantify the impact of different combinations of technological measures to meet given demand
	- Use aggregated economic data		
Limitations	- Depend on past energy economy interactions to project future trends	- Do not provide much data and flexibility	- Poorly describe market interactions
	- Lack the level of technological detail	- Have limited capacity to assess the impact of energy conservation measures	- Neglect the relationships between energy use and macroeconomic activity
	- Less suitable for examining technology – specific policies	- Rely on historic consumption data	- Require a large amount of technical data
	- Typically assume efficient markets and no efficiency gaps	- Require large amounts of data	- Do not determine human behavior within the model but by external assumptions
		- Multicollinearity	

Table 1: Benefits and limitations of bottom-up and top-down modelling approaches, 2010, Kavgic et al.

3.5.1 Top-Down Macro Models

Top-down macro models are built on the aggregate level. These emphasize economy-wide features and primarily reflect sectoral differences (Bohringer and Rutherford, 2009). These models are capable of interpreting feedback effects due to changes in relative prices and incomes. However, top-down models are less adept at incorporating technical details and adapting to changes in technology. Modern models have become hybrid versions that incorporate bottom-up methodology so as to allow a comprehensive analysis.

One such model is constructed by O'Neill and Chen (2002), in which the effect of population variables is analyzed on greenhouse gas emissions and energy use. Through their analysis of American residential energy use, these authors go beyond what many macro models consider primary factors, and include many demographic variables, such as household size and number of children. This type of projection model demonstrates the significant effect that lifestyle factors will have upon future energy consumption.

3.5.2 Bottom-Up Building Physics

The second modelling approach towards domestic energy consumption is the bottom-up building physics model. Bottom-up techniques employ disaggregated data so as to estimate individual energy components. Building physics models employ databases and estimate domestic energy consumption through scenarios employing engineering techniques. The benefit of this type of model is that it can accurately estimate the effect of a change in technology and demonstrates the past, present, and perceived future energy consumption of households (Kavgic et al., 2010). The drawback to this modelling technique is its inflexibility to include sociodemographic variables and the large data requirements necessary to construct such a model.

The Canadian Residential Hybrid End-Use Energy Model is the current hybrid of a bottom-up building physics model and statistical techniques. It is constructed from a database of 17,000 Canadian homes (Swan, 2009). Running a simulation on the earlier version, CREEM (Canadian Residential End-Use Energy Model), Farahbakhsh, Ugursal and Fung (1996) found that upgrading between 10%-90% of the housing stock to standards established by R-2000[3] would have greenhouse gas effects between 0.9 and 122.8 PJ per year, which is illustrated in Figure 3.[4]

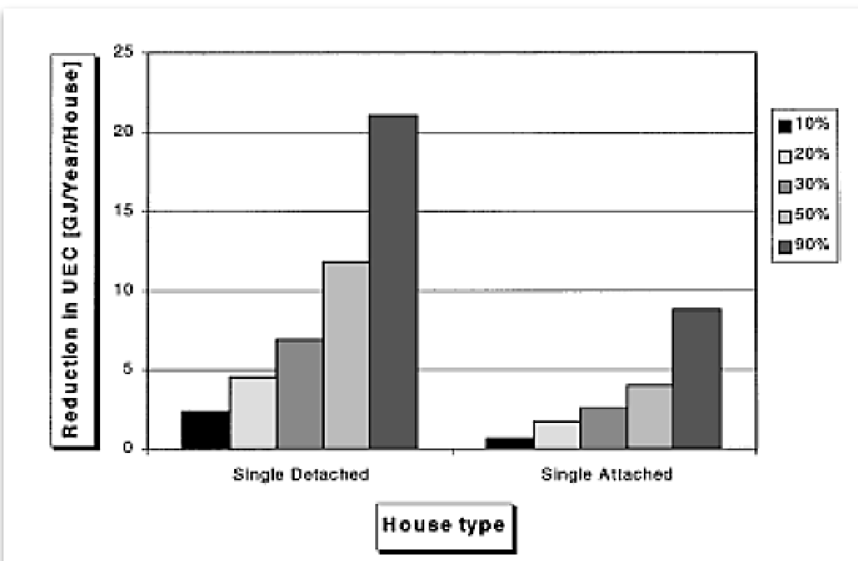

Figure 3: Effect of the R-2000 upgrades on the average UEC of Canadian houses by house type, Farahbakhsh et al. 1998

[3] R-2000 standards are administered by Natural Resources Canada as an indicator of energy efficiency in the residential construction industry (NRC, 2010).
[4] As demonstrated in Figure 3, the possible savings in GJ/Year/House vary greatly between a 10-90% adoption rate in environmental standards. What this demonstrates are the potential efficiency gains in the residential sector.

These are significant results, as in 2009, the Canadian residential sector consumed 1422.3 PJ, which caused emissions of 67.9 MT of greenhouse gases. (NRC, 2012) This demonstrates the crucial role of advances in technology on energy consumtion.

3.5.3 Bottom-Up Statistical

The third modelling method is the bottom-up statistical technique. These models employ regression analysis to estimate individual effects on domestic energy consumption. The benefit of such a model is the flexibility in model specification in terms of variables and determining factors. However, these models cannot demonstrate well the effect of a change in technology on consumption. Furthermore, these suffer from multicollinearity.[5]

A popular regression was the PRISM (Princeton Scorekeeping Method) model, which was used by policymakers for comparison of different American regional markets (Fels, 1986). The PRISM adjusted for weather and allowed for comparison of consumption and conservation efforts across regions. These regressions use individual household characteristics that determine consumption to illustrate the impact of variables. This thesis uses a bottom-up statistical regression, as American survey data is well suited to this type of modelling technique.

[5] Swan and Ugursal (2009) demonstrate that as these models rely on historical data, they are incapable of incorporating new technologies in analysis. Furthermore, the indirect effects within the household in explanatory variables lead to multicollinearity, which often overestimates the true significance of variables.

3.6 Meta-Analysis

Guerin, Yust, and Coopet (2000) perform a comprehensive meta-analysis of qualitative factors from studies on domestic energy consumption taking place from 1975-1998 in the United States. The purpose of this type of study is to demonstrate which factors are consistently proven to be significant across time, region, and data sets. There are several drawbacks to this type of analysis, most notably in the methodology, units of analysis, and specific research questions that vary across studies. For example, Wiehl and Gladhart (1990) employ a systems approach while Seligman et al. (1978) use an experimental study. Furthermore, as the studies vary on specific research questions, the range in occupant predictor variables are varied. Regardless of these faults, Guerin et al. (2000) present the variables that are commonly used in a majority of literature for the period of 1975-1998. These vital characteristics, attitudes, and actions are presented in Table 2. This meta-analysis provides the experimental evidence of significant variables to include in model construction.

Occupant Predictor Category	Study Code Number In Which the Variable was Significantly Related to		Total Number of Studies
	Energy-Conservation Behavior	Energy-Consumption Change	
Occupant characteristics			
Age	12, 21,31,34,45	13, 28, 32, 36, 37, 44	11
Income	5, 12, 29, 31	18, 32, 33, 36, 37	9
Home Ownership	1, 7, 12, 16, 24, 25, 41		7
Education	5, 7, 22, 29, 31	21	6
Number of Occupants	16	21, 24, 32, 36	5
Physical size of home		19, 24, 32, 36	4
Daily occupancy rate	45	4, 42	3
Home technology ownership		1, 19	2
Gender	3	32	2
Presence of a handy-person		1	1
Occupant Attitudes			
Comfort	3, 8, 14, 15, 34, 39, 45	40	8
Health concerns	3, 8, 14, 15, 39, 45		6
Motivation	1, 7, 16, 21, 29		5
Folk knowledge	26, 27	10	3
Occupant actions			
Major weatherization		2, 9, 11, 14, 17, 21, 35, 40	8
Response to incentives	20, 23, 39	6, 30, 38	6
Participation in energy audit	11, 29	21, 31	4
Installing flow restrictors	43	11	2
Lowering space temperature	42	11	2

1 Archer et al (1986)
2 Auch and McDonald (1994(
3 Becker, Selgman, Fazio, and Darley (1981)
4 Bernard, McBride, Desmond, and Collins (1988)
5 Berry, Soderstrom, Hirst, Newman, and Weaver (1981)
6 Bittle, Valesano, and Thaler (1979-1980)
7 Black, Stern, and Elworth (1985)
8 Brown, Berry, and Kinney (1994)
9 Bryan (1996)
10 Craig and McCann (1978)
11 Dunsworth (1984)
12 Eichner and Morris (1984)
13 Fritzsche (1981)
14 Gladhart and Weihl (1990)
15 Gladhart, Weihl, and Krabacher (1988)
16 Gmelch and Dillman (1988(
17 Harrigan and Gregory (1994)
18 Heslop, Moran, and Coussineau (1981)
19 Hewett, Dunsworth, and Quaid (1988)
20 Hirst (1985)
21 Hirst and Goeltz (1984)
22 Hogan (1976)
23 Hutton and McNeill (1981)
24 Johnson, Carroll, Brandt, and Olson (1987)
25 Kasulis, Huettner, and Dikeman (1981)
26 Kempton, Harris, Keith, and Weihl (1985)
27 Kempton and Montgomery (1981)
28 Langston and WIlliams (1988)
29 Laquantra and Chi (1988)
30 Madden, Meter, Weenig, and Zieverunk (1983)
31 Minnesota Department of Public Service (1986)
32 Morrison, Gladhart, Zuiches, Keith, Keefe, and Long (1976)
33 Newman and Day (1975)
34 Peters (1990)
35 Quaid and Faber (1988)
36 Ritchie, McDougall and Claxton (1981)
37 Schwartz and True (1990)
38 Seligman and Darley (1977)
39 Seligman, Darley, and Becker (1978)
40 Shen et al. (1990)
41 Tienda, and Aborampah (1981)
42 Turner and Gruber (1988)
43 Turner and Gruber (1990)
44 Warriner (1981)
45 Weihi and Gladhart (1990)

Table 2: Occupant predictors of energy behavior and consumption change identified by research study code number, Guerin et al. 2000

3.7 Policy Implications

All the approaches from sections 3.1-3.6 have developed significant conclusions about the consumption decisions of the household in regards to energy use. These provide insightful avenues for policy intervention for government, especially in the pursuit of energy conservation. The conclusions offer perspectives on lifestyles, the decision making process of the household, and the interaction of the household with the market. In this section, the most important conclusions and their ramifications for American households are presented.

3.7.1 Efficiency and Technology

In their bottom-up physics model using the STAR (Statistically Representative Housing Stock) database, Ugursal and Fung (1996) draw the conclusion that "improving appliance efficiency reduces overall end-use consumption in the residential sector. However, the magnitude of savings as a result of improving only appliance efficiency is quite small" (Ugursal and Fung, 1996, p.1). This is a significant conclusion, as it implies that if Americans would like to reduce household energy consumption, and by extension greenhouse gas emissions, then improving only appliance efficiency will not be effective. A similar conclusion is corroborated by Kelly (2012), who demonstrates in the English housing sector that homes that are considered energy efficient, in fact, use more energy.

3.7.2 Jevon's Paradox

Upgrading to efficient technologies that do not decrease energy consumption demonstrates an empirical application of Jevon's Paradox. First articulated in 1865, Jevon theorized that "with fixed real energy prices, energy-efficiency gains will increase energy consumption above what it would be without these gains" (Saunders, 1992, p. 3). What this would seem to indicate is consumers substitute the monetary savings of efficiency gains for increased consumption. This rebound effect is certainly controversial, as it would imply that technological improvements cause consumption to increase. Sorrell (2009) argues economy and micro effects have not been sufficiently isolated and therefore, Jevon's Paradox remains a theoretical argument. The purpose in presenting this paradox is to demonstrate that to reduce energy consumption, it is crucial to change behaviour and a natural adoption rate for efficient technologies may not be sufficient into reduce greenhouse gas emissions.

3.7.3 The Rosenfeld Curve

Californian energy consumption deserves a specific reference. Since the 1970's, electricity consumption per capita has remained relatively constant where the rest of the country's average consumption has increased (Sudarashan and Sweeney, 2008). This anomaly, compared to the other states has been termed the 'Rosenfeld Curve' (Figure 4). This division occurred in the 1970's and since then, American average consumption has been increasing compared to Californian average consumption. As a result, California now consumes 40% less electricity per capita than the national average (Sudarashan and Sweeney, 2008). Some of this can be attributed to climate characteristics. California has a temperate climate with fewer heating degree days on average. Relative to the national industry profile, California has smaller and lighter industries.

The Californian government has a long history of promoting energy conservation in the state. One of these measures was the introduction of building codes relatively early, as compared to the rest of the country. Costa and Kahn (2010) perform a micro-analysis of Californian domestic energy consumption, and find that the vintage of the home, specifically in reference to the phase of the building code legislation, has a significant effect on the Rosenfeld curve. They conclude that as new housing stock increases, the effect of these building codes will be greater nationally. There are two broad policy implications arising from the practices adopted in California. Firstly, in comparison to the national consumption average, the trend in energy consumption in California underlines the importance of public policy on energy consumption. Secondly, the timing of when a technology is adopted matters.

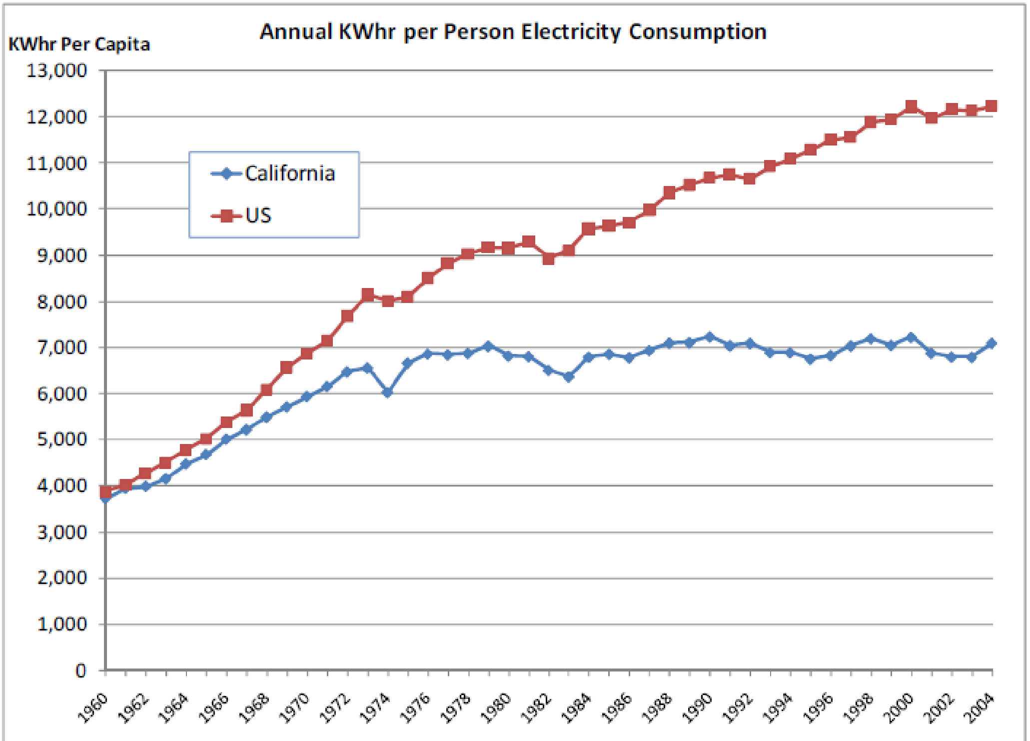

Figure 4: Annual Kwh per person Electricity Consumption, Sudarashan and Sweeney, 2008

3.7.4 Energy Paradox

One of the reasons other energy markets and regions have not been able to reproduce the effect of the Rosenfeld curve may be due to delays in technological diffusion. Although it may be beneficial to adopt certain efficient technologies, households may choose not to. This phenomenon is referred to as the energy paradox. Jaffe and Stavins (1994) give several reasons for why there may be a delay in adopting conservation technologies.

Market failures:

1. A lack of information on new technologies is a market failure. Without knowledge of more efficient technologies, consumers cannot retrofit. Many

models of technological diffusion in other sectors are constructed in a mathematical 'epidemic' model, where knowledge is spread logistically throughout the population. If the information about these technologies is epidemic, then 'infection' depends upon having a large segment of the population spreading this information. All this demonstrates the importance of public awareness and marketing.

2. Another market failure is the principal/agent problem. This occurs when energy efficiency decisions are made by a party other than one which pays the energy bills. Most notably, the principal/agent issue occurs in situations of tenant and landlord utility agreements. Where tenants are not responsible for energy bills, there is no incentive to upgrade appliances. Conversely, where tenants are responsible for energy bills, landlords have no incentive to upgrade dwelling and major appliance efficiency.
3. Finally, consumers may be facing artificially low energy prices. Some consumers live in regions where energy expenditures are subsidized. Others face pricing schemes that are not competitive. Finally, the externalities associated with energy consumption may not be factored into energy prices. This represents another market failure for why energy-conserving technologies are not adopted instantaneously, even if it is economically efficient to do so.

Non-market failures:

1. Cost of acquiring private information can be a consumer challenge. Researching, learning, and comparing all require time and resources, which may explain why energy conservation technologies are slowly adopted.
2. Second, Jaffe and Stavins (1994) credit high implicit consumer discount rates with delays in adoption. As technologies, such as renovations, are often irreversible, consumers may be uncertain of the real monetary savings. With uncertain returns, it is understandable that a consumer would be reluctant to adopt these technologies.
3. A final non-market failure may be the assumption of adopter heterogeneity. Even when a technology is deemed economically viable for the average consumer, it may well be that a given user is not considered to be average. This consumer will therefore judge a technology to lack benefit for them.

These failures, both market and non-market, demonstrate the role for government intervention in the diffusion of energy efficient technologies.

3.7.5 Energy Star Program

A successful and long lasting government policy has been the Energy Star program. It began in 1992 as a voluntary labeling method to demonstrate energy efficiency to consumers. As one of the most recognized energy efficiency rating programs in the world, the Energy Star label encompasses a wide range of everyday household appliances. As Brown et al. (2002, p.2) illustrate, the "Energy Star program is a market transformation that intends to cause long-lasting changes to markets for energy-consuming products, resulting in increased market share for energy efficient products." This program is the result of efforts in traditional demand-side management initiatives. Currently, Energy Star products typically incur savings for office equipment of 30–70%; consumer electronics of 20–40%; residential heating and cooling equipment of 10–30%; residential and commercial lighting fixtures of 70–90%; and appliances, 10–50% (Webber et al., 2000). The success of Energy Star ratings is high. In 2000, Energy Star rated products accounted for approximately 20% market share.

3.7.6 Projections to the Year 2035

In its annual Energy Outlook projections, the Energy Information Administration (EIA) makes energy consumption predictions to 2035 based on technological efficiency scenarios. This projection is demonstrated in Figure 5. Using four possible technological adoption scenarios, household consumption per capita is predicted to fall in each scenario. The primary cause for the decrease is the projected state population shifts towards warmer regions. Furthermore, the fall in space-heating demand is offset by a partial increase in the demand for cooling. The different projection cases depend on what degree federal and state efficiency regulations are applied. The reference case assumes only labeling programs such as Energy Star are in place and upgrades are voluntary. The other three scenarios are based on how willingly old technologies are replaced with high efficiency alternatives. The high technology case assumes earlier availability, lower costs, and higher efficiency technologies that correspond to an annual decline in delivered energy intensity of

0.4%, while the best available technology assumes annual declines of 0.3%. Clearly, legislation that regulates efficiency standards would have a large effect on possible

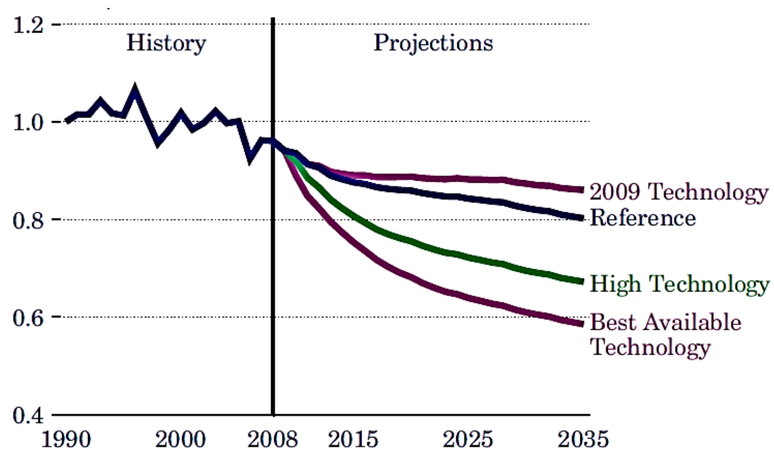

Figure 5: Residential delivered energy consumption per capita in four cases, 1990-2035 (index, 1990=1) (EIA, 2009)

reductions in residential energy consumption.

The findings presented in the literature highlight the importance of constructing a comprehensive empirical model for estimating households' energy consumption. The next section is a consideration of modelling approaches and variable selection, based on the conclusions of the literature reviewed.

Chapter 4: Methodology

This section presents the empirical model and methods employed to estimate residential energy consumption. The data source and its strengths and weaknesses are discussed. Finally, the selection of variables and their theoretical applicability are examined.

4.1 Modelling Household Energy Consumption

Modelling household energy analysis through a bottom-up approach is generally undertaken through one of three statistical approaches: regression analysis, conditional demand method and the neural-network method. Swan and Ugursul (2009) summarize these following approaches.

1. Regression analysis uses goodness of fit to measure model applicability, and the coefficients may or may not have statistical significance. Regression analysis allows for the inclusion of occupant behavior variables, however, it relies on historical data.
2. The conditional demand method regresses energy consumed on end use appliances and treats coefficients as the usage level of an appliance and the appliance efficiency rating. The benefit to this approach is the ease of acquiring information about appliance presence in the home, however, the data requirements for this analysis requires large sample sizes.
3. Neural networks allow all end uses to affect one another giving a precise estimate by accounting for non-linearity. This method has not been historically popular due to data and computation requirements.

Furthermore, coefficients lack statistical significance in relating dwelling characteristics to energy consumption.

This thesis uses regression analysis as the data available is particularly well suited to this type of specification. The Residential Energy Consumption Survey (RECS) contains questions about appliance use, behavior, and demographic factors.

The fundamental approach of this thesis in modelling household energy consumption is estimating the relationship between energy consumption of households and its end uses, while controlling for exogenous variables such as climate. This relationship is assumed in a household production model, where households value electricity and fuel as inputs that produce living conditions (Costa and Kahn, 2010). In this model, energy consumption is determined by input prices, behavioral, appliance, demographic, dwelling, weather, and regional characteristics.

4.2 Specification Issues

The use of regression analysis in modelling household energy consumption has unique challenges. As Ugursal and Fung (2009) demonstrate, bottom-up regression models suffer from multicollinearity, in that many inputs in energy consumption are correlated with one another. This is due to the high saturation of similar function appliances in the household, such as primary and secondary space heating (Ayindalp et al., 2003). Furthermore, the reliance on historical data severely limits the capacity of bottom-up models to predict future consumption. As this regression estimates current consumption rather than projecting future consumption, reliance on historical data is not a concern. Finally, the set of potentially relevant explanatory variables makes different regression studies difficult to compare.

As Min et al. (2010) demonstrate, models for domestic energy consumption are further susceptible to endogeneity as energy prices are used as an explanatory variable for consumption. These issues will be investigated and addressed.

4.3 Data

The Residential Energy Consumption Survey (RECS) is a study periodically administered by the EIA that samples Americans about their home energy use. This thesis uses the 2009 RECS, as it is the most recent. The study is designed to estimate the energy consumption decisions, expenditures, and energy related characteristics of households. In a summary publication of RECS, the Energy Information Administration (1996) distinguishes the core characteristics of energy use in the following categories:

1. Energy consumption and expenditure by the household
2. Housing-unit characteristics, equipment, and appliances most directly related to energy use
3. Socioeconomic characteristics of the household occupying the housing-unit
4. Energy sources, uses and suppliers
5. Ownership and use of vehicles
6. Use of energy assistance programs
7. Participation in demand-side management programs of utility companies.

This information is gathered from several sources. The primary data source is the Household Survey. This survey is administered through personal interviews, where most of the participating households allow a Supplier Survey that surveys companies to obtain billing information on each household's energy consumption (EIA, 1996). Information about weather in the region is collected from the National Oceanic and Atmospheric Administration. The Census Bureau's Current Population Survey is used to supplement the sampling and estimation procedures for the RECS sample which estimate the consumption habits of 114.7 million households (Census Bureau, 2011).

The 1993 Residential Energy Use Survey collected data from 7,111 households, and cost approximately four million dollars over a 3 year period. The 2009 RECS includes 12,083 households.

4.4 Survey Issues

There are certain aspects of using the RECS that could negatively impact empirical results. The EIA (1996) identifies several of the sources for errors and demonstrates the measures taken to diminish these errors.

1. Coverage errors: The RECS has consistently not achieved full coverage of its survey areas. As a result, these inconsistencies are adjusted upward to reflect benchmark estimates as reported in the Current Population Survey. In 1993, this was adjusted upwards by 4.2 percent, as used in the sample weights. Also, the survey under-reports newly constructed dwellings. This is

attributed to a need to complete the dwelling survey list before the survey begins, and errors in updating survey homes.

2. Nonresponse errors: The RECS includes adjustments for nonresponses that are designed to minimize the effects of bias as a result of response rates by region and urban status. In some categories, such as income, the nonresponse rate in 1993 was 14.4%.
3. Measurement errors: The Household Survey is self-reported, meaning questions about dwelling structure may be difficult for residents to report, and as such, may result in large variability and bias. Secondly, when comparing the RECS and the Current Population Survey, RECS consistently underestimates family income, as it does not ask for individuals' incomes and does not question as extensively about the sources of income.

Most of these errors are diminished through the use of multiple data sources in RECS. By supplementing the Household Survey with other surveys, variability is diminished through the sampling weights. The role of sampling weights is to make the RECS sample representative of the population in the United States. This adjusts for problems of over and under representation of certain subpopulations within the survey, and allows results to be nationally representative.

4.5 Dependent Variable

In this model, the dependent variable is the amount of energy consumed by the household in 2009. In the RECS, it is measured in thousands of British Thermal Units (BTU). A natural logarithmic transformation is conducted on the dependent variable so as to "linearize anticipated multiplicative relationships between these variables, and disassociate the proportional relationships between means and standard deviations seen when dividing the sample population into various segments" (Sanquist et al., 2011, p. 355). Min et al. (2010) provide three reasons for why a logarithmic model is preferable to a linear one. Log models provide higher adjusted R^2 values for combinations of explanatory variables. In comparing average size of prediction intervals at 95% confidence levels, the log-linear models consistently had smaller intervals for combinations of predictor variables. Finally, the normality probability plots of the prediction residuals are more linear. For the reasons presented above, following Min et al. (2010), this thesis adopts a logarithmic transformation of the dependent variable as well.

4.6 Explanatory Variables

The explanatory variables can be divided into 7 broad categories based, on the results of the literature reviewed in Chapter 3.

1. Location Variables:
   - The location of a household in the United States has been argued to be an important explanatory variable. As political initiatives differ across state boundaries, the policies of different governments could possibly explain differences in household consumption. As Costa and Kahn (2010) show, the building codes established by California have contributed to greater energy efficiency within the state. Furthermore, the state division can act as a proxy for variables such as

'community approach' and general attitudes towards energy conservation. These political divisions are captured by census division region variables. These include the North East Census Region, Mid-Western Census Region, Southern Census Region, and Western Central Census Region.

- A second location variable is the distinction between metropolitan and rural households. As Lariviere and Lafrance (1999), in their study of Canadian households, show urban designation can importantly affect a household's consumption. Lifestyles may be drastically different in urban settings when compared to those of rural residents. Location variables included in the regression are summarized in table 3.

EXPLANATORY VARIABLE	DEFINITION
REGIONC_MWCR	Census region dummy variable: Resident of the Mid-Western census region when the base is a resident of the North Eastern census region
REGIONC_SCR	Census region dummy variable: Resident of the South census region when the base is a resident of the North Eastern census region
REGIONC_WCR	Census region dummy variable: Resident of the West census region when the base is a resident of the North Eastern census region
METRO_1	Dummy variable: resident resides in a census metropolitan statistical area

Table 3: Location explanatory variables

2. Weather Variables: Climate is an important factor in American domestic energy consumption, as the average temperatures in the US differ drastically across the country. Weather variables included in the

regression are summarized in table 4. The RECS collects local data from the National Oceanic and Atmospheric Administration on the number of days where the temperature is below 65 degrees Fahrenheit as heating degree days. The RECS records the number of degrees in each day for the year when the temperature was below 65. Conversely, days where the temperature is above 65 degrees are collected as cooling degree days. We would expect that all else being equal, the higher the number of these days, the higher the energy consumption of these households.

EXPLANATORY VARIABLE	DEFINITION
LOG(HDD65)	The logarithm of the number of degrees during 2009 when the temperature fell below 65 degrees Fahrenheit
LOG(CDD65)	The logarithm of the number of degrees during 2009 when the temperature rose above 65 degrees Fahrenheit

Table 4: Weather explanatory variables

3. Dwelling Characteristics: This is the category with the most variables, as the RECS questions households extensively on the physical traits of their home. These questions have several purposes: to determine the average size, construction materials, and general energy efficiency of the home. Dwelling characteristics included in the regression are summarized in table 5.

   - Type of Dwelling: The type of dwelling can be an important factor in explaining energy consumption. In their engineering study, Ugursul and Fung (1996) found envelope size was a significant indicator of household efficiency. Envelope size is the number of shared walls, roof, and ceiling with other dwellings. By sharing envelope, heat loss is reduced and efficiency is increased. In the RECS mobile homes, single detached homes, single attached homes, and apartments are the categories for the type of dwelling. These all have different envelope sizes. All else being equal, we would expect apartment buildings to be the most energy efficient.

- Year of Construction: The year in which a dwelling was constructed can act as an indicator of the building codes in effect during that era, which were less strict in the past. Furthermore, older homes require large investments in retrofits to be as technologically efficient as newer homes, and may not have been undertaken. We would expect that, on average, the older the home, the less energy efficient it is. In the RECS, home construction periods range from before 1950, 1950-1959, 1960-1969, 1970-1979, 1980-1989, 1990-1999, 2000-2004, and 2005-2009.
- Total Square Footage: Total square footage in the RECS is an indicator of the area that is heated in the home. The larger a home, the more energy is used to heat, cool and light it. Therefore, we would expect that as the square footage increases, energy consumption will increase. The squared variable of square footage is also included to determine at what rate the impact of square footage is changing.
- Number of Windows: Windows act as a significant point of heat loss in the home. As the number of windows in a heated area increases, we

would expect energy consumption to increase. The number of windows is categorized into dummy variables. The base is having 0 to 2 windows and the other categories are 3-5 windows, 6-9 windows, 10-15 windows, 16-19 windows, 20-29 windows, and more than 30 windows.

- Outside Wall Material: The major outside wall material acts as a layer of insulation for the home. In the RECS, possible construction materials include brick, wood, siding, stucco, composition, stone, concrete, and glass. The majority of RECS respondents had either brick, wood, or siding homes so the base dummy variable is siding, stucco, composition, stone, concrete, and glass.
- Insulation: Respondents in the RECS were asked to classify the level of insulation in their homes. We would expect that the higher the insulation, the less heat is lost and the more energy efficient the home is. Categories in the RECS included 'well insulated,' 'adequately insulated,' and 'poorly insulated.' The base dummy variable is well insulated.

EXPLANATORY VARIABLE	DEFINITION
TYPEHUQ_2	Dummy variable for type of housing unit: single family detached when the base is a mobile home
TYPEHUQ_3	Dummy variable for type of housing unit: single family attached when the base is a mobile home
TYPEHUQ_4	Dummy variable for type of housing unit: apartment building when the base is a mobile home
YEARMADERANGE_1	Year range when dwelling was built: before 1950
YEARMADERANGE_2	Year range when dwelling was built: 1950-1959
YEARMADERANGE_3	Year range when dwelling was built: 1960-1969
YEARMADERANDE_4	Year range when dwelling was built: 1970-1979
YEARMADERANGE_5	Year range when dwelling was built: 1980-1989
YEARMADERANGE_6	Year range when dwelling was built: 1990-1999
YEARMADERANGE_7	Year range when dwelling was built: 2000-2004
TOTSQFT	Total square footage of the dwelling in thousands of feet
TOTSQFTSQ	The squared variable of square footage of the dwelling in hundreds of feet
WINDOWS_3	When the base is having 0-2 windows in a heated area, dummy variable for 3-5 windows
WINDOWS_4	When the base is having 0-2 windows in a heated area, dummy variable for 6-9 windows
WINDOWS_5	When the base is having 0-2 windows in a heated area, dummy variable for 10-15 windows
WINDOWS_6	When the base is having 0-2 windows in a heated area, dummy variable for 16-19 windows
WINDOWS_7	When the base is having 0-2 windows in a heated area, dummy variable for 20-29 windows
WINDOWS_8	When the base is having 0-2 windows in a heated area, dummy variable for more than 30 windows
WALLTYPE_1	When the base brick and all other building materials, dummy variable for the major outside wall material as wood
WALLTYPE_2	When the base brick and all other building materials, dummy variable for the major outside wall material as siding
ADQINSUL_2	Level of insulation reported by the respondent. When the base is having a well insulated home, dummy variable for adequate insulation
ADQINSUL_3	Level of insulation reported by the respondent. When the base is having a well insulated home, dummy variable for poor insulation

Table 5: Dwelling explanatory variables

4. Appliance Characteristics: The end use purpose of energy in the household is towards appliance use. Therefore, the knowledge of which appliances consume the most energy helps households determine where conservation and upgrades would be most beneficial. In Figure 6, the distribution of energy consumption of the household is illustrated. Space heating characteristics including age as a proxy for efficiency, water heating, cooling, and major appliances are included in the list of explanatory variables included in the regression specification. Appliance characteristics are summarized in table 6.

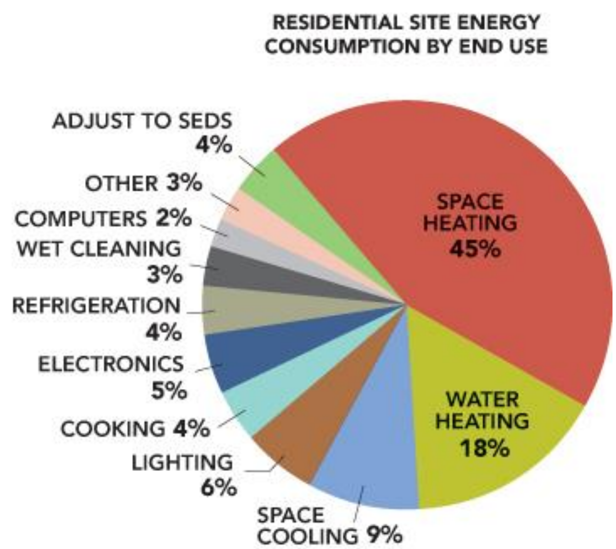

Figure 6: Residential Site Energy Consumption by End-Use, DoE (2011)

- Television: Televisions are popular appliances used in many American households. We would expect that as the number of televisions increases, energy consumption will increase.

- Refrigerators: Virtually all the households in the RECS own a refrigerator. Therefore, in order to measure the impact of having a refrigerator on energy consumption, a dummy variable that measures the presence of a second refrigerator in the household is included. We would expect that with a second refrigerator energy consumption will be higher.
- Clothes Washer and Dryer: In the RECS, the presence of the clothes washer and dryer are separate variables. However, their presence in the home is highly correlated. To eliminate the correlation among explanatory variables in the regression and multicollinearity, these variables were combined. The washerdryer variable is a dummy variable for having both a washer and a dryer in the home.
- Dishwasher: This is a dummy variable for the presence of a dishwasher in the home. All else being equal, we would expect homes that own a dishwasher to consume more energy.
- Oven: This is a dummy variable for the presence of a separate oven in the home. Similar to the refrigerator variable, virtually all the households in the RECS have an oven with a stove. This makes it difficult to separate the impact of the two appliances individually. Therefore a dummy variable for the presence of a detached oven and stovetop is included.
- Age of the Refrigerator: The age of the refrigerator is a variable that proxies the efficiency level of the appliance. We would expect, all else

being equal, the older a refrigerator, the less efficient it is. The dummy variable base for the age of the fridge is 0 to 2 years old. The categories are 2-4 years old, 5-9 years old, 10-14 years old, 15-19 years old, and more than 20 years old.

- Age of Space Heating Equipment: As space heating consumes 45% of energy within the home, we would expect the efficiency of this equipment is important to consumers. All else being equal, age is a proxy for the efficiency of space heating equipment. The dummy variable base for the age of the space heating equipment is 0 to 2 years old. The categories are 2-4 years old, 5-9 years old, 10-14 years old, 15-19 years old, and more than 20 years old.
- Refrigerator Energy Star rating: In the RECS the presence of an Energy Star rated fridge is a direct question about the efficiency of the appliance. In testing this efficiency, a preliminary test of Jevon's Paradox and the effect of appliance efficiency can be done.

EXPLANATORY VARIABLE	DEFINITION
TVCOLOR	Number of televisions used
FRIG_2	Dummy variable if a second fridge is owned by the household
WASHERDRYER	Dummy variable if both a washer and dryer are in the home
DISHWASH	Dishwasher used
OVEN	Number of separate ovens
STOVE	Number of separate cooktops
AGERFRI1_2	Age of most used refrigerator: when base is less than 2 years old, 2-4 years old
AGERFRI1_3	Age of most used refrigerator: when base is less than 2 years old, 5-9 years old

AGERFRI1_5	Age of most used refrigerator: when base is less than 2 years old, 10-14 years old
AGERFRI1_6	Age of most used refrigerator: when base is less than 2 years old, 15-19 years old
AGERFRI1_4	Age of most used refrigerator: when base is less than 2 years old, 20 years and older
EQUIPAGE_2	Age of most used space heating equipment: when base is less than 2 years old, 2-4 years old
EQUIPAGE_3	Age of most used space heating equipment : when base is less than 2 years old, 5-9 years old
EQUIPAGE_5	Age of most used space heating equipment : when base is less than 2 years old, 10-14 years old
EQUIPAGE_6	Age of most used space heating equipment : when base is less than 2 years old, 15-19 years old
EQUIPAGE_4	Age of most used space heating equipment : when base is less than 2 years old, 20 years and older
ESFRIG	If the most used refrigerator has an Energy Star rating

Table 6: Appliance Characteristic explanatory variables

5. Behavioral Characteristics: Habits, customs, and lifestyle determine how appliances are used and vary depending on the choices that the household undertakes. As Ayers et al. (2009) in their experimental study show, households were more likely to make behavioral rather than durable changes in their consumption. This would indicate that with policy intervention, the ease with which behavior can be changed is greater than the ease with which retrofits can be promoted. Behavioral characteristics included in the regression are summarized in table 7.

   - Number of hot meals cooked: We would expect the more often a household cooks hot meals, the higher their energy consumption. This is because they are using appliances more often than those who do not cook hot meals. When the base is never cooking, dummy variables include cooking 3 or more times a day, 2 times a day, once a day, a few times a week, once a week, and less than once a week.

- Hours of TV Watched: We would expect the more time a household spends watching television the higher their energy consumption will be. This variable is for hours spent watching television on weekends. When the base is zero hours, dummy variables include 1-3 hours, 3-6 hours, 6-10 hours, and more than 10 hours.
- Temperature in the home: These are three variables that measure the temperature preferences residents prefer to keep inside the home. We would expect the temperature kept inside the home depends upon the climate the household lives in. These temperature variables are included for winter time preferences. The temperature kept inside the dwelling when a resident is home is most likely higher when compared to the temperature kept at night or when residents are away.
- Battery operated tools and appliances: We would expect the use of battery operated tools and appliances in a household reduces energy consumption when compared to appliances that are corded. Battery operated appliances are often left to discharge and corded appliances are left charging. In the RECS respondents had the option of choosing between 0 appliances which is the base, 1-3, 4-8, and more than 8 appliances.

- Additional Energy: There were several questions included in the RECS that distinguished for activities that would use unusual amounts of energy. These include the presence of someone in the home during working hours, the operation of a home-based business or service, and a dummy variable for any other work that could possibly use unusual amounts of energy.
- Use of Central Air Conditioning: Respondents were asked about their air conditioning use during the summer. We would expect the more often air conditioning was used, the higher the amount of energy consumed. When the base is using air conditioning a few times, respondents could say they used air conditioning quite a bit, and all summer.

EXPLANATORY VARIABLE	DEFINITION
NUMMEAL_2	Frequency hot meals are cooked. When base is never, 3 or more times a day
NUMMEAL_3	Frequency hot meals are cooked. When base is never, 2 times a day
NUMMEAL_4	Frequency hot meals are cooked. When base is never, once a day
NUMMEAL_5	Frequency hot meals are cooked. When base is never, a few times a week
NUMMEAL_6	Frequency hot meals are cooked. When base is never, once a week
NUMMEAL_7	Frequency hot meals are cooked. When base is never, less than once a week
TVONWE1_2	Usage of most used tv on weekends: 1-3 hours
TVONWE1_3	Usage of most used tv on weekends: 3-6 hours
TVONWE1_4	Usage of most used tv on weekends: 6-10 hours
TVONWE1_5	Usage of most used tv on weekends: more than

	10 hours
TEMPHOME	Temperature when someone is home
TEMPGONE	Temperature when no one is home
TEMPNITE	Temperature at night
BATTOOLS_2	Number of rechargeable tools and appliances used when base is 0, 1-3
BATTOOLS_3	Number of rechargeable tools and appliances used when base is 0, 4-8
BATTOOLS_4	Number of rechargeable tools and appliances used when base is 0, more than 8
ATHOME	A household member is at home on typical work days
HBUSNESS	Dummy variable for a home based business or service
OTHWORK	Dummy variable for any activities done that use an unusual amount of energy
USECENAC_2	Frequency with which central air conditioning was used during 2009. When base is used only a few times, turned on quite a bit
USECENAC_3	Frequency with which central air conditioning was used during 2009. When base is used only a few times, turned all summer

Table 7: Behavioral Characteristics explanatory variables

6. Demographic Characteristics: Demographic characteristics can play a crucial role in determining the consumption of a household. For example, Brounen et al. (2012) theorize that age acts as a proxy for generational effects: termed the Nintendo effect, the authors theorize that younger generations spend more leisure time using technology, which uses more energy. Furthermore, cultural practices could cause variations in energy use. Demographic characteristics included in the regression are summarized in table 8.
   - Number of household members: All else being equal, we would expect that as the number of residents increases, energy use will increase.

- Householder Race: In the RECS, the majority of respondents identify themselves as white alone. The next largest category identifies itself as black or African American. As there are few respondents of other minorities in the survey; these are considered the base. It may well be that race is a proxy for cultural practices.
- Age of the respondent: This variable in the survey asks the respondent for their age.
- Presence of children: To expand on the age variables in the household, a dummy variable that accounts for children under the age of 10 is included.
- Presence of elderly residents: As a further expansion of the age variables, a dummy variable that accounts for residents over the age of 70 is included.
- Gender: This variable is a dummy variable for the gender of the respondent where the base is female.
- Education: The highest level of education received is a variable that could proxy for a couple effects. Perhaps those with more education are more energy aware and conscientious of their energy consumption. Furthermore, education could be a proxy for the overall wealth of an individual. When the base variable is no education, categories include kindergarten to grade 12, GED or high school diploma, some college, associate's degree, bachelor's degree, master's degree, professional degree, and doctoral degree.

- Income: All else being equal, we would expect that as gross household income in 2009 increases, energy consumption will increase. This is consistent with economic theory if energy is a normal good. Income is measured in $5,000 increments.
- Poverty level: A separate variable was included for those who live at or below 100% of the poverty level. As this is considered a 'necessity level' of energy consumption it may well be that this income group behaves differently.
- Property ownership: This dummy variable controls for if the dwelling is owned, rented, or occupied without rent. It may be that property owners behave differently than tenants and residents who occupy their dwelling without the payment of rent.

EXPLANATORY VARIABLE	DEFINITION
NHSLDMEM	Number of household members in residence
HHOLDERRACE_1	Dummy variable for householder's race: white alone
HHOLDERRACE_2	Dummy variable for householder's race: black or African American
HHAGE	Age of householder
CHILDREN	Dummy variable: an additional family member is a child under 10
ELDERLY	Dummy variable: an additional family member is over the age of 70
HHSEX	Sex of householder: female

EDUCATION_2	Highest education completed by householder: kindergarten to grade 12
EDUCATION_3	Highest education completed by householder: high school diploma or GED
EDUCATION_4	Highest education completed by householder: some college, no degree
EDUCATION_5	Highest education completed by householder: Associate's degree
EDUCATION_6	Highest education completed by householder: Bachelor's degree
EDUCATION_7	Highest education completed by householder: Master's degree
EDUCATION_8	Highest education completed by householder: professional degree
EDUCATION_9	Highest education completed by householder: doctorate degree
MONEYPY	2009 gross household income
POVERTY100	Household income is at or below 100% of the poverty line
KOWNRENT_2	Dummy variable for home ownership: when the base is owned by a resident, the unit is rented
KOWNRENT_3	Dummy variable for home ownership: when the base is owned by a resident, the unit is occupied without payment of rent

Table 8: Demographic Characteristics explanatory variables

7. Inputs: The energy used for consumption and its price has an important effect on the quantity of energy consumed. We would expect all else being equal, as the price of a source of energy increases, consumption will fall. Therefore, consumers may choose to substitute readily available alternatives such as kerosene, fuel oil, propane, wood, or solar and a substitution effect could alter composition and level of energy consumed by the household. The inputs included in this regression are the price of electricity and natural gas. These are summarized in table 9.

EXPLANATORY VARIABLE	**DEFINITION**
LOG(DOLLAREL)	The log of total electricity cost in whole dollars, 2009
LOG(DOLLARNG)	The log of total natural gas cost in whole dollars, 2009

Table 9: Input explanatory variables

4.7 Specification

This thesis uses a logarithmic specification where energy use in BTUs is explained by the independent variables mentioned earlier.

$$\text{Ln(energy use)} = \beta_0 + \beta_1 X_i + \beta_2 Z_i + \beta_3 W_i + \beta_4 U_i + \beta_5 V_i + \beta_6 T_i + \beta_7 R_i + \varepsilon_i$$

The log of energy consumed in thousands of BTUs is determined by the vectors of explanatory variables: location (X), weather (Z), dwelling (W), appliance (U), behavioral (V), and demographic (T) variables, as well as inputs prices (R). The majority of these variables are discrete. In most cases, the survey does not ask for a direct answer, but rather offers respondents several categories to choose from. Therefore, the logarithm is not applicable to many explanatory variables.

The advantages of a logarithmic specification are that by interpreting energy consumed as a percentage change, the impact of a relative change in BTUs is easier to understand rather than the absolute change in BTUs.

The specification for modeling the energy consumption of households has been presented in this section. The next chapter will present the results obtained from the regression analysis.

Chapter 5: Results

This section presents the empirical results obtained from the regression analysis. First, the overall model is presented and the main conclusions are drawn. Dummy variable coefficients are transformed so as to allow for direct comparison with other variables.[6] Next, hypothesis tests that are relevant extensions of the model are performed.

Min et al. (2010) construct a highly similar model for the United States using 2005 data. Through the comparison to Min et al. (2010), the following conclusions about the model can be made:

- Although multicollinearity is a concern, Min et al. (2010) found that there was no noticeable presence of multicollinearity. Similarly for this specification, the correlations among unrelated variables was below 60%. Those with higher correlations were corrected or combined.[7]
- The Hausman-Wu test done by Min et al. (2010) would indicate endogeneity between the prices of energy and the quantity of energy consumed is not a concern. Following Min et al. (2010), endogeneity of prices is assumed to not apply to this specification.

The model output shows that 65.24% of variation in household energy consumption is explained by the R^2 value of this model. Given the cross-sectional nature of the data and presence of a large number of sub-populations in the data including region, dwelling characteristics, etc., we expect heteroscedastic disturbances. Therefore robust standard errors are calculated using STATA.

[6] The formula for transformations is

$$\frac{\%\Delta\ in\ total\ energy\ consumed}{change\ in\ the\ category\ of\ discrete\ variable} = (e^{\beta_i} - 1)$$

[7] For example, the variables for the presence of a washer and a dryer were combined into one variable.

The total output of this regression is in Appendix A. Conclusions based on the regression results are discussed in various categories. The significance of variables are evaluated at a level of significance of 10%.

5.1.1 Region Variables

EXPLANATORY VARIABLE	EFFECT	P-VALUE
REGIONC_MWCR	-16.0543%	0.000
REGIONC_SCR	-16.222%	0.000
REGIONC_WCR	-29.0362%	0.000
METRO_1	INSIGNIFICANT	0.342

Table 10: Coefficient estimates for Region Variables

- Geographic Location: When the base region is the North East census region, the Southern, Midwestern, and Western census regions are statistically significant and, all else being equal, consume less energy. Households in the Western Census region consume 29.04% less energy than households in the North East census region. As Min et al. (2010) theorize, this is due to the high heating demands of the northeastern region. Dwelling heating is done through a larger variety of inputs than in other regions. The most fuel oil is consumed in the northeast, while cooling is done overwhelmingly through electricity. Therefore, all else being equal, we would expect the infrastructure required for home heating to be more energy intensive, and this will increase energy consumption.

- Urban Designation: In terms of urban–rural energy use, the coefficient for residents of metropolitan statistical areas is insignificant, which indicates that they consume similar levels of energy to rural residents. This result indicates that there is no rural-urban divide in energy consumption. Using the argument of Lariviere and Lafrance (1999), this would indicate that significant differences in lifestyles do not exist between rural and urban residents, as they relate to energy consumption.

5.1.2 Weather Variables

EXPLANATORY VARIABLE	EFFECT	P-VALUE
LOG(HDD65)	0.240	0.000
LOG(CDD65)	0.0441	0.000

Table 11: Coefficient estimates for Weather Variables

The heating and cooling degree variables attempt to control for variation in climate across regions. We observe that for every percentage increase in the number of degrees below 65 °F, energy consumed increases by 0.240%. It is a similar situation for cooling degree days: for every percentage that temperature increases above 65 degrees, energy consumption increases by 0.0441%. This confirms the earlier presented theories that, ceteris paribus, household heating is a larger factor to energy consumption than household cooling, on average. This would also indicate, all else being equal, a dwelling in a colder climate consumes more energy than a dwelling in a warmer climate.

5.1.3 Dwelling Variables

EXPLANATORY VARIABLE	EFFECT	P-VALUE
TYPEHUQ_2	-7.29984%	0.024
TYPEHUQ_3	-16.5565%	0.000
TYPEHUQ_4	-21.8078%	0.000
YEARMADERANGE_1	19.36311%	0.000
YEARMADERANGE_2	14.56819%	0.000
YEARMADERANGE_3	11.62781%	0.000
YEARMADERANGE_4	9.450259%	0.000
YEARMADERANGE_5	4.425112%	0.064
YEARMADERANGE_6	INSIGNIFICANT	0.384
YEARMADERANGE_7	INSIGNIFICANT	0.759
TOTSQFT	0.121	0.000
TOTSFTSQ	-0.00595	0.000
WINDOWS_3	INSIGNIFICANT	0.230
WINDOWS_4	11.07106%	0.001
WINDOWS_5	15.37298%	0.000
WINDOWS_6	20.32184%	0.000
WINDOWS_7	24.73234%	0.000
WINDOWS_8	31.52148%	0.000
WALLTYPE_1	5.823243%	0.000
WALLTYPE_2	4.508686%	0.011
ADQINSUL_2	INSIGNIFICANT	0.222
ADQINSUL_3	7.907048%	0.000

Table 12: Coefficient estimates for Dwelling Variables

This section consists of variables that act as indicators of home efficiency, where certain construction materials, age, or type of dwelling impact the energy consumption of the home.

- Type of Dwelling: When the base group is living in a mobile home, the impact of living in a single family detached home reduces consumption by 7.30%. It is a similar situation for single family attached homes, and apartments. This is consistent with the theory of envelope size presented in chapter 4. This would explain why, all else being equal, apartment buildings consume 21.81% less energy than mobile homes.
- Year of Construction: The year in which the dwelling was constructed is also a significant factor. As demonstrated in the methodology section, the year of construction reflects when building codes came into effect, and acts as an indicator of the effectiveness of conservation policies. When the base group is dwellings constructed between 2005-2009, houses constructed before 1950 uses 19.36% more energy, on average. This number falls with houses constructed from 1959- 1969, where they use 14.57% more energy than new houses. This trend continues: consumption falls until houses constructed from 1990- 2004 consume comparable amounts of energy to new houses. This would indicate that the innovations in construction technology or changes in construction codes have a significant impact on energy use. All else being equal, the older a home, the more energy it consumes.
- Total Square Footage: Total square footage plays an important role in energy consumption. For every 1000 square footage increase in dwelling size, energy consumed increases. The negative and significant coefficient of the squared term for total square footage of the house indicates that energy consumption

with respect to increases in the area of the house increases at a decreasing rate.

- Number of Windows: Windows are an additional source of heat loss in the home. We would expect that as the number of windows in the home increases, more energy is consumed. When the base group is having 0 to 2 windows in the heated area, having 3-5 windows does not impact consumption on average. However, as more windows are added, their impact on consumption is significant and increasing. Having 6-9 windows in the heated area increases consumption by 11.07%, and this trend continues so that having more than 30 windows increases energy consumption by 31.52%. What this indicates is that windows are a significant point of heat loss in the home.
- Wall Construction Material: The next variable that proxies for efficiency is the type of material used for wall construction. Setting siding and all other materials as the base, we observe that brick and wood are both less efficient. The use of these increases consumption by 5.82% and 4.51%. We can therefore observe that construction material plays a significant role in home efficiency.
- Level of Insulation: Finally, the self-reported question about the adequacy of insulation within the home yields similar results. Respondents could choose between classifying their home as well insulated, adequately insulated or poorly insulated. When the base group is well insulated, adequate insulation

does not differ. However, having a home that is poorly insulated increases energy consumption by 7.91%.

From this analysis, we can observe the proxy for efficiency with the greatest impact in all categories is the number of windows in the home. Year of construction has a large effect, especially when the home is quite old. The type of dwelling is also significant. The level of insulation and the type of wall material seem to have smaller impacts on overall energy consumption.

5.1.4 Appliance Variables

EXPLANATORY VARIABLE	EFFECT	P-VALUE
TVCOLOR	2.860138%	0.000
FRIG_2	4.508686%	0.000
WASHERDRYER	19.24381%	0.000
DISHWASH	6.502684%	0.000
OVEN	8.393723%	0.000
STOVE	INSIGNIFICANT	0.371

Table 13: Coefficient estimates for Appliance Variables

In this section, the impact and significance of major and minor appliances is analyzed. In interpreting which appliances consume the most energy, policy makers and consumers can identify where conservation measures can be implemented and upgrades promoted.

- Televisions: The number of TV's in a household are significant. As they increase, consumption increases by 2.82% for each TV.

- Refrigerator: The presence of a second refrigerator increases consumption by 4.51%.
- Clothes washer and dryer: The presence of both a clothes washer and dryer together in the home has a large impact on energy consumption. These together increase consumption by 19.24%
- Dishwasher: A dishwasher in the home increases energy consumption by 6.05%.
- The presence of a separate oven increases energy consumption by 8.39%. The presence of a separate cooktop was, however, insignificant. This can most likely be attributed to the smaller overall energy requirements for use of a stovetop, when compared to an oven.

This appliance analysis would indicate that a combination of a washer and dryer contribute most to energy consumption. Importantly, this demonstrates that when choosing where to conserve energy, it may be most beneficial for the household to conserve first in their use of the clothes washer and dryer, followed by the oven, rather than other appliances. As these contribute the most to overall energy consumption, these represent the greatest potential for energy conservation.

5.1.5 Behavioral Variables

EXPLANATORY	EFFECT	P-VALUE

VARIABLE		
NUMMEAL_2	INSIGNIFICANT	0.365
NUMMEAL_3	INSIGNIFICANT	0.907
NUMMEAL_4	INSIGNIFICANT	0.675
NUMMEAL_5	INSIGNIFICANT	0.604
NUMMEAL_6	INSIGNIFICANT	0.542
NUMMEAL_7	INSIGNIFICANT	0.349
TVONWE1_2	INSIGNIFICANT	0.322
TVONWE1_3	INSIGNIFICANT	0.467
TVONWE1_4	INSIGNIFICANT	0.528
TVONWE1_5	INSIGNIFICANT	0.151
TEMPHOME	0.00510	0.001
TEMPGONE	0.00440	0.001
TEMPNITE	0.00434	0.001
BATTOOLS_2	-2.4495%	0.020
BATTOOLS_3	INSIGNIFICANT	0.272
BATTOOLS_4	INSIGNIFICANT	0.564
ATHOME	3.883511%	0.000
HBUSNESS	3.138236%	0.060
OTHWORK	INSIGNIFICANT	0.118
USECENAC_2	7.293727%	0.000
USECENAC_3	5.833826%	0.000

Table 14: Coefficient estimates for Behavioral Variables

The behavioral category reflects the preferences, lifestyles, and customs of RECS respondents in this model. This variety is captured by the explanatory variables of this section.

- Meals Cooked at Home: This category was insignificant and determined the number of hot meals prepared in the dwelling does not impact the amount of energy consumed. To some degree, this can be attributed to the insignificance of the stove variable.

- Hours of TV Watched: The number of hours of television watched on weekends was insignificant to determining total energy consumption. This can be attributed to the low marginal contribution of televisions to energy consumption.
- Temperature Inside the Home: The temperature preferences of the household inside the dwelling significantly contribute to energy consumption. As theorized in chapter 4, the temperature when someone is present in the home contributes the most to consumption. This temperature settings contributes more to consumption than the temperature kept when residents are away or at night.
- Battery Operated Tools and Appliances: The number of battery operated tools and appliances is partially significant to total energy consumption in the household. Having 1-3 battery operated appliances reduces consumption by 2.45%, however, having more of these is insignificant. The negative impact of 1 to 3 battery operated tools is theorized in chapter 4. The insignificance of having more battery operated appliances may be because at a higher quantity their use becomes interchangeable with equivalent corded devices.
- Additional Energy: There are 3 questions in the RECS about activities that would explain higher-than-average energy consumption. When a household member is at home on typical weekdays, energy consumed is predicted to be 3.81% higher. If a household member runs a home business, this contributes

to a 3.08% increase in consumption. The final component was a question that asked if there was any other work that occurred in the home that would contribute to higher than average consumption. This was insignificant.

- Air Conditioning: Finally, when asked with what frequency respondents used central air conditioning, the regression analysis found using central air conditioning 'quite a bit' increased consumption by 7.29% and 'leaving it on all summer' increased consumption by 5.83%.[8] This difference is most likely due to a self-response bias. Classifying energy use as 'quite a bit' is preferable to the stigma of a more wasteful classification of 'leaving it on all summer'.

5.1.6 Demographic Variables

EXPLANATORY VARIABLE	COEFFICIENT	P-VALUE
NHSLDMEM	0.0501	0.000
HHOLDERRACE_1	INSIGNIFICANT	0.225
HHOLDERRACE_2	13.76901%	0.000
HHAGE	INSIGNIFICANT	0.171
CHILDREN	-2.55675%	0.037
ELDERLY	19.84152%	0.005
HHSEX	INSIGNIFICANT	0.425
EDUCATION_2	INSIGNIFICANT	0.302
EDUCATION_3	INSIGNIFICANT	0.527
EDUCATION_4	INSIGNIFICANT	0.179
EDUCATION_5	INSIGNIFICANT	0.663
EDUCATION_6	INSIGNIFICANT	0.553

[8] As there were few respondents to the usecenac question, including them in the regression reduced the number of observations drastically. This regression is included in Appendix D, and these variables were dropped from the overall main specification.

EDUCATION_7	INSIGNIFICANT	0.906
EDUCATION_8	8.06903%	0.064
MONEYPY	0.00605	0.000
POVERTY100	INSIGNIFICANT	0.564
KOWNRENT_2	INSIGNIFICANT	0.858
KOWNRENT_3	INSIGNIFICANT	0.154

Table 15: Coefficient estimates for Demographic Variables

Demographic characteristics are those that capture socioeconomic factors, wealth effects, and lifecycle effects.

- Number of household members: The number of household members is significant: for every additional member, consumption increases by 5.01%.
- Householder race: Being 'white alone' did not contribute significantly to energy consumption. However, being identified as 'black alone' increased consumption by 13.78%, compared to the base of 'all other ethnicities'. This can most likely be attributed to different cultural practices or lifestyle patterns.
- Age: The age included in the RECS is the survey respondent's age. This was insignificant, most likely because the respondent's age may not be a good proxy for the average age in the household if more than one individual is present.
- Presence of children: The dummy variable for the presence of a child found that consumption falls by 2.56% for households with children under 10.
- Presence of elderly residents: The dummy variable for the presence of residents over the age of 70 found that consumption increases by 19.84%,

compared to a resident under the age of 70. This indicates that family composition is an important factor to explaining energy consumption.

- Gender: Gender of the respondent was not significant in this regression.
- Education: The educational achievement of the respondent was included so as to control for any possible wealth effects: as income is an annual measurement, it could be that education is a proxy for life-cycle expected wealth. This was, however, not the case. Education was insignificant, and yet the variable for having achieved a PhD was significant. Overall this variable can be disregarded as there were few observations in the sample who had completed this level of education.
- Income: For every $5,000 increase in income for 2009, this regression found that consumption increases by 0.61%. This is consistent with energy being considered a normal good.
- Below the poverty line: This variable controlled for household who have income below the poverty line. This variable was insignificant, and shows that this income group does not behave differently from other income groups.
- Property ownership: A variable for property ownership was included. In this regression, as age, income, and type of dwelling are already controlled for, the variable for home ownership was insignificant.

5.1.7 Inputs

EXPLANATORY	COEFFICIENT	P-VALUE

VARIABLE		
LNPREL	-0.0218122	0.286
LNPRNG	-0.3489845	0.000

Table 16: Coefficient estimates for Input Variables

The effect of the price of electricity on the total quantity of energy consumed is insignificant. However, for every percentage increase in the price of natural gas, the quantity of total energy consumed falls by 0.3499%. The effect of the price of natural gas is consistent with economic theory and the effect of the price of electricity is not. There are several possible reasons for the insignificance of the price of electricity.

- The explanatory variable is total energy consumed, and electricity is the largest component in this consumption. It may well be that the lack of close substitutes makes this demand for electricity inelastic.
- Since the average price of electricity per BTU is much smaller in magnitude to the price of natural gas per BTU, it may be that consumers are less responsive to percent changes of a relatively lower price.

Regardless, the relationship between input prices and quantities are further examined through auxiliary regressions in the next section.

5.2 Input Prices

In the Residential Energy Consumption Survey, sources of energy included electricity, natural gas, propane, fuel oil, kerosene, wood, solar, and 'other.' With so many possible inputs, consumers have a degree of substitution in the fuels they choose to consume. The most frequently observed inputs are electricity and natural gas, but the substitution for others is possible. This is why a separate regression of the logarithm of total BTU's of electricity consumed was regressed on all the explanatory variables including the price of electricity and the price of natural gas. This way, the direct effect of the price of electricity on the quantity of electricity consumed could be observed, rather than total quantity. Below are the results for prices in these regressions.

LN(TOTALBTUEL)=EXPLANATORY VARIABLES + LN (PRICEEL) + LN (PRICENG)

EXPLANATORY VARIABLE	COEFFICIENT	P-VALUE
LNPREL	-0.517	0.000
LNPRNG	0.0823	0.002

Table 17: Coefficient estimates in for total quantity of electricity consumed

In this auxiliary regression, both the price of electricity and natural gas are significant. Furthermore, these behave according to economic theory. As the price of electricity increases by 1%, the amount of electricity consumed falls by 0.517%, which makes electricity a normal good. As the price of natural gas, a substitute good, increases by 1%, the consumption of electricity increases by 0.0823%. As this equation is not a demand equation and these coefficients are not estimates of the elasticity of demand, further modelling would be necessary to estimate the price elasticity of demand and the cross price elasticity of demand.

The same analysis is done for the total BTU of natural gas consumption.

LN(TOTALBTUNG)=EXPLANATORY VARIABLES + LN(PRICEEL) + LN (PRICENG)

EXPLANATORY VARIABLE	COEFFICIENT	P-VALUE
LNPREL	0.165	0.000
LNPRNG	-1.179	0.000

Table 18: Coefficient estimates in for total quantity of natural gas consumed

A similar relationship is found in this auxiliary regression. As the price of natural gas increases by 1%, the quantity of natural gas consumed falls by 1.179%. As the price of electricity increases by 1%, the quantity of natural gas consumed increases by 0.165%. This is consistent with theories of demand and substitute goods.

5.4 HYPOTHESIS TESTING

In this section, several of the more interesting corollaries from the literature review that apply to this model are tested.

5.4.1 JEVON'S PARADOX

This model is capable of addressing the issue of appliance efficiency and a limited version of Jevon's Paradox, first introduced in the literature review. By including variables that estimate the effect of appliance efficiency on energy consumption, one can observe, if all else held equal, this efficiency is significant. If appliance efficiency is significant in reducing energy consumption, this would indicate that Jevon's Paradox does not apply in situations of residential energy consumption. The following variables test for appliance efficiency and included are their corresponding p-values:

EXPLANATORY VARIABLE	COEFFICIENT	P-VALUE
AGERFRI1_2	0.00533	0.713
AGERFRI1_3	0.02440	0.112
AGERFRI1_5	-0.00405	0.803
AGERFRI1_6	-0.03005	0.180
AGERFRI1_4	-0.01486	0.585
EQUIPAGE_2	-0.00661	0.745
EQUIPAGE_3	0.03415	0.072
EQUIPAGE_5	0.05443	0.012
EQUIPAGE_6	0.05964	0.006
EQUIPAGE_4	0.04954	0.009
ESFRIG	-0.00578	0.680

Table 19: Coefficient estimates for testing Jevon's Paradox

A first glance would suggest the results of this test are inconclusive. The age of the fridge and the Energy Star rating of the fridge would both indicate the efficiency of the fridge has no effect on energy consumed.[9] The age of main space heating equipment is insignificant when the equipment is newer. When the space equipment is more than 5 years old, it begins to increase energy consumption. This would indicate that gains from improving appliance efficiency can be made when appliances are out of date, and not by replacing relatively new models. In this sense, we can demonstrate through this analysis that replacing very old equipment may be beneficial to reducing energy consumption on average. The limited presence of Jevon's Paradox is proven in the case of refrigerators and not space heating equipment. Further research is required to analyze the existence of Jevon's Paradox beyond appliance efficiency.

5.4.2 THE PRINCIPAL AGENT ISSUE

One of the secondary issues raised in the literature review is the principal-agent issue in energy bill agreements. The hypothesis is consumption varies greatly, depending on whether the tenant or landlord pays the bills. As Maruejols and Young (2010) find in the Canadian market, there is a drastic difference in consumption depending upon the landlord-tenant agreement. In the RECS, there is a question that asks respondents who pays for electricity bills. Possible answers include paid by the household, inclusion in rent or condominium fees, or paid in some other way.[10]

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[9] As there were few respondents to the esfrig question, including them in the regression reduced the number of observations drastically. This regression is included in Appendix E, and these variables were dropped from the overall main specification.

[10] As there were few respondents to the pelheat question, including them in the regression reduced the number of observations drastically. This regression is included in Appendix E, and these variables were dropped from the overall main specification.

EXPLANATORY VARIABLE	COEFFICIENT	P-VALUE
PELHEAT_2	16.99956%	0.003
PELHEAT_3	38.26473%	0.023

Table 22: Coefficient estimates for testing the Principal-Agent issue

When the base dummy variable is that bills are paid by the household, we observe that these are significantly different. Households where electricity costs are included in rent consume 17.00% more electricity. When the costs of electricity were assumed by another party, respondents could specify that this was either a relative, rental or condominium agent, or another party altogether. These households consumed 38.26% more energy than those where the household assumed the costs of electricity. Altogether, this does demonstrate the presence of a principal-agent issue in energy bill payment, and that all else being equal, a household that directly pays its energy costs consumes less energy.

Chapter 6: Conclusion

From the results section several conclusions regarding domestic energy consumption are observed.

- All categories; region, weather, dwelling, appliance, behavior, demographic, and inputs are significant explanatory factors to explaining domestic energy consumption.
- The majority of explanatory variables behave in a manner consistent with the theory reviewed.
- Certain dwelling factors have a greater impact on consumption.
- The presence of a washer and a dryer in the dwelling are the appliances that most contribute to energy consumption.

The purpose of this thesis was to examine what factors determine energy consumption in the United States. Using the data from the RECS, regression analysis was used to determine the significance of certain factors. The dependent variable was total energy consumed in British Thermal Units. The results demonstrate the majority of explanatory variables are significant and this model could be expanded to include more variables from the RECS.

Through several hypothesis tests, this thesis is able to test for several theories in the field of domestic energy consumption. This thesis lays the groundwork for testing for the presence of Jevon's Paradox. Ultimately, it is found to be conclusive only in the case of appliance efficiency. The presence of a principal agent issue in the case of landlord-tenant bill agreements is found to be significant and contribute to energy consumption.

This thesis is of value to policy makers as it clearly demonstrates the effect of American household consumption decisions. Because many of these explanatory variables are dummy variables, identifying high energy consuming categories is simplified. Furthermore, this thesis collects theory from multi-disciplinary approaches to domestic energy consumption, and is able to represent their strengths. Finally, this thesis contributes to existing literature on estimates of consumption. As few estimates for 2009 are currently published, this may provide a base for future work.

This study would benefit from further research by expanding and refining the specification. Kelly (2011) applies structural equation modelling to the English residential sector, and this modelling approach has not yet been applied to the American sector. In addition, this model could be further validated by incorporating data from previous RECS. Finally, forecasting of domestic energy consumption from this model would be a beneficial tool to policymakers and consumers.

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Appendix A

Main Results

. regress lntotalbtu regionc_mwcr regionc_scr regionc_wcr metro_1 lnhdd65 lncdd65 typehuq_2-typehuq_4 yearmaderange_1-yearmaderange_7 totsqft totsqftsq windows_3-windows_8 walltype_1 walltype_2 adqinsul_2 adqinsul_3 lnprel lnprng tvcolor frig_2 washerdryer dishwash oven stove nummeal_2-nummeal_7 agerfri1_2 agerfri1_3 agerfri1_5 agerfri1_6 agerfri1_4 equipage_2-equipage_3 equipage_5 equipage_6 equipage_4 tvonwe1_2-tvonwe1_5 temphome tempgone tempnite battools_2 -battools_4 athome hbusness othwork nhsldmem hholderrace_1 hholderrace_2 hhage children elderly hhsex education_2-education_8 moneypy poverty100 kownrent_2 kownrent_3[pw=nweight], robust
(sum of wgt is 6.6440e+07)

Linear regression **Number of obs = 7154**
F(83, 7070) = 112.41
Prob > F = 0.0000
R-squared = 0.6145
Root MSE = .3358

lntotalbtu	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
regionc_mwcr	-.1753107	.0196782	-8.91	0.000	-.213886	-.1367354
regionc_scr	-.1771866	.0208767	-8.49	0.000	-.2181112	-.136262
regionc_wcr	-.3428794	.0234975	-14.59	0.000	-.3889416	-.2968173
metro_1	.0140043	.0147239	0.95	0.342	-.0148589	.0428674
lnhdd65	.2399651	.0140462	17.08	0.000	.2124305	.2674998
lncdd65	.0441009	.0103197	4.27	0.000	.0238713	.0643305
typehuq_2	-.075826	.0336716	-2.25	0.024	-.1418325	-.0098196
typehuq_3	-.1814389	.0363635	-4.99	0.000	-.2527222	-.1101556
typehuq_4	-.2459181	.0410279	-5.99	0.000	-.3263452	-.165491
yearmadera~1	.1773354	.0251992	7.04	0.000	.1279375	.2267334
yearmadera~2	.1359706	.024238	5.61	0.000	.088457	.1834843
yearmadera~3	.1102416	.0235712	4.68	0.000	.064035	.1564483
yearmadera~4	.0903281	.023148	3.90	0.000	.0449511	.1357051
yearmadera~5	.0433466	.0233914	1.85	0.064	-.0025077	.0892008
yearmadera~6	.0209233	.0240213	0.87	0.384	-.0261658	.0680123
yearmadera~7	.0073968	.0240894	0.31	0.759	-.0398257	.0546193
totsqft	.1206294	.0097049	12.43	0.000	.1016049	.1396539
totsqftsq	-.0059497	.0009629	-6.18	0.000	-.0078373	-.0040622
windows_3	.0467825	.0389887	1.20	0.230	-.029647	.1232119
windows_4	.1049835	.0329922	3.18	0.001	.0403089	.1696581
windows_5	.1428608	.033406	4.28	0.000	.077375	.2083467
windows_6	.1854867	.0346202	5.36	0.000	.1176208	.2533526
windows_7	.2206485	.0351051	6.29	0.000	.1518319	.2894651
windows_8	.2741734	.0394657	6.95	0.000	.1968088	.3515379
walltype_1	.0565944	.0116951	4.84	0.000	.0336685	.0795203
walltype_2	.0441149	.0172359	2.56	0.011	.0103273	.0779024
adqinsul_2	.0145715	.0119269	1.22	0.222	-.0088089	.0379519

adqinsul_3	.076063	.0160935	4.73	0.000	.0445149	.1076112
lnprel	-.0218122	.0204257	-1.07	0.286	-.0618528	.0182283
lnprng	-.3489845	.0270864	-12.88	0.000	-.4020819	-.2958872
tvcolor	.0281595	.0036097	7.80	0.000	.0210833	.0352357
frig_2	.0441464	.0102515	4.31	0.000	.0240503	.0642424
washerdryer	.1757365	.0242569	7.24	0.000	.1281857	.2232873
dishwash	.0629696	.0126157	4.99	0.000	.038239	.0877003
oven	.0805613	.0170691	4.72	0.000	.0471008	.1140217
stove	-.0194223	.0216989	-0.90	0.371	-.0619587	.023114
nummeal_2	-.0511516	.0564397	-0.91	0.365	-.1617902	.0594871
nummeal_3	-.0064261	.0550771	-0.12	0.907	-.1143937	.1015416
nummeal_4	-.0226419	.0540524	-0.42	0.675	-.1286007	.0833169
nummeal_5	-.0280834	.05419	-0.52	0.604	-.134312	.0781452
nummeal_6	-.0364867	.0598077	-0.61	0.542	-.1537277	.0807544
nummeal_7	-.0542044	.0578621	-0.94	0.349	-.1676315	.0592227
agerfri1_2	.0053392	.0145166	0.37	0.713	-.0231177	.0337961
agerfri1_3	.0244089	.0153624	1.59	0.112	-.0057061	.0545238
agerfri1_5	-.0040543	.0162488	-0.25	0.803	-.0359069	.0277982
agerfri1_6	-.0300595	.0224263	-1.34	0.180	-.0740217	.0139027
agerfri1_4	-.0148648	.027215	-0.55	0.585	-.0682143	.0384847
equipage_2	-.0066108	.020291	-0.33	0.745	-.0463872	.0331656
equipage_3	.0341591	.018973	1.80	0.072	-.0030336	.0713518
equipage_5	.0544371	.0217609	2.50	0.012	.0117792	.097095
equipage_6	.0596434	.0214975	2.77	0.006	.0175018	.101785
equipage_4	.0495429	.0190221	2.60	0.009	.0122539	.086832
tvonwe1_2	-.0235497	.0237741	-0.99	0.322	-.070154	.0230546
tvonwe1_3	-.0166899	.0229595	-0.73	0.467	-.0616975	.0283176
tvonwe1_4	.0148422	.0235071	0.63	0.528	-.0312388	.0609231
tvonwe1_5	.0392442	.0273518	1.43	0.151	-.0143735	.0928619
temphome	.0051045	.0015963	3.20	0.001	.0019753	.0082338
tempgone	.0044018	.0013077	3.37	0.001	.0018384	.0069653
tempnite	.0043435	.001283	3.39	0.001	.0018285	.0068585
battools_2	-.024797	.0106345	-2.33	0.020	-.0456438	-.0039501
battools_3	-.0214806	.0195545	-1.10	0.272	-.0598133	.0168522
battools_4	.0125651	.0217665	0.58	0.564	-.0301037	.055234
athome	.0380984	.0106793	3.57	0.000	.0171636	.0590331
hbusness	.0309259	.0164629	1.88	0.060	-.0013464	.0631982
othwork	.0499229	.031904	1.56	0.118	-.0126186	.1124644
nhsldmem	.0501148	.0045538	11.00	0.000	.041188	.0590417
hholderrac~1	.0198362	.0163536	1.21	0.225	-.0122218	.0518943
hholderrac~2	.1288601	.020473	6.29	0.000	.088727	.1689932
hhage	.0006492	.0004742	1.37	0.171	-.0002804	.0015788
children	-.0258684	.012409	-2.08	0.037	-.0501938	-.001543
elderly	.1813858	.0652554	2.78	0.005	.0534656	.3093059
hhsex	-.0079452	.0099654	-0.80	0.425	-.0274804	.0115899
education_2	.0354613	.0343379	1.03	0.302	-.0318513	.1027739
education_3	.0193399	.0306042	0.63	0.527	-.0406534	.0793333
education_4	.0411048	.0305812	1.34	0.179	-.0188436	.1010532
education_5	.0141124	.0323692	0.44	0.663	-.049341	.0775658
education_6	.0179367	.0302228	0.59	0.553	-.0413091	.0771825

education_7	.0037957	.0320791	0.12	0.906	-.059089	.0666804
education_8	.0776291	.0419781	1.85	0.064	-.0046606	.1599188
moneypy	.0060545	.001115	5.43	0.000	.0038688	.0082402
poverty100	.0457743	.0192555	2.38	0.017	.0080277	.0835208
kownrent_2	-.003776	.0211118	-0.18	0.858	-.0451614	.0376093
kownrent_3	.0628571	.0441146	1.42	0.154	-.0236208	.149335
_cons	5.591756	.2271889	24.61	0.000	5.146397	6.037114

Appendix B

Main results including who pays for electricity

. regress lntotalbtu regionc_mwcr regionc_scr regionc_wcr metro_1 lnhdd65 lncdd65 typehuq_2-typehuq_4 yearmaderange_1-yearmaderange_7 totsqft totsqftsq windows_3-windows_8 walltype_1 walltype_2 adqinsul_2 adqinsul_3 lnprel lnprng tvcolor frig_2 washerdryer dishwash oven stove nummeal_2-nummeal_7 agerfri1_2 agerfri1_3 agerfri1_5 agerfri1_6 agerfri1_4 equipage_2-equipage_3 equipage_5 equipage_6 equipage_4 tvonwe1_2-tvonwe1_5 temphome tempgone tempnite battools_2-battools_4 athome hbusness othwork nhsldmem hholderrace_1 hholderrace_2 hhage children elderly hhsex education_2-education_8 moneypy poverty100 kownrent_2 kownrent_3 pelheat_2 pelheat_3 [pw=nweight], robust
(sum of wgt is 2.2926e+07)

Linear regression

Number of obs = 2580
F(85, 2494) = 54.66
Prob > F = 0.0000
R-squared = 0.6524
Root MSE = .35101

lntotalbtu	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
regionc_mwcr	-.1169758	.0369273	-3.17	0.002	-.189387	-.0445645
regionc_scr	-.1425273	.0372355	-3.83	0.000	-.2155429	-.0695117
regionc_wcr	-.3198802	.0424788	-7.53	0.000	-.4031775	-.2365828
metro_1	.0420782	.0245636	1.71	0.087	-.006089	.0902454
lnhdd65	.1831407	.0224242	8.17	0.000	.1391687	.2271128
lncdd65	.0420056	.0176604	2.38	0.017	.0073751	.0766362
typehuq_2	-.0118507	.0439693	-0.27	0.788	-.0980708	.0743694
typehuq_3	-.0805619	.0505773	-1.59	0.111	-.1797397	.018616
typehuq_4	-.2390835	.0566145	-4.22	0.000	-.3500999	-.1280672
yearmadera~1	.1588926	.0397262	4.00	0.000	.0809928	.2367924
yearmadera~2	.0891122	.0411462	2.17	0.030	.0084279	.1697965
yearmadera~3	.0588249	.042952	1.37	0.171	-.0254004	.1430502

yearmadera~4	.0771167	.0399929	1.93	0.054	-.0013061	.1555394
yearmadera~5	.0300092	.040892	0.73	0.463	-.0501765	.1101949
yearmadera~6	-.0054392	.039099	-0.14	0.889	-.0821091	.0712307
yearmadera~7	-.0240657	.0420714	-0.57	0.567	-.1065641	.0584328
totsqft	.1476845	.022449	6.58	0.000	.103664	.1917051
totsqftsq	-.0094043	.0027859	-3.38	0.001	-.0148672	-.0039414
windows_3	.1173391	.0558064	2.10	0.036	.0079076	.2267707
windows_4	.1804364	.0537017	3.36	0.001	.0751318	.285741
windows_5	.2423306	.0543796	4.46	0.000	.1356968	.3489643
windows_6	.2892972	.0571633	5.06	0.000	.1772048	.4013897
windows_7	.3281624	.0575326	5.70	0.000	.2153458	.4409789
windows_8	.3421696	.0657034	5.21	0.000	.2133308	.4710085
walltype_1	.0249627	.0220176	1.13	0.257	-.018212	.0681374
walltype_2	.0145611	.0198039	0.74	0.462	-.0242727	.053395
adqinsul_2	.0096443	.0183912	0.52	0.600	-.0264192	.0457078
adqinsul_3	.1064735	.0230985	4.61	0.000	.0611794	.1517677
lnprel	-.0401633	.0379487	-1.06	0.290	-.1145775	.0342509
lnprng	-.2842429	.035687	-7.96	0.000	-.354222	-.2142637
tvcolor	.0461123	.0069173	6.67	0.000	.0325481	.0596765
frig_2	.0381486	.0186329	2.05	0.041	.0016111	.0746862
washerdryer	.2132362	.0376583	5.66	0.000	.1393913	.287081
dishwash	.0652005	.0204036	3.20	0.001	.0251907	.1052103
oven	.0783239	.032577	2.40	0.016	.0144432	.1422046
stove	-.0083975	.0402	-0.21	0.835	-.0872263	.0704313
nummeal_2	.0736828	.1096506	0.67	0.502	-.1413329	.2886985
nummeal_3	.0788886	.1069463	0.74	0.461	-.130824	.2886013
nummeal_4	.0734063	.1067112	0.69	0.492	-.1358453	.2826579
nummeal_5	.0623201	.106615	0.58	0.559	-.1467429	.271383
nummeal_6	.0427212	.1156405	0.37	0.712	-.1840401	.2694825
nummeal_7	.1078827	.1118392	0.96	0.335	-.1114246	.3271899
agerfri1_2	.0113337	.0274296	0.41	0.680	-.0424535	.0651209
agerfri1_3	.0505142	.0258235	1.96	0.051	-.0001234	.1011519
agerfri1_5	.032064	.029293	1.09	0.274	-.0253771	.089505
agerfri1_6	.0348931	.0362523	0.96	0.336	-.0361947	.1059809
agerfri1_4	-.0536706	.0507762	-1.06	0.291	-.1532385	.0458973
equipage_2	.0507115	.0354632	1.43	0.153	-.0188289	.1202518
equipage_3	.0828942	.0339415	2.44	0.015	.0163379	.1494506
equipage_5	.0779766	.0345629	2.26	0.024	.0102017	.1457516
equipage_6	.0700771	.0368866	1.90	0.058	-.0022544	.1424085
equipage_4	.0813819	.0346434	2.35	0.019	.0134491	.1493147
tvonwe1_2	.0274522	.0406066	0.68	0.499	-.0521739	.1070782
tvonwe1_3	.0152454	.038891	0.39	0.695	-.0610165	.0915073
tvonwe1_4	.0406972	.0393918	1.03	0.302	-.0365468	.1179411
tvonwe1_5	.0658881	.0407642	1.62	0.106	-.0140471	.1458233
temphome	.0041711	.0027572	1.51	0.130	-.0012356	.0095779
tempgone	.0036712	.0018884	1.94	0.052	-.0000318	.0073742
tempnite	.00191	.0019717	0.97	0.333	-.0019563	.0057764
battools_2	-.0413025	.0189589	-2.18	0.029	-.0784794	-.0041256
battools_3	-.0330828	.0262407	-1.26	0.208	-.0845387	.0183731
battools_4	.0001815	.034403	0.01	0.996	-.06728	.0676429
athome	.0489775	.0175244	2.79	0.005	.0146136	.0833413
hbusness	.0854644	.0256	3.34	0.001	.0352649	.135664
othwork	.1471526	.0631606	2.33	0.020	.0232999	.2710053
nhsldmem	.0383947	.0076561	5.01	0.000	.0233818	.0534077
hholderrac~1	.0325838	.0314514	1.04	0.300	-.0290898	.0942574

hholderrac~2	.1013519	.0382194	2.65	0.008	.026407	.1762968
hhage	-.0003415	.0006573	-0.52	0.603	-.0016304	.0009475
children	.0003361	.0211962	0.02	0.987	-.0412278	.0419
elderly	.2299594	.1054464	2.18	0.029	.0231878	.4367309
hhsex	-.0232539	.016457	-1.41	0.158	-.0555246	.0090169
education_2	.0142856	.0582752	0.25	0.806	-.0999871	.1285583
education_3	.0582732	.0512016	1.14	0.255	-.0421289	.1586752
education_4	.0719071	.05014	1.43	0.152	-.0264133	.1702274
education_5	.0627434	.0538076	1.17	0.244	-.0427688	.1682556
education_6	.0144676	.0500882	0.29	0.773	-.0837511	.1126863
education_7	.0462957	.0526434	0.88	0.379	-.0569336	.149525
education_8	.0949427	.0810296	1.17	0.241	-.0639495	.2538349
moneypy	.005015	.001644	3.05	0.002	.0017913	.0082388
poverty100	.0315826	.0312668	1.01	0.313	-.0297289	.0928941
kownrent_2	-.0043573	.0275131	-0.16	0.874	-.0583082	.0495937
kownrent_3	.0853835	.0816673	1.05	0.296	-.0747591	.2455261
pelheat_2	**.1566991**	**.0519998**	**3.01**	**0.003**	**.0547318**	**.2586663**
pelheat_3	**.3235914**	**.1423017**	**2.27**	**0.023**	**.0445498**	**.602633**
_cons	6.051767	.3693294	16.39	0.000	5.327543	6.775991

Appendix C

Main results including use of central air conditioning

. regress lntotalbtu regionc_mwcr regionc_scr regionc_wcr metro_1 lnhdd65 lncdd65 typehuq_2-typehuq_4 yearmaderange_1-yearmaderange_7 totsqft totsqftsq windows_3-windows_8 walltype_1 walltype_2 adqinsul_2 adqinsul_3 lnprel lnprng tvcolor frig_2 washerdryer dishwash oven stove nummeal_2-nummeal_7 agerfri1_2 agerfri1_3 agerfri1_5 agerfri1_6 agerfri1_4 equipage_2-equipage_3 equipage_5 equipage_6 equipage_4 tvonwe1_2-tvonwe1_5 temphome tempgone tempnite battools_2-battools_4 athome hbusness othwork nhsldmem hholderrace_1 hholderrace_2 hhage children elderly hhsex education_2-education_8 moneypy poverty100 kownrent_2 kownrent_3 usecenac_2 usecenac_3 [pw=nweight], robust
(sum of wgt is 4.0702e+07)

Linear regression

Number of obs = 4397
F(85, 4311) = 78.30
Prob > F = 0.0000
R-squared = 0.6588
Root MSE = .29161

lntotalbtu	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
regionc_mwcr	-.1479736	.0219776	-6.73	0.000	-.1910611	-.1048862
regionc_scr	-.174034	.0246244	-7.07	0.000	-.2223105	-.1257575
regionc_wcr	-.3136005	.0260563	-12.04	0.000	-.3646842	-.2625167
metro_1	.0153659	.0172796	0.89	0.374	-.0185109	.0492428

lnhdd65	.1973938	.0172688	11.43	0.000	.1635381	.2312495
lncdd65	.0554515	.0149081	3.72	0.000	.0262239	.0846791
typehuq_2	-.0439288	.0487995	-0.90	0.368	-.1396009	.0517434
typehuq_3	-.1651052	.0510488	-3.23	0.001	-.2651871	-.0650233
typehuq_4	-.3013507	.0600959	-5.01	0.000	-.4191695	-.1835319
yearmadera~1	.1825699	.0342832	5.33	0.000	.1153573	.2497825
yearmadera~2	.1216606	.0243737	4.99	0.000	.0738756	.1694457
yearmadera~3	.0967294	.0236141	4.10	0.000	.0504336	.1430252
yearmadera~4	.0768206	.02339	3.28	0.001	.0309643	.122677
yearmadera~5	.0637279	.0239952	2.66	0.008	.0166849	.1107708
yearmadera~6	.0238734	.0244922	0.97	0.330	-.024144	.0718908
yearmadera~7	-.0164764	.0235152	-0.70	0.484	-.0625782	.0296255
totsqft	.1000429	.0109489	9.14	0.000	.0785774	.1215083
totsqftsq	-.0040904	.0009806	-4.17	0.000	-.0060128	-.002168
windows_3	.0352358	.0488711	0.72	0.471	-.0605766	.1310483
windows_4	.0547815	.0330002	1.66	0.097	-.0099159	.1194789
windows_5	.0821576	.0332096	2.47	0.013	.0170497	.1472655
windows_6	.1372659	.0349167	3.93	0.000	.0688113	.2057206
windows_7	.1712267	.0358974	4.77	0.000	.1008492	.2416041
windows_8	.2481561	.039795	6.24	0.000	.1701376	.3261747
walltype_1	.0449117	.012273	3.66	0.000	.0208503	.068973
walltype_2	.054489	.0250394	2.18	0.030	.005399	.103579
adqinsul_2	.0088873	.0145515	0.61	0.541	-.0196411	.0374156
adqinsul_3	.0606769	.0211096	2.87	0.004	.0192912	.1020626
lnprel	-.0627261	.0252352	-2.49	0.013	-.1121999	-.0132522
lnprng	-.3433156	.0275025	-12.48	0.000	-.3972346	-.2893966
tvcolor	.0289605	.0038043	7.61	0.000	.0215022	.0364188
frig_2	.0550751	.0109763	5.02	0.000	.033556	.0765943
washerdryer	.1875506	.0365908	5.13	0.000	.1158138	.2592874
dishwash	.0704601	.0148644	4.74	0.000	.0413182	.099602
oven	.0839195	.017826	4.71	0.000	.0489713	.1188677
stove	-.0233826	.0213477	-1.10	0.273	-.065235	.0184698
nummeal_2	-.0441423	.0872407	-0.51	0.613	-.2151789	.1268942
nummeal_3	.0339444	.0872217	0.39	0.697	-.137055	.2049438
nummeal_4	.0187474	.0851205	0.22	0.826	-.1481326	.1856273
nummeal_5	.0155488	.0852771	0.18	0.855	-.1516382	.1827359
nummeal_6	.0079263	.0911603	0.09	0.931	-.1707949	.1866475
nummeal_7	.0024144	.0886611	0.03	0.978	-.1714069	.1762358
agerfri1_2	.0070944	.0171057	0.41	0.678	-.0264416	.0406305
agerfri1_3	.0209616	.0186297	1.13	0.261	-.0155621	.0574854
agerfri1_5	-.0007947	.0183998	-0.04	0.966	-.0368678	.0352784
agerfri1_6	-.0285961	.0270077	-1.06	0.290	-.081545	.0243528
agerfri1_4	-.0044448	.030859	-0.14	0.885	-.0649443	.0560546
equipage_2	-.0095056	.0229385	-0.41	0.679	-.0544768	.0354656
equipage_3	.0371268	.0224191	1.66	0.098	-.0068262	.0810798
equipage_5	.0432763	.0260244	1.66	0.096	-.0077449	.0942975
equipage_6	.0582099	.0249621	2.33	0.020	.0092714	.1071484
equipage_4	.0603834	.0234389	2.58	0.010	.0144311	.1063356
tvonwe1_2	.0237796	.0318051	0.75	0.455	-.0385747	.0861339
tvonwe1_3	.0221702	.0307363	0.72	0.471	-.0380888	.0824291

tvonwe1_4	.0498182	.0311632	1.60	0.110	-.0112777	.1109141
tvonwe1_5	.0676644	.0372293	1.82	0.069	-.0053242	.1406529
temphome	.0052019	.0019781	2.63	0.009	.0013237	.0090801
tempgone	.0048485	.0014736	3.29	0.001	.0019596	.0077375
tempnite	.0036764	.0014761	2.49	0.013	.0007825	.0065704
battools_2	-.028234	.0119687	-2.36	0.018	-.0516987	-.0047692
battools_3	-.0166137	.023715	-0.70	0.484	-.0631073	.02988
battools_4	.0135158	.0234443	0.58	0.564	-.0324471	.0594787
athome	.0439292	.0130101	3.38	0.001	.0184228	.0694356
hbusness	.0466497	.0184922	2.52	0.012	.0103955	.0829039
othwork	.0624812	.043778	1.43	0.154	-.0233463	.1483087
nhsldmem	.0499553	.0054573	9.15	0.000	.0392561	.0606545
hholderrac~1	.0068958	.0184065	0.37	0.708	-.0291904	.042982
hholderrac~2	.0868899	.0234413	3.71	0.000	.0409329	.1328469
hhage	-.0000547	.0006381	-0.09	0.932	-.0013057	.0011964
children	-.0371978	.0139658	-2.66	0.008	-.064578	-.0098176
elderly	.124245	.049952	2.49	0.013	.0263135	.2221766
hhsex	.0005489	.0110876	0.05	0.961	-.0211886	.0222864
education_2	-.0217802	.0446057	-0.49	0.625	-.1092303	.06567
education_3	.0235255	.0379595	0.62	0.535	-.0508947	.0979457
education_4	.0255424	.0373561	0.68	0.494	-.0476947	.0987795
education_5	-.0043554	.0387045	-0.11	0.910	-.0802362	.0715254
education_6	.0131639	.0368244	0.36	0.721	-.0590308	.0853586
education_7	-.0030537	.0391434	-0.08	0.938	-.079795	.0736876
education_8	.1004411	.0497706	2.02	0.044	.0028651	.1980171
moneypy	.0052084	.0013283	3.92	0.000	.0026043	.0078126
poverty100	.0454246	.0250063	1.82	0.069	-.0036007	.0944498
kownrent_2	.0137895	.0320524	0.43	0.667	-.0490497	.0766287
kownrent_3	.0450878	.0560192	0.80	0.421	-.0647386	.1549142
usecenac_2	**.0703962**	**.0187811**	**3.75**	**0.000**	**.0335756**	**.1072169**
usecenac_3	**.0567417**	**.0132204**	**4.29**	**0.000**	**.0308229**	**.0826606**
_cons	5.796912	.2914943	19.89	0.000	5.225433	6.36839

Appendix D

Main specification including Energy Star fridge rating

. regress lntotalbtu regionc_mwcr regionc_scr regionc_wcr metro_1 lnhdd65 lncdd65 typehuq_2-typehuq_4 yearmaderange_1-yearmaderange_7 totsqft totsqftsq windows_3-windows_8 walltype_1 walltype_2 adqinsul_2 adqinsul_3 lnprel lnprng tvcolor frig_2 washerdryer dishwash oven stove nummeal_2-nummeal_7 agerfri1_2 agerfri1_3 agerfri1_5 agerfri1_6 agerfri1_4 equipage_2-equipage_3 equipage_5 equipage_6 equipage_4 tvonwe1_2-tvonwe1_5 temphome tempgone tempnite battools_2 -battools_4 athome hbusness othwork nhsldmem hholderrace_1 hholderrace_2 hhage children elderly hhsex education_2-education_8 moneypy poverty100 kownrent_2 kownrent_3 esfrig[pw=nweight], robust
(sum of wgt is 4.1063e+07)

Linear regression **Number of obs = 4499**
F(81, 4417) = 77.12
Prob > F = 0.0000
R-squared = 0.6219
Root MSE = .32705

lntotalbtu	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
regionc_mwcr	-.192479	.0246978	-7.79	0.000	-.240899	-.1440589
regionc_scr	-.1895203	.0262528	-7.22	0.000	-.240989	-.1380516
regionc_wcr	-.3720365	.0285466	-13.03	0.000	-.4280021	-.3160708
metro_1	.011372	.0190149	0.60	0.550	-.0259067	.0486507
lnhdd65	.2360959	.0167072	14.13	0.000	.2033415	.2688504
lncdd65	.049061	.0126306	3.88	0.000	.0242987	.0738233
typehuq_2	-.0875182	.0374455	-2.34	0.019	-.1609301	-.0141062
typehuq_3	-.1746294	.0413051	-4.23	0.000	-.2556081	-.0936508
typehuq_4	-.2221982	.0495434	-4.48	0.000	-.3193281	-.1250683
yearmadera~1	.2089723	.0294099	7.11	0.000	.1513141	.2666306
yearmadera~2	.1498785	.0270379	5.54	0.000	.0968707	.2028863
yearmadera~3	.1258528	.0264361	4.76	0.000	.0740248	.1776807
yearmadera~4	.104608	.0266857	3.92	0.000	.0522907	.1569253
yearmadera~5	.0689473	.0268913	2.56	0.010	.0162268	.1216678
yearmadera~6	.0508482	.0281801	1.80	0.071	-.004399	.1060954
yearmadera~7	.0248883	.0263769	0.94	0.345	-.0268237	.0766003
totsqft	.1166886	.0119703	9.75	0.000	.0932207	.1401564
totsqftsq	-.0058302	.0011754	-4.96	0.000	-.0081346	-.0035258
windows_3	.0285823	.0502904	0.57	0.570	-.0700121	.1271768
windows_4	.0438575	.0395225	1.11	0.267	-.0336263	.1213414
windows_5	.0877718	.0397156	2.21	0.027	.0099094	.1656342
windows_6	.1216578	.041827	2.91	0.004	.039656	.2036596
windows_7	.1664748	.0422835	3.94	0.000	.0835778	.2493717
windows_8	.2205928	.0477668	4.62	0.000	.126946	.3142397
walltype_1	.048532	.0138231	3.51	0.000	.0214318	.0756323
walltype_2	.0471382	.0222094	2.12	0.034	.0035967	.0906796
adqinsul_2	-.0002689	.0144686	-0.02	0.985	-.0286345	.0280967
adqinsul_3	.0578547	.0201543	2.87	0.004	.0183421	.0973673
lnprel	-.0168959	.0250494	-0.67	0.500	-.0660054	.0322136
lnprng	-.3392423	.0295578	-11.48	0.000	-.3971904	-.2812941
tvcolor	.0339178	.0045022	7.53	0.000	.0250913	.0427444
frig_2	.0539257	.012496	4.32	0.000	.0294273	.0784242
washerdryer	.1918573	.0296968	6.46	0.000	.1336367	.250078
dishwash	.0644868	.015799	4.08	0.000	.0335129	.0954607
oven	.0553759	.0200094	2.77	0.006	.0161475	.0946043
stove	.0153496	.0236955	0.65	0.517	-.0311055	.0618047
nummeal_2	-.1111819	.0619115	-1.80	0.073	-.2325595	.0101957
nummeal_3	-.0528914	.0600721	-0.88	0.379	-.1706629	.06488
nummeal_4	-.0669669	.0589484	-1.14	0.256	-.1825352	.0486014
nummeal_5	-.0820975	.0590298	-1.39	0.164	-.1978255	.0336304

nummeal_6	-.0735692	.0666203	-1.10	0.270	-.2041785	.05704
nummeal_7	-.1292295	.0648072	-1.99	0.046	-.2562841	-.0021748
agerfri1_2	.0011306	.0151652	0.07	0.941	-.0286007	.030862
agerfri1_3	.0193868	.0170642	1.14	0.256	-.0140675	.0528411
agerfri1_5	(dropped)					
agerfri1_6	(dropped)					
agerfri1_4	(dropped)					
equipage_2	.003937	.0242039	0.16	0.871	-.0435147	.0513887
equipage_3	.0355934	.0239438	1.49	0.137	-.0113484	.0825353
equipage_5	.0488424	.0292816	1.67	0.095	-.0085643	.106249
equipage_6	.0390999	.0274393	1.42	0.154	-.0146948	.0928946
equipage_4	.0375464	.0241373	1.56	0.120	-.0097748	.0848677
tvonwe1_2	.0095421	.0298112	0.32	0.749	-.0489028	.0679871
tvonwe1_3	.0081174	.0288746	0.28	0.779	-.0484913	.064726
tvonwe1_4	.0289505	.0295056	0.98	0.327	-.0288952	.0867962
tvonwe1_5	.0745648	.0351242	2.12	0.034	.0057037	.1434259
temphome	.0034527	.0019799	1.74	0.081	-.0004289	.0073344
tempgone	.0055899	.0016049	3.48	0.001	.0024434	.0087363
tempnite	.0049893	.0015807	3.16	0.002	.0018904	.0080881
battools_2	-.0165367	.0130562	-1.27	0.205	-.0421335	.00906
battools_3	-.0069871	.025805	-0.27	0.787	-.0575778	.0436036
battools_4	-.0134097	.0236468	-0.57	0.571	-.0597694	.0329499
athome	.0331062	.0127044	2.61	0.009	.0081992	.0580132
hbusness	.0165227	.0205442	0.80	0.421	-.0237541	.0567996
othwork	.0601604	.0401295	1.50	0.134	-.0185135	.1388342
nhsldmem	.0481833	.0057466	8.38	0.000	.036917	.0594496
hholderrac~1	.0235746	.0211054	1.12	0.264	-.0178025	.0649518
hholderrac~2	.1175119	.0252797	4.65	0.000	.0679511	.1670727
hhage	.0009398	.0006021	1.56	0.119	-.0002407	.0021202
children	-.0063449	.0147972	-0.43	0.668	-.0353548	.0226651
elderly	.1594203	.0760254	2.10	0.036	.0103724	.3084683
hhsex	.0008238	.0122862	0.07	0.947	-.0232633	.0249109
education_2	-.0377204	.0400851	-0.94	0.347	-.1163072	.0408664
education_3	-.027379	.0347265	-0.79	0.430	-.0954604	.0407024
education_4	.0040855	.035917	0.11	0.909	-.0663298	.0745009
education_5	-.0412917	.037647	-1.10	0.273	-.1150986	.0325152
education_6	-.0366009	.0352297	-1.04	0.299	-.1056688	.032467
education_7	-.0381932	.0368669	-1.04	0.300	-.1104709	.0340845
education_8	.0412511	.0533456	0.77	0.439	-.063333	.1458352
moneypy	.0051	.0013974	3.65	0.000	.0023603	.0078397
poverty100	.0263282	.0231954	1.14	0.256	-.0191463	.0718028
kownrent_2	-.0243192	.0259954	-0.94	0.350	-.0752832	.0266449
kownrent_3	.0395906	.0623105	0.64	0.525	-.0825693	.1617504
esfrig	**-.0057847**	**.0140261**	**-0.41**	**0.680**	**-.0332829**	**.0217134**
_cons	5.784734	.2718142	21.28	0.000	5.251842	6.317626

Appendix E

Regression of electricity use

. regress lnbtuel regionc_mwcr regionc_scr regionc_wcr metro_1 lnhdd65 lncdd65 typehuq_2-typehuq_4 yearmaderange_1-yearmaderange_7 totsqft totsqftsq windows_3-windows_8 walltype_1 walltype_2 adqinsul_2 adqinsul_3 lnprel lnprng tvcolor frig_2 washerdryer dishwash oven stove nummeal_2-nummeal_7 agerfri1_2 agerfri1_3 agerfri1_5 agerfri1_6 agerfri1_4 equipage_2-equipage_3 equipage_5 equipage_6 equipage_4 tvonwe1_2-tvonwe1_5 temphome tempgone tempnite battools_2-battools_4 athome hbusness othwork nhsldmem hholderrace_1 hholderrace_2 hhage children elderly hhsex education_2-education_8 moneypy poverty100 kownrent_2 kownrent_3[pw=nweight], robust
(sum of wgt is 6.6440e+07)

Linear regression	
Number of obs =	**7154**
F(83, 7070) =	108.16
Prob > F =	0.0000
R-squared =	0.6014
Root MSE =	.42309

lnbtuel	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
regionc_mwcr	-.0441512	.0261734	-1.69	0.092	-.0954589	.0071564
regionc_scr	.1374215	.0311851	4.41	0.000	.0762894	.1985536
regionc_wcr	-.1674042	.0325651	-5.14	0.000	-.2312416	-.1035669
metro_1	-.114076	.0193085	-5.91	0.000	-.1519265	-.0762255
lnhdd65	-.0085619	.018465	-0.46	0.643	-.0447588	.027635
lncdd65	.1233407	.0124443	9.91	0.000	.0989462	.1477351
typehuq_2	-.1549114	.0418856	-3.70	0.000	-.2370197	-.072803
typehuq_3	-.2657554	.0451115	-5.89	0.000	-.3541873	-.1773234
typehuq_4	-.2753571	.0474239	-5.81	0.000	-.3683222	-.182392
yearmadera~1	.0766321	.0337466	2.27	0.023	.0104786	.1427856
yearmadera~2	.0668041	.032382	2.06	0.039	.0033257	.1302825
yearmadera~3	.1027847	.032418	3.17	0.002	.0392358	.1663336
yearmadera~4	.1174422	.0315656	3.72	0.000	.0555641	.1793203
yearmadera~5	.1124455	.03129	3.59	0.000	.0511078	.1737833
yearmadera~6	.0958149	.0321018	2.98	0.003	.0328858	.1587439
yearmadera~7	.0967997	.0331136	2.92	0.003	.0318871	.1617124
totsqft	.1051527	.0187601	5.61	0.000	.0683774	.1419281
totsqftsq	-.0064948	.0024309	-2.67	0.008	-.0112601	-.0017296
windows_3	-.0140866	.0419137	-0.34	0.737	-.0962499	.0680768
windows_4	.0293503	.0370738	0.79	0.429	-.0433255	.102026
windows_5	.0323664	.037056	0.87	0.382	-.0402745	.1050072
windows_6	.0550794	.0401454	1.37	0.170	-.0236175	.1337763
windows_7	.0781496	.0399231	1.96	0.050	-.0001116	.1564109
windows_8	.1281234	.0464759	2.76	0.006	.0370168	.21923
walltype_1	.0118787	.0142074	0.84	0.403	-.015972	.0397294
walltype_2	.0619639	.0201473	3.08	0.002	.0224693	.1014586

adqinsul_2	-.0396669	.0140576	-2.82	0.005	-.0672241	-.0121097
adqinsul_3	.000396	.0186135	0.02	0.983	-.0360921	.0368841
lnprel	**-.5173204**	**.0448567**	**-11.53**	**0.000**	**-.6052529**	**-.4293878**
lnprng	**.0823493**	**.0262116**	**3.14**	**0.002**	**.0309667**	**.1337319**
tvcolor	.0714219	.0049098	14.55	0.000	.0617972	.0810466
frig_2	.1331281	.014206	9.37	0.000	.1052802	.1609761
washerdryer	.1793047	.0272261	6.59	0.000	.1259334	.2326759
dishwash	.1131284	.0157581	7.18	0.000	.0822379	.1440189
oven	.1018706	.0209259	4.87	0.000	.0608496	.1428915
stove	-.0183108	.0262866	-0.70	0.486	-.0698404	.0332187
nummeal_2	.0593222	.0647764	0.92	0.360	-.0676589	.1863033
nummeal_3	.0707336	.0627988	1.13	0.260	-.0523708	.193838
nummeal_4	.0668636	.0618235	1.08	0.280	-.054329	.1880561
nummeal_5	.0589919	.0619696	0.95	0.341	-.0624871	.1804708
nummeal_6	.0479506	.0718143	0.67	0.504	-.092827	.1887283
nummeal_7	.0568278	.0669324	0.85	0.396	-.0743798	.1880354
agerfri1_2	-.0016693	.0202853	-0.08	0.934	-.0414345	.0380959
agerfri1_3	.0202243	.0199322	1.01	0.310	-.0188488	.0592974
agerfri1_5	.0363545	.0212165	1.71	0.087	-.0052361	.0779451
agerfri1_6	.0281213	.0265904	1.06	0.290	-.0240039	.0802464
agerfri1_4	.0278896	.0333242	0.84	0.403	-.0374358	.0932149
equipage_2	.022835	.0256189	0.89	0.373	-.0273857	.0730556
equipage_3	.0297354	.0238998	1.24	0.213	-.0171154	.0765861
equipage_5	.0387682	.0257106	1.51	0.132	-.0116322	.0891686
equipage_6	.0663206	.0274879	2.41	0.016	.012436	.1202051
equipage_4	.0068518	.0233295	0.29	0.769	-.038881	.0525845
tvonwe1_2	.0679995	.028201	2.41	0.016	.0127172	.1232819
tvonwe1_3	.0756863	.0271391	2.79	0.005	.0224856	.1288871
tvonwe1_4	.1173496	.0276326	4.25	0.000	.0631815	.1715177
tvonwe1_5	.1514857	.0309213	4.90	0.000	.0908707	.2121008
temphome	.0024744	.0020702	1.20	0.232	-.0015837	.0065326
tempgone	.0030033	.001815	1.65	0.098	-.0005547	.0065613
tempnite	.0027054	.0016912	1.60	0.110	-.0006099	.0060206
battools_2	-.0097428	.0133476	-0.73	0.465	-.035908	.0164225
battools_3	.0320997	.02246	1.43	0.153	-.0119287	.0761281
battools_4	.1007514	.0263939	3.82	0.000	.0490115	.1524913
athome	.0426938	.0129664	3.29	0.001	.0172758	.0681118
hbusness	.1143816	.0208934	5.47	0.000	.0734242	.1553391
othwork	.126719	.0428897	2.95	0.003	.0426423	.2107956
nhsldmem	.0781344	.0058668	13.32	0.000	.0666337	.0896352
hholderrac~1	.0216986	.0195893	1.11	0.268	-.0167022	.0600994
hholderrac~2	.0199854	.0251191	0.80	0.426	-.0292555	.0692264
hhage	-.0024808	.0005404	-4.59	0.000	-.0035402	-.0014214
children	-.0659883	.0162939	-4.05	0.000	-.0979293	-.0340473
elderly	.2527633	.0971561	2.60	0.009	.0623082	.4432185
hhsex	.0097434	.0120738	0.81	0.420	-.0139249	.0334118
education_2	.0003473	.0392116	0.01	0.993	-.0765192	.0772138
education_3	.029856	.0349747	0.85	0.393	-.0387048	.0984169
education_4	.0413671	.0353886	1.17	0.242	-.0280052	.1107393
education_5	.0059975	.0391712	0.15	0.878	-.0707898	.0827848

education_6	.0071148	.0349437	0.20	0.839	-.0613853	.0756149
education_7	-.040332	.037963	-1.06	0.288	-.1147509	.0340868
education_8	.0325387	.0525443	0.62	0.536	-.0704639	.1355413
moneypy	.0086385	.0013303	6.49	0.000	.0060308	.0112463
poverty100	.0397435	.0233936	1.70	0.089	-.0061151	.085602
kownrent_2	-.020425	.0234347	-0.87	0.383	-.0663641	.0255141
kownrent_3	.0558076	.0677534	0.82	0.410	-.0770093	.1886245
_cons	6.347647	.2811579	22.58	0.000	5.796493	6.898801

Appendix F

Regression of natural gas use

. regress lnbtung regionc_mwcr regionc_scr regionc_wcr metro_1 lnhdd65 lncdd65 typehuq_2-typehuq_4 yearmaderange_1-yearmaderange_7 totsqft totsqftsq windows_3-windows_8 walltype_1 walltype_2 adqinsul_2 adqinsul_3 lnprel lnprng tvcolor frig_2 washerdryer dishwash oven stove nummeal_2-nummeal_7 agerfri1_2 agerfri1_3 agerfri1_5 agerfri1_6 agerfri1_4 equipage_2-equipage_3 equipage_5 equipage_6 equipage_4 tvonwe1_2-tvonwe1_5 temphome tempgone tempnite battools_2-battools_4 athome hbusness othwork nhsldmem hholderrace_1 hholderrace_2 hhage children elderly hhsex education_2-education_8 moneypy poverty100 kownrent_2 kownrent_3[pw=nweight], robust
(sum of wgt is 6.6440e+07)

Linear regression

Number of obs = 7154
F(83, 7070) = 73.83
Prob > F = 0.0000
R-squared = 0.4553
Root MSE = .67395

lnbtung	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
regionc_mwcr	-.1832348	.0360413	-5.08	0.000	-.2538865	-.1125831
regionc_scr	-.2721345	.0435346	-6.25	0.000	-.3574754	-.1867936
regionc_wcr	-.394463	.0452074	-8.73	0.000	-.4830831	-.3058428
metro_1	.1713085	.0379121	4.52	0.000	.0969895	.2456276
lnhdd65	.382714	.025335	15.11	0.000	.3330498	.4323783
lncdd65	.036464	.0184603	1.98	0.048	.0002764	.0726517
typehuq_2	.0758673	.0788327	0.96	0.336	-.0786683	.2304029
typehuq_3	-.0018082	.081238	-0.02	0.982	-.161059	.1574425
typehuq_4	-.1769573	.0833459	-2.12	0.034	-.3403403	-.0135742
yearmadera~1	.1165041	.045512	2.56	0.010	.0272869	.2057213
yearmadera~2	.1475805	.0448185	3.29	0.001	.0597229	.2354381
yearmadera~3	.0710296	.046652	1.52	0.128	-.0204223	.1624814
yearmadera~4	.0641876	.0437996	1.47	0.143	-.0216726	.1500479
yearmadera~5	-.0143151	.0467829	-0.31	0.760	-.1060236	.0773933

yearmadera~6	-.0931448	.0479556	-1.94	0.052	-.1871522	.0008625
yearmadera~7	-.1606227	.0569886	-2.82	0.005	-.2723373	-.0489081
totsqft	.0959153	.0184387	5.20	0.000	.05977	.1320606
totsqftsq	-.0034658	.001613	-2.15	0.032	-.0066278	-.0003038
windows_3	.1042713	.0698776	1.49	0.136	-.0327097	.2412523
windows_4	.1390903	.0658752	2.11	0.035	.0099551	.2682255
windows_5	.2040584	.0646887	3.15	0.002	.0772493	.3308676
windows_6	.2539828	.0690305	3.68	0.000	.1186624	.3893032
windows_7	.2868152	.0696133	4.12	0.000	.1503523	.4232782
windows_8	.3492536	.0791234	4.41	0.000	.1941481	.5043592
walltype_1	.0190468	.0248439	0.77	0.443	-.0296546	.0677483
walltype_2	.0215418	.0299992	0.72	0.473	-.0372657	.0803492
adqinsul_2	.0700033	.0222443	3.15	0.002	.0263978	.1136088
adqinsul_3	.1352376	.0290568	4.65	0.000	.0782775	.1921976
lnprel	**.1651616**	**.0446826**	**3.70**	**0.000**	**.0775703**	**.2527529**
lnprng	**-1.178637**	**.0374378**	**-31.48**	**0.000**	**-1.252026**	**-1.105248**
tvcolor	.000366	.0081673	0.04	0.964	-.0156444	.0163765
frig_2	-.0158587	.0225779	-0.70	0.482	-.0601182	.0284007
washerdryer	.2906006	.041276	7.04	0.000	.2096872	.3715139
dishwash	.0975551	.0254104	3.84	0.000	.047743	.1473672
oven	.076846	.0344524	2.23	0.026	.009309	.144383
stove	-.0488646	.0417934	-1.17	0.242	-.1307922	.033063
nummeal_2	-.189278	.1013976	-1.87	0.062	-.3880478	.0094918
nummeal_3	-.0954408	.0952181	-1.00	0.316	-.2820968	.0912153
nummeal_4	-.1302145	.0948907	-1.37	0.170	-.3162287	.0557996
nummeal_5	-.1167522	.0947855	-1.23	0.218	-.3025601	.0690557
nummeal_6	-.1596396	.1076161	-1.48	0.138	-.3705993	.0513201
nummeal_7	-.1049254	.1023314	-1.03	0.305	-.3055255	.0956748
agerfri1_2	.0387072	.0316921	1.22	0.222	-.0234188	.1008333
agerfri1_3	.0527141	.0315661	1.67	0.095	-.0091649	.1145931
agerfri1_5	-.0134969	.0347671	-0.39	0.698	-.0816509	.054657
agerfri1_6	.0138721	.0465539	0.30	0.766	-.0773875	.1051317
agerfri1_4	.010007	.0486875	0.21	0.837	-.0854351	.1054491
equipage_2	-.0244655	.0417459	-0.59	0.558	-.1062999	.0573689
equipage_3	.0648489	.0388202	1.67	0.095	-.0112503	.1409482
equipage_5	.100295	.0416589	2.41	0.016	.0186311	.1819589
equipage_6	.1026801	.0444614	2.31	0.021	.0155224	.1898377
equipage_4	.0456568	.0376221	1.21	0.225	-.0280938	.1194073
tvonwe1_2	-.0289337	.0441115	-0.66	0.512	-.1154054	.057538
tvonwe1_3	-.0299409	.0427277	-0.70	0.483	-.1137	.0538182
tvonwe1_4	.0097859	.0435237	0.22	0.822	-.0755336	.0951054
tvonwe1_5	.0341204	.0469197	0.73	0.467	-.0578563	.1260971
temphome	.009045	.0034257	2.64	0.008	.0023296	.0157605
tempgone	.0036957	.0033198	1.11	0.266	-.0028121	.0102035
tempnite	.0017272	.0029299	0.59	0.556	-.0040163	.0074706
battools_2	-.0295763	.0219	-1.35	0.177	-.0725067	.0133542
battools_3	-.0455815	.0335102	-1.36	0.174	-.1112715	.0201084
battools_4	-.0151709	.047762	-0.32	0.751	-.1087987	.0784568
athome	.0557595	.020863	2.67	0.008	.0148616	.0966573
hbusness	-.0520203	.0336039	-1.55	0.122	-.1178941	.0138534

othwork	-.0692757	.0797434	-0.87	0.385	-.2255968	.0870453
nhsldmem	.0412055	.0087442	4.71	0.000	.0240642	.0583468
hholderrac~1	-.0076066	.0357999	-0.21	0.832	-.0777852	.0625719
hholderrac~2	.1774429	.0413294	4.29	0.000	.0964249	.258461
hhage	.0012436	.0008034	1.55	0.122	-.0003313	.0028185
children	-.0076701	.0264821	-0.29	0.772	-.0595829	.0442427
elderly	.4648756	.2415399	1.92	0.054	-.008615	.9383663
hhsex	-.0138591	.0189475	-0.73	0.465	-.0510018	.0232836
education_2	.0514498	.0728297	0.71	0.480	-.0913182	.1942177
education_3	.020008	.0650649	0.31	0.758	-.1075387	.1475548
education_4	.0231133	.0660386	0.35	0.726	-.1063423	.1525688
education_5	.0264232	.071409	0.37	0.711	-.1135598	.1664062
education_6	.0270753	.0648937	0.42	0.677	-.1001359	.1542865
education_7	.0264106	.0697137	0.38	0.705	-.1102492	.1630704
education_8	.0799624	.0902288	0.89	0.376	-.0969131	.2568379
moneypy	.0064108	.002056	3.12	0.002	.0023804	.0104413
poverty100	.0676348	.0374242	1.81	0.071	-.0057278	.1409973
kownrent_2	.0483146	.0316166	1.53	0.127	-.0136635	.1102926
kownrent_3	.0609142	.0847802	0.72	0.472	-.1052804	.2271088
_cons	.3429232	.4412105	0.78	0.437	-.5219815	1.207828