Econometric Analysis of Household Energy Consumption in the United States, 2006 and 2008

by

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Abstract

Household expenditures on electricity and gasoline account for a very large share of household budget in the United States. Considering the upward trend in energy price during recent years, this study investigated U.S. household energy consumption patterns of in-home electricity usage and gasoline for transportation. Cross-sectional data for 2006 and 2008 were used to examine the variation in household energy consumption on a quarterly basis. Consumer Expenditure Survey (CES) data were obtained from the Bureau of Labor Statistics, whereas energy prices data were obtained from U.S. Energy Information Administration. Descriptive statistical analysis, and OLS and Tobit models were applied in the econometric investigation. Natural environment, home structural characteristics, household characteristics, household preference and market environment related explanatory variables were used to examine energy uses. The results strongly indicate that lifestyle such as large home and heavy dependence on individual transportation influence energy uses for American households. The findings from this study help us to better understand household energy consumption behavior and promote sustainable growth and develop effective policies to reduce energy consumption and GHGs emissions.

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Chapter I

Introduction

The global energy consumption had increased by 2% per year from 1970 to 2002, and 4.1% per year from 2002 to 2005 (Randolph and Masters, 2008). Energy consumed by households represents an increasing share of the total energy consumed in the world (Mathews et al., 1999). The increasing energy use is accompanied by environmental problems. The American with less than 5% of the world's population accounted for 20 to 22% of the world's energy consumption, economic output, and carbon dioxide emissions in 2005 (IEA, 2009).

Almost 40% of the total US carbon dioxide emissions are associated with residences and cars (EIA, 2009b). The 111 million households in the United States consume more than 22% of the nation's total energy budget for space heating, water heating, air conditioning, lighting and operation of various appliances, and transportation accounted for 29% which almost catches up the industry (30%) (EIA, 2009a). Household vehicles accounted for 31% of the petroleum consumption and 13% of total US energy consumption in the United States (EIA, 1993). American consumed 113.1 billion gasoline-equivalent gallons (GEG) to fuel passenger travel by light-duty vehicles in 2001, a rise of 3.3 percent per year from 90.6 billion GEG in 1994 (EIA, 2005).

Regarding the sources of in-home energy, natural gas and electricity produced mainly by coal are two important sources (EIA, 2009a). Considering the environmental issues, a greater attention on renewable energy has been received, though it still accounts for small energy source.

Wood remains the primary source of renewable biomass energy in the U.S. Wood energy totaled 2,041 trillion Btu, accounting for about 28% of the renewable biomass energy consumed in the U.S. in 2008 (EIA, 2009a).

About 24% of the U.S. wood energy consumption was in the residential sector. Residential wood energy has been mainly used for heating and competes with other home heating energies, such as natural gas, electricity, and petroleum products (Skog and Watterson, 1984; Hardie and Hassan, 1986; Howard and Westby, 2009). The share of the U.S. energy residential sector captured by wood energy, nonetheless, experienced a sharply decline in the last 50 years as energy price has been relatively low, especially with the rising income. Wood energy share in the U.S. residential energy market declined from 18% in 1945 to 2% by 1973 (EIA, 2009a). Historical data show that energy from wood sources began to decline and that wood has stopped replacing other conventional energies since 1985 (EIA, 2009a).

The entire transportation sector is not only the second largest consumer of energy, it also has become the largest contributor to the nation's greenhouse gas emissions of carbon dioxide, topping industrial emissions in 1999 (EIA, 2009a), primarily due to heavy dependence on petroleum products, such as motor gasoline. Within this larger picture, it is clear that any effort to reduce energy demands, oil imports, and carbon emissions must focus on U.S. residential and household transportation energy consumption.

The significant household energy consumption is well related with cheap energy cost in the United States. The world faced significant oil price hikes in 1973 and during the late 1970s and early 1980s (Unander, 2004). Then it was a time of relative energy stability. Prices for gasoline were fairly constant throughout the late 1980s and 1990s, and have been increasing since 2003, but it appears to set a new record in 2008 (Figure 1). Household energy consumption in America

decreased after the energy crisis to a low point in 1982, but has been steadily rising (EIA, 1995). Many technological improvements have enabled consumers to use less energy (i.e., appliances use less energy and houses are built with more insulation). But households own more appliances, there were larger housing units continually for nearly three decades in the United States according to the National Association of Home Builders and the increasing dependence of US households on the automobile to pursue daily activity with miles of travel significant increase (Polzin and Chu, 2004).

Considering the sizeable and increasing share of energy consumption of households, it is critical to understand household energy consumption pattern and behavior, and explore mechanism either using market or regulation and other methods. In particular, it is important to focus on three distinct consumption categories as the major demand areas: residential energy, auto fuel and housing in the United States (Shammin et al., 2010). These three categories account for most of the direct and indirect energy consumption by households. Considering their importance, this thesis is aimed at examining direct household energy consumption: In-home energy usage and gasoline consumption. It is hypothesized that household characteristics, lifestyle, and energy prices influence household energy consumption. More specifically, the following questions are addressed:

- What are the patterns of US household energy consumption?
- How has U.S. household energy usage changed through recent years with significant variation of energy pricing?
- What factors influence household energy consumption?
- What are the policy implications of household consumption changes?

The resource use and environmental impacts of household consumption are identified as key aspects of sustainable development. Answers to these questions are important as the U.S. society attempts to look for ways to reduce energy consumption, reduce oil dependency, and minimize impacts on the environment by investing in clean and renewable energy sources (e.g., wood, wind, water). The information and finding would be useful to policy making for sustainable development.

The rest of this thesis is structured as follows. The second chapter presents literature that has addressed similar or complementary subjects and background. The third chapter presents the methodology including the theory underlying the econometric model used to estimate parameters and describes the data sources. Then, chapter four discusses the variables considered in model estimation and presents the empirical results. The last chapter summarizes the conclusions regarding household energy consumption and discusses future extensions.

Chapter II

Literature and Background

The U.S. Department of Energy tracks national energy consumption in four broad sectors: (1) The industrial sector has long been the country's largest energy user, currently representing about 30% of the total; (2) transportation sector, followed by (3) the residential and (4) commercial sectors. Researchers have studied household energy consumption from various viewpoints. In this study I will focus on residential electricity use and household transportation oil use.

2.1. Household In-home Energy Consumption

A legacy of research over the past years has documented household energy consumption. Newman and Day (1975) examined the relationship between energy use and individual's behavior. Some 50 studies in this area were annotated by Cummingham and Lepreato (1977). Ellis and Gaskell (1978) provided one of the first major literature reviews. Over 500 studies were covered by Joerges (1979), while 400 consumer energy studies were listed by Anderson and McDougall (1980). Stem and Gardner (1980) has referenced more than 130 studies in their thoughtful review. It is clear that interest and concern have been well established since the 1970s.

The previous studies provide us a range of household variables as possible determinants of energy consumption. Generally speaking, the earlier year's studies were conducted on region/state level. For example, Morrison and Gladhart (1976) studied households in Lansing, Michigan considering house descriptions, appliance ownerships, and demographics as influencing factors. It was found the families with higher income and child- rearing families

consumed more energy while appliance ownership was apparently unrelated. However, given the same explanatory factors, Sierra Pacific Power Company (1979) according to a Nevada documented that type of hot water heater used, full-time use of home, type of heating systems and occupation explained 44% of electricity consumption. It was also found that 45% of winter gas consumption was explained by type of hot water heater, number of bedrooms and bathroom, and use of portable heaters.

Hirst et al (1982) initially investigated the disaggregate data on national level – the National Interim Energy Consumption Survey (NIECS) conducted by the US Department Energy's Energy Information Administration (EIA). It was found fuel price as well as year the house was built, floor area were the most important determinates of household energy consumption based. Richie et al (1981) adopted comparative comprehensive cross-section of predictor variables (climatic, dwelling appliance/vehicle descriptions, demographic characteristics an attitudinal variables) based on household in-home and transportation consumption data in Canada.

There is also increasing attention to on the relation between household energy consumption and geospatial variables .Gladhart (1976) found no differences in residential energy consumption between rural and urban families, but found rural families consumed more gasoline. Ewing and Rong (2008) explored the relationship between residential energy use and city form showing that compact development provided reducing in not only in transportation energy use but also on residential energy use. But it was commended by Randolph (2009) that most of the energy argument for compact development lied in the transportation sector. Considering both indirect and direct energy use, Shammin (2010) documented the effect of location (urban/ rural) differed the U.S. household energy intensity at about 10% with all other variables being the same.

Besides the physical influencing factors mentioned above, a wide variety of household energy use behavior studies have been conducted as well. After the 1973 Arab oil embargo, the consumer attitudinal studies have been paid close attention. Most of these studies looked for household views about the oil crisis; some of them have focused on alternative programs for reducing energy consumption (Craig and McCann 1978; Winett el. 1978; Battalio et al.1979). More importantly, many other researchers analyzed the relationship between attitudes and actual consumption (Weihl and Gladhart, 1990; Emery and Gartland, 1996).

As early as the 1970s, Seligman et al. (1978) initially investigated the relation between occupant behavior and homeowners' summer electricity consumption. The results of two attitudinal surveys demonstrated that energy consumption could be captured from their energy-related attitudes. And personal comfort and health concerns were the best predictors of consumption. The consumption feedback was found to reduce energy usage (Matsukawa, 2004; Seligman et al., 1978). It was found that households with the same energy installations with a 37% variation in energy consumption because of differences in behavior (Desmedt et al, 2009).

Research on energy consumption and practices at the household level was comparatively minimal in the 1990s as in the 1970s due to the general energy price stability. Guerin et al. (2000) identified a lot of variables that affect energy behavior and residential energy consumption. The householder’s age, income, education, homeownership, desire for comfort, incentives, and major weatherization were reported to play a role in energy consumption. Yust et al. (2002) reorganized these variables and identified that individual energy consumption decision was affected by the human ecosystem model developed by Guerin (1992) adapted from the findings of Bubolz et al. (1979) and Morrison (1974).

2.2. Gasoline Consumption

Several factors can be used to capture influence household gasoline usage such as household demographic characteristics, vehicle attributes, fuel costs, travel costs, and land use or urban form. For example, Polzin (2006) investigated the major factors influencing demand for travel indicating by vehicle miles of travel (VMT). These factors were divided into three major categories: socio-economic conditions, land use conditions, and transportation system conditions.

One of the important trends in household gasoline usage is that the impact of urban form on transportation energy use (Newman and Kenworthy 1989, 1999; Holtzclaw, 1991; Ewing, 1997; Ewing, et al., 2002; Handy et al., 2005; Hankey and Marshall ,2010). An important contribution to the literature about the impact of urban form is the work of Newman and Kenworthy (1989) about land use and travel in 32 major cities in Europe, North-America, Australia and Asia. It was found that gasoline consumption per capital in ten large United States cities varied by up to 40%, primarily because of land use and transportation planning factors rather than price and income variations. They claimed that residents in compact areas drive between one-third and one-fourth as much as do residents of areas characterized by sprawl. Another study by the Natural Resources Defense Council showed that as density doubles, automobile use may drop as much as 40% (Benfield et al., 1999).

There are also studies on disaggregate household level data that attempt to control for observable differences between households living in low and high density areas. Schmalensee and Stoker (1999) used the Residential Transportation Energy Consumption Survey (RTECS), focused on 1991 data along with data for 1988. It was well documented that household structure has strong effects on gasoline demand. The most striking of these effects was the number of licensed drivers with the elasticity of roughly 0.6. Allowing for this effect cuts the estimated income elasticity in half. Household size also mattered, but the elasticity was only around 0.1. In

all specifications it has been found that urban households drive less than suburban households, who drive less than rural households.

Bento et al. (2005) used the 1990 National Personal Transportation Survey (NPTS) to build disaggregate models of number of vehicles per household and vehicle miles traveled (VMT) per vehicle. They supplemented the density measures in the data with road density, rail and bus transit supply, population centrality, city shape, jobs-housing balance, population density, land area, and climate. The study found that the magnitudes of the impact of any of their built environment measures were frequently statistically insignificant and small in magnitude. Following that study, Brownstone and Golob (2009) based on California household data claimed that density directly influences vehicle usage, and both density and usage influence fuel consumption. This total effect of residential density on fuel usage is decomposed into to two paths of influence. Increased mileage leads to a difference of 45 gallons, but there is an additional direct effect of density through lower fleet fuel economy of 20 gallons per year, a result of vehicle type choice.

While earlier studies have contributed to our understanding of household vehicle gasoline usage and residential electricity consumption, this thesis attempts to make a contribution from the following aspects:

It extends the framework proposed and applied by Yust et al. (2002) for residential energy consumption to household in-home and transportation energy consumption including energy prices, and household spatial variables in the environmental component.

The disaggregate data used in this thesis represent significant variation in energy prices. We incorporate a comprehensive set of household energy expenditures in-home and on

transportation, as well as household demographics, individual characteristics, vehicle attributes and built environment characteristics.

Chapter III

Methodology and Data

3.1. Conceptual Framework

Energy consumption is like other consumption activities whereby household are assumed to maximize utility and subject to budget. Each household is assumed to maximize its satisfaction (or utility) when consuming (or not consuming) goods and services, possessing wealth and spending leisure time. Given that the year 2006 and 2008 are not too much apart, tastes and preferences are likely to be the same. Following Yust et al. (2002) who categorized the determination variables into 4 environments (i.e., human organism (HO), natural environment (NE), social environment (SE), and designed environment (DE) relative to the housing and appliances), I grouped the variables accordingly that might influence household energy consumption in following 5 dimensions (Figure 2):

In this study, quarterly household in-home electricity and transportation energy expenditure (gasoline and motor oil) are used as dependent variables of household energy consumption; household transportation energy consumption does not include public transportation consumption. Seen from Figure 2, the dependent variables are specified as follows:

Natural environment (NE). NE includes location variables - region, degree of urbanity (population size of the area of residence) and urban/rural; climate variables – heating degree-days (HDDs) and cooling degree-days (CDDs). The natural environment of the household is the

first and basic component to lead the household energy consumptions, which should dominates the in home energy consumption to obtain comfortable indoor temperature.

Structural Characteristics (SC). SC includes house type, building age, room/bathroom number, the ownership of air-conditions and swimming pool. House type has been well documented to be linked to housing consumption. Bigger houses require more energy than smaller ones because there is more space to heat and cool and detached houses and mobile home require more energy than attached houses of the same size because there is more exposed surface area.

Household characteristics (HC). HC includes household income, education, race, marital status, family size.

Household Preference (HP). HP includes the household activities/preferences on in-home and transportation energy consumption such as energy sources choice for in-home or transportation, in home electricity use activities and vehicle number or type preference.

Market Environment (ME). ME includes household energy prices such as electricity prices, gasoline prices and natural gas prices. In accordance with the law of demand, household consumption of energy is expected to be negatively related to energy price. And if any, the price of substitute goods is supposed to be positive. For example, the natural gas is good substitute alternative for electricity in household heating and cooking.

3.2. Econometric Specification

Household energy consumption (electricity and gasoline) was specified as the explained variable. Explanatory variables included in the regression are described in chapter 4. To examine the influencing factors, the following conceptual multiple regression is specified:

$$\text{Household energy consumption} = f(SC, NE, HC, PE, ME)$$

To quantify household consumption of energy, both ordinary least regression (OLS) and Tobit model (Tobin 1958) are used. Using OLS is straightforward. This method minimizes the sum of squared vertical distances between the observed responses in the dataset, and the responses predicted by the linear approximation. While there are many households without electricity consumption and/or gasoline consumption, they could not survive without them. Potential reasons could be their use of natural gas or other energy sources. More likely it could be due to the fact that the utilities are included in the rental fees. Moreover, dependence on public transportation could lead to zero gasoline usage. Thus, given the censored nature of data, Tobit model is used. Tobit model describes relationship between a non-negative dependent variable yi and an independent variable (or vector) xi. The model supposes that there is a latent (i.e. unobservable) variable yi* which depends on xi via a parameter (vector) β, determining the relationship between the explanatory xi and the latent variable.

The observable variable yi is defined to be equal to the latent variable whenever the latent variable is above a certain threshold zero otherwise. For example, if y is the quantity of electricity consumed by household i, and x the price of electricity; β is expected to be negative due to law of demand. But it might be influenced by other factors that could lead household i to consume different amounts of electricity from what a particular price level may suggest. The error term μi accounts for such discrepancies. The use of this model is suitable when energy consumption is either a positive amount or zero, since the “zero” responses from people who do not pay anything to energy are censored. Marginal effects were computed for each explanatory variable to evaluate the effect of each variable on the household energy consumption.

3.3. Data Sources

In this research, we used data for the year 2006 and 2008 to understand U.S. household energy consumption. As energy cost in 2008 was very high relative to 2006, combing the two years better reflected household energy consumption behavior. Additional details about the detail sources and measurement are described in the following two sections.

Consumer Expenditure Survey

Our primary data were obtained from Consumer Expenditure Survey (CE) data, a nationwide household survey designed by the U.S. Bureau of Labor Statistics (BLS). The BLS Division of Consumer Expenditure Surveys conducts a nationwide survey of consumer expenditures every year and publishes results aggregated at the national level. The public-use micro data documentation provides details on the available variables like expenditure, income, and other demographic variables including estimation procedures. The data set includes two surveys: an Interview Survey and a Diary Survey. The Diary Survey was not used in this study as it contains only 2 weeks of data for any given household.

The Interview Survey which we adopted contains five fiscal quarters (3-month intervals) of data. In the Interview Survey, the sample is selected on a rotating panel basis, surveying about 7,000 consumer units each quarter. The sample size is 35832 and 34485 in 2006 and 2008 respectively. Each consumer unit is interviewed once per quarter, for five consecutive quarters. Data are collected on an ongoing basis in 91 areas of the United States. Survey participants record dollar amounts for goods and services purchased during the reporting period. We especially studied data in 2006 and 2008 based on interviews conducted both from January 2006 to March 2007 and January 2008 to March 2009.

CES data is very important and popular national level database used in the household residual energy consumption is the Residential Energy Consumption Survey (RECS) conducted from Energy Information Administration (EIA). The major component of the survey was a home interview, which collected household information on housing structure, energy-using equipment within home, household characteristics and etc. Data concerning actual energy consumption were obtained from records of the energy suppliers. First conducted in 1978, the twelfth RECS was conducted in 2005. The 2005 survey collected data from 4,382 households in housing units statistically selected to represent the 111.1 million housing units in the United States. However, the data is triennially published and unavailable in 2006 and 2008 (the time when the energy price was high) we are interested in.

Hirst et al. (1982) pointed out that before publication of the first national survey results (1979) by EIA most prior analyses of household energy use relied on aggregate data or incomplete disaggregate data. In that case both CES and RECS, as a national disaggregate database can provide the most necessary variables to be used in our study in household in-home energy consumption. The two data sources provide similar expenditure estimates for natural gas and electricity (BLS, 1991). However, it is documented that the RECS is quite weak because of the small number of observations (about 1/7 of CES observation) and considerable variance (Randolph 2008).

Energy Price

The effect of price on consumption should be included in the time of when energy prices were rising rapidly. The key problem with the CES data is that we are interested in household energy use, not energy spending. Fortunately the Department of Energy provides data on prices for electricity, natural gas and motor gasoline retail prices for the year 2006 and 2008 (EIA,2006

2007, 2008, 2009c,2011). This in-home electricity energy is at the state level, so we miss variation in prices within the state. Also natural gas price is also adopted by state as that of the in-home substitute energy for electricity. Motor gasoline retail price are adopted by month in order to obtain the average price during the time when expenditure occurred (3-month intervals). In other words, motor gasoline retail price is taken the average value in the quarter that the gasoline expenditure happened. Given that we have calculated energy prices and total expenditure by energy source, we can derive consumption levels.

Climate data

Climate or temperature factors are standard in household energy consumption models. We adopted monthly heating degree-days (HDDs) and cooling degree-days (CDDs) for households at their states of residence from National Oceanic and Atmospheric Administration (NOAA), which are used to examine the demand of heating/cooling fuel use on HDDs and CDDs(NOAA,2006,2007,2008,2009,2010). In order to match the quarterly household energy consumption, we convert the monthly HDDs/CDDs to quarterly (when energy expenditure or consumption occurred) on a state-wide basis including the variations of temperature both in states and seasons. It must be noted that HDDs and CDDs are quantitative indices reflecting demand for energy to heat or cool houses and businesses. They are based on how far the daily average temperature departs from a human comfort level of 65°F. In other words, every one degree below 65°F counts as one HDD and each degree of temperature above 65°F counts as one CDD. For instance, a day with an average temperature of 50°F contributes 15 HDDs to the total.

Chapter IV

Empirical Results

This chapter reports empirical results. First, we provide descriptive statistics including means, standard deviations, and correlation tests. This is followed by parameter estimates based on estimation of econometrics models.

4.1. Descriptions of variables

Household Energy Expenditures and Consumptions

The average household spent $316.71 and $341.48 per quarter (or $1266.84 and $1365.92 per annum) on electricity in 2006 and 2008 respectively, showing a steady increase with a growth rate of 7.8%. The average electricity consumption per household decreased from 3007.33 to 2931.37 kilowatt-hour (kWh) quarterly at the rate of 2.52% from 2006 to 2008, due to the increase in price. On the average, natural gas cost $138.24 and $143.68 quarterly per household in 2006 and 2008 respectively; and $552.96 and $577.72 annually, increasing by 3.9% from 2006 to 2008. The average quarter consumption remains all almost the same which was 9.87 and 9.88 Mcf (one thousand (1,000) cubic feet) in 2006 and 2008 increasing slightly by 0.10%.

The expenditure on gasoline was much more than that on in-home energy for a household. On the average household spent $547.89and $661.05 on motor gasoline quarterly (or $2191.56 and $2644.2 annually) in 2006 and 2008 respectively, suggesting an increase of 20.65%. The average gasoline consumption per household was 218.99 and 214.44 gallon per quarter in 2006 and 2008 decreasing at the rate of 2.10%. The increasing spending was largely contributed by the

increasing price of the gasoline. Therefore for both of electricity and gasoline, the quarterly household consumption declined and nature gas quarterly consumption kept almost the same with rising household energy expenditure.

Natural Environment (NE)

The regions of CES samples followed the same distribution in both years – over 35% were from the South then the Midwest (over 23%) and around 22% from the West, the least was in the Northeast. Almost 95% of samples were urban residents rather than rural ones. Larger than 33% households were from the biggest population cities with more than 4 million. As a high correlation between the location-dependent variable urban/rural and population of sample city (almost 95% urban households and 5.7% of rural ones are included in population size variables), we choose to keep only population indicating better urbanity degree in the regression models.

Structural Characteristics (SC)

According to the National Association of Home Builders, new houses averaged 2,433 square feet in 2005, up from 2,095 square feet in 1995. It has been documented that the single-family detached housing unit represented 62% of the housing units in the United States in the 1990 census and 73% of the 101.5 million U.S. households (EIA, 1999). According to our results, single-family detached was also the most common (about 63%) housing type in the United Sates. Average building age was 38 years old. The average house had six rooms, three bedrooms and nearly 2 bathrooms. Houses equipped with central air condition became popular during 2006 to 2008. The percentage of houses with window air condition slightly declined from 21.13% to 20.28%.

Household Characteristics (HC)

The household income median was $34770 and $34340 in 2006 and 2008; the corresponding mean values were $50761.26 and $52271.92. The average household income increased a little in 2008; the growth rate was only nearly 3% compared with the gasoline expenditure growth rate of 20.7%. The average household size was about 2.5 persons with standard error1.5 for both years. Over 50% of household lived as married families. The typical interviewed person had high school graduate/some college education.

Household Preference (HP)

From energy sources perspectives, for in- home energy consumption, natural gas (>50%) and electricity (almost 30%) predominated in space and water heating. There was a decline in natural gas use for heating and water heating and an increasing in electricity use from 2006 to 2008. However, natural gas was still dominant in heating and water heating. For cooking, over 56% households used electricity and then natural gas and this trend remained the same in both years (Figure 3).

By examining different electricity usage pattern, the household used electricity mainly for heating, water heating and cooking (26.31%) following by only cooking (20.09%); electricity used for water heating and cooking had the least share (Figure 4).

Regarding household transportation energy consumption preferences, we focus on three indexes: the choices of fuels, number of vehicles owned by a household, and type of vehicle.

Vehicle Fuel Type

Gasoline was dominant household vehicle fuels which accounted for 98.01% in 2006 and 97.95% in 2008 compared to diesel fuel with corresponding shares of 1.75% in 2006 and 1.53% in 2008. Interestingly, hybrid electric powered transport usage doubled from 0.21% in 2006 to 0.47% in 2008.

Number of Vehicles Owned

In CES data, the 35832 U.S. households owned or had regular use of 67129 vehicles in 2006, an average of 1.88 vehicles per household. In 2008, it kept the same average number -1.88 with the total 64931 vehicles for 34485 households. These averages were up slightly from an average of 1.7 vehicles per household in 1997 and 1.6 vehicles per household in 1993(EIA, 1997).

Type of Vehicles Owned

Automobiles and trucks/vans were the most common vehicles owned by United States household which accounted for 88% of household vehicle stocks (Figure 5). It has been reported that in 2001 the passenger cars ranked as the single largest segment (58%) of the nation's vehicle stock (EIA, 2005). But our data shows that the automobile share in household vehicle stock dropped to less than a half in both 2006(48.09%) and 2008(47.83%).On the other hand, it seems consumers' preferences for sports-utility or heavy vehicles is increasing. The share of trucks, minivans (vans), SUVs changed from 39.90% to 40.01% and there was an increase in campers from 1.85% in 2006 to 2.05% in 2008. Moreover, the motorcycle/moped/scooter shared 3.90% in 2008 compared with 3% in 2006.

Market Environment (ME)

Monthly statistics on unit energy prices (Figure 6) suggest that real motor gasoline price has increased in recent years. During the survey period, the energy unit prices peaked around June to July in 2008. Motor gasoline was at $4.06 in 2008, increasing by 140.75% compared with the lowest $1.69. In contrast, there was only 30.38% increase for electricity prices. The price trend in electricity is a striking contrast to gasoline. Electricity prices have been less volatile and have gradually risen throughout the entire period. Electricity prices were quite smooth (Figure 1) but varied mostly across geographic locations (Figure 7). The West North area had the cheapest

electricity whereas people living in Pacific Noncontiguous area spent the most. The difference between regions during 2006 and 2008 increased from $11.82 to $17.31 dollar per unit.

The households without reported electricity spending mostly were more multiple unit structure housing types like deplux-4plux, high-rise or apartment and college dormitory. These household incomes were usually lower than the average level. One possibility could be the utilities were included in the rental fees. The households had no gasoline spending, about 85% of them had no car and the heavy vehicles ownership was less than 5%.

4.2. Econometric Estimation Results

The OLS and Tobit models were used to obtain parameter estimates. Given the censored nature of the data used in this study, estimates based on Tobit model (also known as censored normal regression model; Maddala, 2001) are appropriate. The OLS estimates were obtained just for comparison. The explained variables are household electricity and household gasoline consumption respectively. The variables include the natural environment (NE), the structural characteristics (SC), the household preference (HP) and the market environment (ME). Description statistics of the variables from CES are also reported in Table 1.To identify the predictors of energy use, total unit consumed for household electricity and gasoline were regressed on the independent variables and regression results are shown from Table 2 to Table 5.

4.2.1. Household Electricity Consumption

We began with parameter estimation for household electricity usage in the United States. We used state-wide price data to convert electricity expenditure into consumption in kWh. Before pooling data for the two years, we obtained real income and electricity price in 2008 compared with 2006 using CPI (1.067). Also we added the real natural gas price by state to the substitute effect. The household electricity consumption were regressed on electricity price and natural gas

price as the market environment(ME), location dummy and HDDs/CDDs variables representing nature environment (HO), housing variables reflecting structural characteristics (SC), household characteristics (HC) and household energy-use behavior variables from household preference (HP) factors. Estimation results show that most coefficients are significant and have signs as expected. The parameter estimates in Table 2 provides Tobit parameter estimates for the changes in the latent variables(y*) and marginal effect on the household electricity consumption and Table 3 gives us OLS results.

The natural environment (NE)

The results show that quarterly household consumption of electricity increases with increase in total quarterly HDDs/CDDs. After we controlled for other influences, household in the Northeast, the Midwest and especially the West consume much less electricity than those in the South. Households living in cities with the population size of 330-1190 thousand consume the greatest, more than the area with >1200 thousand population such as LA or New York City; the least household electricity consumption is where population is smallest. Thus, a household is a lower carbon emitter as an electricity user and more environmentally friendly if living in the West region with population less than 125 thousand.

The structural characteristics (SC)

Compared to the mainstream housing type - single family detached house, all others housing types are associated with smaller electricity consumption except the mobile home. The low efficiency of mobile homes is well-known mostly located in the South. Since there is no house size variable in the CES data, the number of room and bathroom/half bathroom are used to capture housing area effect on electricity consumption. As expected, household electricity increases with the number of rooms and bathroom/half bathroom. In addition, bathroom/half

bathroom has a greater marginal effect, suggesting that more electricity is consumed for an additional bathroom/half bathroom rather than common room such as a living room or a bedroom which is about 3 times. The building age is found to have significant positive impact on electricity consumption but is small in magnitude. Additionally, houses equipped with air condition have more electricity consumption than those do not. Families owning a swimming pool spend much more electricity.

The household characteristics (HC)

As expected, the electricity demands increases with household income. Thus, the higher household income, the more electricity is consumed. This result is consistent with previous research studies that income was positively related to energy consumption (e.g., Newman and Day, 1975; Ritchie et al, 1981,Ewing and Fang Rong 2008). Besides income, the other household characteristics predictors like family size and minority also have a positive effect on electricity consumption. The household in the separated or never married statuses consume less than married people, especially those who never marriage. For education, interviewed person with basic and high education level are smaller electricity consumers than high school graduate and an equivalent education level.

The household preferences (HP)

In-home electricity usage structure between heating, water heating and cooking was investigated using various combinations: electricity use in heating, water heating and cooking, any two of three electricity use activities and only electricity use in heating, water heating or cooking. Not surprisingly, there is positive effect and a statistically significant on electricity consumption no matter what kind of electricity use activities, and the more electricity use

activities the more energy consumed. Heating and water heating account for a greater share of electricity consumption and cooking use the least.

The market environment (ME)

We examined both real electricity and natural gas price impacts on household electricity consumption. Higher electricity prices are likely to reduce household electricity consumption and considering the natural gas price effect, it is the opposite effect to that of electricity price; thus the substitution effect is significant.

4.2.2. Household Gasoline Consumption

We now turned to household gasoline consumption to measure energy for transportation.

Unlike in-home electricity, gasoline price varies over time. Thus, we obtained nominal monthly average motor gasoline retail price and deflated it by the CPI to get the corresponding real monthly prices relative to Oct, 2005. Then we averaged over the months in each rotating quarter, and merged household data. The regressions were estimated using framework components in Figure 2 and results are in Table 4 and Table 5. As structural characteristics (SC) do not influence gasoline consumption, housing characteristics were not included in the model.

The nature environment (NE)

The location characteristics are statistically significant. The South is the biggest consumer, not only for electricity consumption but also gasoline consumption. The Northeast consumes the least, compared with a household in the South.

We find some interesting results regarding gasoline consumption as city size varies. Thus, places with the population of more than 12000 consumes most compared to cities with other sizes. Cities having population size of 125-329.9 thousand seem to be the least gasoline consumer. This suggested that household gasoline consumption is not negative linearly

relationship with population size of the cities. Medium population size cities such as Pittsburgh, Newark or Montgomery consume less than others. In addition, household gasoline consumption shows seasonality as well. The great consumption quarter is around February to April and lasts till summer. It seems pleasant weather increases the probability of household driving.

The household characteristics (HC)

Among the household characteristics (HC), family size strongly increases gas consumption. The interviewed person with high education level tends to be a bigger consumer than high school graduate and an equivalent education level. The household of minority and the household in the separated or never married statuses consume less.

The household preferences (HP)

Household preferences (HP) reflect vehicle-dependent life style and play an important role in household gasoline consumption. Apparently the number of vehicles owned by household and household preferences to larger vehicles (trucks. minivans, vans or SUVs) is strongly related to household gas consumption.

The market environment (ME)

Consistent with a priori expectation, the results show that an increase in gasoline price reduces household gasoline consumption, suggesting that increasing gasoline price would be effective to reduce it consumption, especially in the long run. From 2006 to 2008, there was a significant increase in using hybrid vehicles.

Chapter V

Summary and Conclusions

This thesis presents a comprehensive analysis of U.S. household energy consumption based on CES data for year 2006 and 2008. Important findings of the study are presented in this chapter.

Descriptive statistics suggest that costlier energy results in higher energy expenditures. Household expenditure on gasoline increased at the rate of 20.65% from 2006 to 2008 compared to electricity at 7.8% and natural gas at 3.9% .The U.S. households spend more on the way than in home which is twice as large as electricity and 4.6 times as large as natural gas in 2008.A comparison of 2006 with 2008 suggests that electricity tends to play a greater role in household in-home and hybrid electric powered transport usage doubled its share. Faced with the instability of energy resources, the U.S. households seem to be making adjustments to consumption patterns.

Primary factors driving household total electricity gasoline consumption are the structural characteristics (SC) and the household preference (HP). These two factors comprehensively indicate the American lifestyle with large house, highly car-dependent and preference to heavy vehicles. That also means there are opportunities for households to design a significantly less energy lifestyle specially using tax benefit for the household prefer renewable energy like using wood energy for heating.

The nature environment (NE) shows the relation between electricity consumption and temperature by HDDs and CDDs. Spatially, the South region is always the biggest consumer than the rest of the U.S. regions not only in electricity but in gasoline consumption. Medium

urbanization (Population Size: 125-330 thousand) is the best scale to reduce gasoline consumption.

The household characteristics (HC) also impact household energy consumption. Household income, family size and a married status have a positive relation with energy consumption. Minority households tend to consume more electricity and less gasoline which reflects the difference between cultures.

The market environment (ME) indicates that higher energy prices are likely to reduce household energy consumption. The availability of substitute goods also reduces household energy consumption. The continuous highly cost fossil fuels would promote demand for renewable, clean and affordable energy from wood, solar, wind. Again taking wood energy for example, it is promising in the further especially considering the improved technologies like advanced wood combustion, re-growth of forest in the United States and if some polices can improve its price competitiveness (Richter Jr. et al., 2009).

The aforementioned aspects explain the importance of factors influencing household electricity and gasoline consumption but there are limitations in this study primarily caused by the use of secondary data. Although the survey was selected in 2006 and 2008, the same households were not included each year. Thus, one cannot interpret the data as if it were longitudinal.

This study was initiated by that the real value of gasoline prices rose to record levels in the United States in 2008 and energy becomes headline issue again in these years. The public attention has once again focused on how dependent we are on a stable and affordable energy supply. Nationally, the chosen lifestyle is important based on our observation in this study. The household reliance on energy is counted to be stronger with the increasing house size and

preference to car culture. Consumers will have difficulty achieving a significant reduction in their household energy consumption in the future.

The findings provide insights into factors influencing household energy consumption and help us better understand household energy consumption behavior during high energy price year. It provides support for further research, identifies needed technology improvements, frames education program and promotes smart urban growth and development of effective policies to reduce energy consumption and GHGs emissions.

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Table 1. Statistical Description of Variables

Variables	Descriptions	2006	2008
Quarterly Energy consumption		Mean(SD) \Percentage	Mean(SD) \Percentage
Electricity(kHw)	Average electricity consumption	3007.33 (2516.09)	2931.37 (2340.93)
Nature gas(Mcf)	Average natural gas consumption	9.87 (15.97)	9.88 (15.81)
Gasoline (gallon)	Average gasoline consumption	218.99 (207.61)	214.44 (198.07)
Natural Environment			
Region	Northeast	18.85	18.69
	Midwest	23.01	23.44
	South*	35.29	35.53
	West	22.45	21.84
	Missing	0.4	0.5
Population (thousand)			
	More than 1200*	56.64	57.38
	330-1190	9.16	6.41
	125-329.9	20.94	23.13
	Less than 125	12.86	12.57
	Missing	0.4	0.5
Structural Characteristics			
Building	Single family detached*	62.96	63.72
	Town house, duplex-4plex,muti-unit structure	16.37	15.31
	Apartment or flat	13.39	13.97
	Mobile home or trailer	5.27	5.33
	Others	1.97	1.66
	Missing	0.04	NA
One and half Bathroom	Bathrooms/half bathroom No.	1.78(0.78)	1.82(0.81)
Room	Rooms No. excluding all baths	6 (2.34)	6 (2.47)
Building age	How long the building has been built?	38(30.80)	38(29.88)
Swim pool	The single family detached house with swim pool	5.71	5.66
Central Air Condition	House with central air condition	58.58	60.93
Window Air condition	House with window air condition	21.13	20.28
Household Characteristics			
Income	Amount of the household income before taxes in past 12 months	50761.26 (59200.03)	52271.92 (62184.70)
Family Size	Number of Family Members	2.55(1.51)	2.52(1.50)

Marital status	Married*	53.54	53.4
Separated	Widowed/Divorced/Separated	26.42	26.19
Never married	Never married	20.03	20.41
Race	White*	82.14	81.77
Minority	Black/ Native American/Asian/Pacific Islander/Multi-race	17.87	18.23
Education		0.28	0.24
Basic education	Under high school	15.19	14.52
	High school/ Some college(less than college)*	46.96	46.74
High education	Associate's /Bachelor's/Master's Professional(Doctorate)degree	37.87	38.74
Household Activities/Preference			
Electricity Use			
	No electricity is used for heating, water heating and cooking.*		
Heating, water & cooking	Heating, Water heating and cooking all use electricity	24.64	26.31
Heating &Water heating	heating and water heating use electricity	1.39	1.62
Heating & Cooking	Both heating and cooking use electricity	2.05	1.98
Cooking & Water heating	Both cooking and water heating use electricity	8.14	7.7
Only Heating	Only heating use electricity	1.63	1.82
Only Water heating	Only water heating use electricity	2.68	2.49
Only Cooking	Only cooking use electricity	22.03	20.91
Vehicles			
Vehicles Number	Number of owned vehicles	1.88(1.51)	1.88(1.51)
Vehicle Type	Automobile and other vehicles*	60.1	59.99
	Truck, including vans	39.9	40.01

Source: Consumer Expenditure Survey (2006, 2008)
*the base variable for dummy variables

Table 2.Tobit Model results – Household Electricity Consumption

Variables	Coefficient	SE	Marginal Effect
Intercept	1389.53	73.54	
Structural Characteristics			
Building Type			
Townhouse	-647.65	25.57	-564.54
Apartment	-975.82	28.84	-850.60
Mobile	130.32	38.33	113.60
Others	-877.68	87.01	-765.05
Room No.	132.82	5.05	115.77
One and half Bathroom	414.73	14.52	361.51
Building age	2.56	0.34	2.23
Swimming Pool	1092.89	35.66	952.65
Central Air Condition	320.25	23.31	279.16
Window Air Condition	203.67	25.21	177.54
Natural Environment			
Region			
Northeast	-344.29	30.61	-300.11
Midwest	-483.54	25.61	-421.49
West	-660.46	26.74	-575.70
Population			
330-1190 thousand	176.13	33.04	153.53
125-329.9 thousand	-112.44	21.17	-98.01
Less than 125 thousand	-211.60	27.41	-184.44
Temperature			
Quarterly HDDs	0.20	0.01	0.17
Quarterly CDDs	0.76	0.03	0.67
Household Characteristics			
Log income	11.45	2.36	9.98
Education			
Basic Education	-175.69	24.72	-153.15
High Education	-10.46	18.25	-9.12
Race			
Minority	227.47	22.10	198.28
Family Size	261.53	6.29	227.97
Marital			
Separated	-200.88	21.70	-175.10
Never married	-496.80	24.64	-433.05
Household Preference			

Heating, water heating & cooking	1065.40	24.54	928.68
Heating & water heating	716.82	68.31	624.83
Heating & cooking	346.87	58.83	302.36
Water heating& cooking	383.46	33.27	334.26
Only Heating	409.57	62.74	357.01
Only Water Heating	359.59	52.33	313.45
Only Cooking	40.07	22.43	34.93
Market Environment			
Electricity Price	-120.99	3.53	-105.46
Natural gas price	7.12	2.85	6.20
_Sigma	2101.91	5.95	
Number of Observations			69085
No. Obs of Lower Bound			5130
Model Fit Summary			
Log Likelihood			-585096
AIC			1170263
Schwarz Criterion			1170593
Algorithm converged.			

Table 3.OLS Model results – Household Electricity Consumption

	OLS with all observation		OLS excludes no energy use	
Variable	**Coefficient**	**SD**	**Coefficient**	**SD**
Intercept	1437.62	68.64	1635.51	70.89
Structural Characteristics				
Townhouse	-590.62	23.91	-456.99	24.77
Apartment	-862.76	26.77	-705.92	28.43
Mobile	113.30	36.08	91.88	36.45
Others	-850.23	78.20	-403.05	93.61
Room No.	119.24	4.73	118.34	4.96
One and half Bathroom	415.38	13.64	437.95	13.97
Building age	2.61	0.32	3.15	0.33
Swimming Pool	1081.01	33.68	1075.07	33.43
Central Air Condition	290.22	21.78	216.87	22.54
Window Air Condition	186.40	23.50	132.67	24.43
Natural Environment				
Region				
Northeast	-339.75	28.65	-324.28	29.39
Midwest	-445.77	24.01	-429.37	24.55
West	-626.66	25.05	-625.83	25.68
Population				
330-1190 thousand	165.55	30.98	199.03	31.64
125-329.9 thousand	-95.57	19.85	-82.58	20.25
Less than 125 thousand	-196.88	25.70	-122.98	26.30
Temperature				
Quarterly HDDs	0.20	0.01	0.21	0.01
Quarterly CDDs	0.77	0.03	0.83	0.03
Household Characteristics				
Log income	8.03	2.21	0.75	2.27
Education				
Basic Education	-118.12	23.04	-24.65	24.08
High Education	-38.24	17.12	-73.57	17.42
Race				
Minority	238.23	20.65	230.07	21.31
Family Size	249.49	5.91	253.29	6.00
Marital				
Separated	-180.00	20.37	-154.41	20.71
Never married	-395.13	23.01	-297.82	23.90
Household Preference				
Heating, water heating &	1052.12	22.97	1100.03	23.67

cooking				
Heating & water heating	725.69	63.57	945.25	67.54
Heating & cooking	352.30	54.92	362.88	56.88
Water heating & cooking	355.48	31.27	316.76	31.60
Only Heating	414.67	58.60	516.59	60.86
Only Water Heating	351.40	49.23	338.53	49.67
Only Cooking	48.57	21.02	26.19	21.42
Market Environment				
Electricity Price	-111.93	3.30	-123.65	3.39
Natural gas price	9.18	2.66	10.21	2.74
Number Observations Used		69085		63955
F value		995.49		866.32
R-Square		0.33		0.32
Adj R-Square		0.33		0.32

Table 4. Tobit Model results – Household Gasoline Consumption

Variables	Coefficient	SE	Marginal Effect
Intercept	102.06	6.28	
Natural Environment			
Region			
Northeast	-39.32	2.09	-32.17
Midwest	-29.70	1.93	-24.29
West	-23.82	1.95	-19.48
Population			
330-1190 thousand	-13.83	2.76	-11.31
125-329.9 thousand	-20.27	1.80	-16.58
Less than 125 thousand	-18.01	2.30	-14.73
Seasonality			
Nov-Jan	3.77	2.73	3.09
Dec-Feb	8.10	2.72	6.63
Jan-Mar	18.44	3.39	15.09
Feb-Apr	34.22	3.43	27.99
Mar-May	21.73	3.56	17.77
Apr-Jun	21.59	3.74	17.66
May-Jul	19.12	3.83	15.64
Jun- Aug	8.83	3.80	7.22
Jul-Sep	0.69	3.71	0.57
Aug-Oct	-6.31	3.51	-5.16
Sep-Nov	-7.36	3.36	-6.02
Household Characteristics			
Log real income	1.84	0.20	1.50
Education			
Basic Education	-52.72	2.18	-43.12
High Education	22.86	1.55	18.70
Race			
Minority	-15.19	1.92	-12.43
Family Size	25.25	0.55	20.65
Marital			
Separated	-34.46	1.92	-28.19
Never married	-27.67	2.10	-22.64
Household Preference			
Vehicle No.	44.58	0.57	36.47
Heavy vehicle	68.29	1.67	55.86
Market Environment			

Gasoline Price	-23.83	2.12	-19.49
_Sigma	2101.91	5.95	
Number of Observations			70317
No. Obs of Lower Bound			7110
Model Fit Summary			
Log Likelihood			-424978
AIC			850014
Schwarz Criterion			850279
Algorithm converged.			

Table 5. OLS Model results – Household Gasoline Consumption

	OLS with all Observation		OLS excludes no energy use	
Variable	**Coefficient**	**SD**	**Coefficient**	**SD**
Intercept	132.38	5.75	163.86	6.25
Natural Environment				
Region				
Northeast	-26.29	1.90	-17.28	2.11
Midwest	-25.37	1.77	-23.47	1.91
West	-20.96	1.80	-20.39	1.93
Population				
330-1190 thousand	-14.31	2.53	-16.84	2.74
125-329.9 thousand	-20.84	1.65	-23.55	1.78
Less than 125 thousand	-19.32	2.11	-20.77	2.27
Seasonality				
Nov-Jan	3.74	2.50	4.20	2.72
Dec-Feb	8.11	2.49	9.43	2.70
Jan-Mar	18.84	3.11	22.32	3.38
Feb-Apr	33.21	3.15	37.38	3.42
Mar-May	20.93	3.26	23.94	3.54
Apr-Jun	21.31	3.43	24.53	3.72
May-Jul	19.04	3.51	22.93	3.82
Jun- Aug	9.55	3.48	11.95	3.78
Jul-Sep	0.87	3.40	1.59	3.68
Aug-Oct	-5.10	3.21	-5.00	3.49
Sep-Nov	-7.91	3.08	-8.57	***3.33***
Household Characteristics				
Log income	1.24	0.19	0.68	0.20
Education				
Basic Education	-35.48	1.96	-29.01	2.25
High Education	18.15	1.43	15.00	1.53
Race				
Minority	-7.28	1.75	-1.13	1.96
Family Size	23.99	0.50	26.31	0.55
Marital				
Separated	-29.78	1.77	-28.02	1.91
Never married	-21.15	1.92	-14.70	2.11
Household Preference				
Vehicle No.	38.86	0.53	33.91	0.56
Heavy vehicle	57.67	1.55	47.85	1.63

Market Environment				
Gasoline Price	-24.01	1.94	-28.30	2.11
Number Observations Used		70317		63207
F value		1045.73		866.32
R-Square		0.29		0.22
Adj R-Square		0.29		0.22

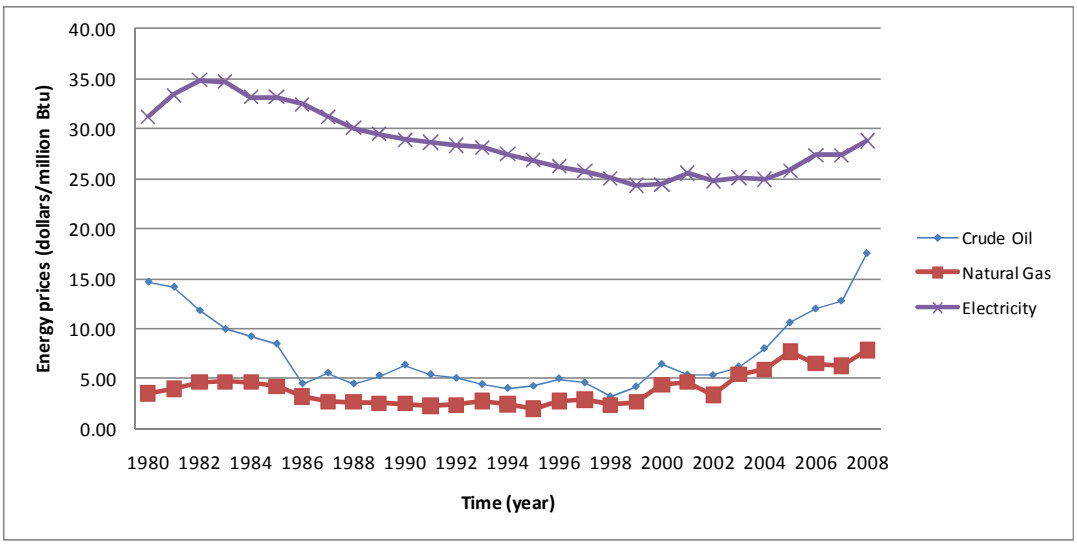

Fig. 1 Selected Energy prices from 1980- 2008(2008 dollar per million Btu).
Sources: U.S. Energy Information Administration, 2009a.

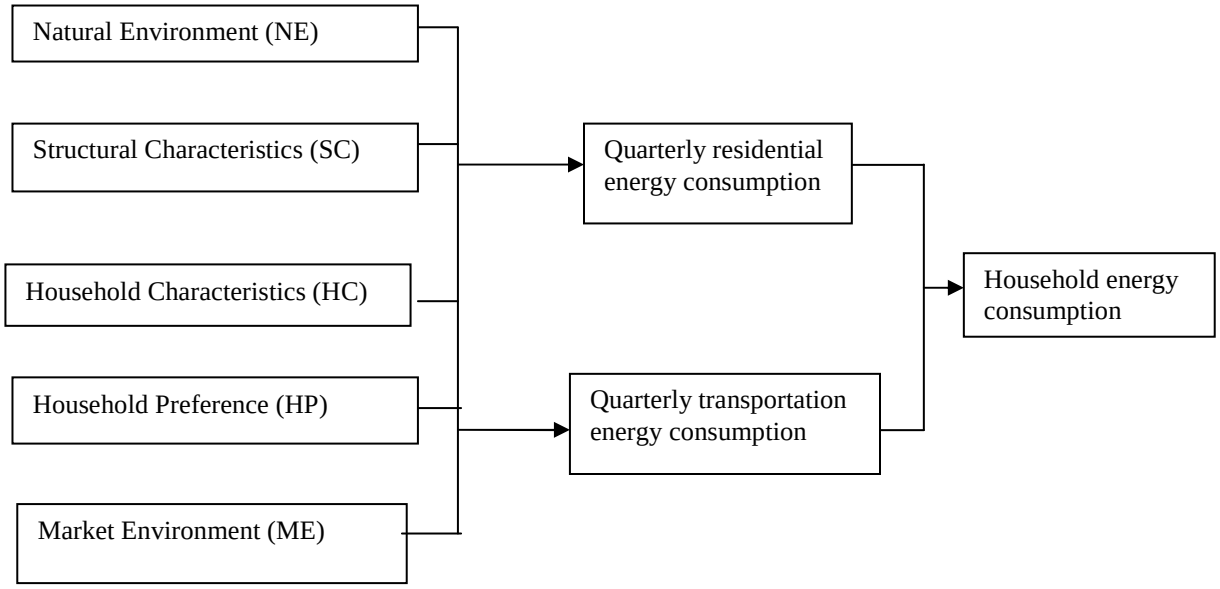

Figure 2. Factors influencing household energy consumption
Modified from Yust et al. (2002)

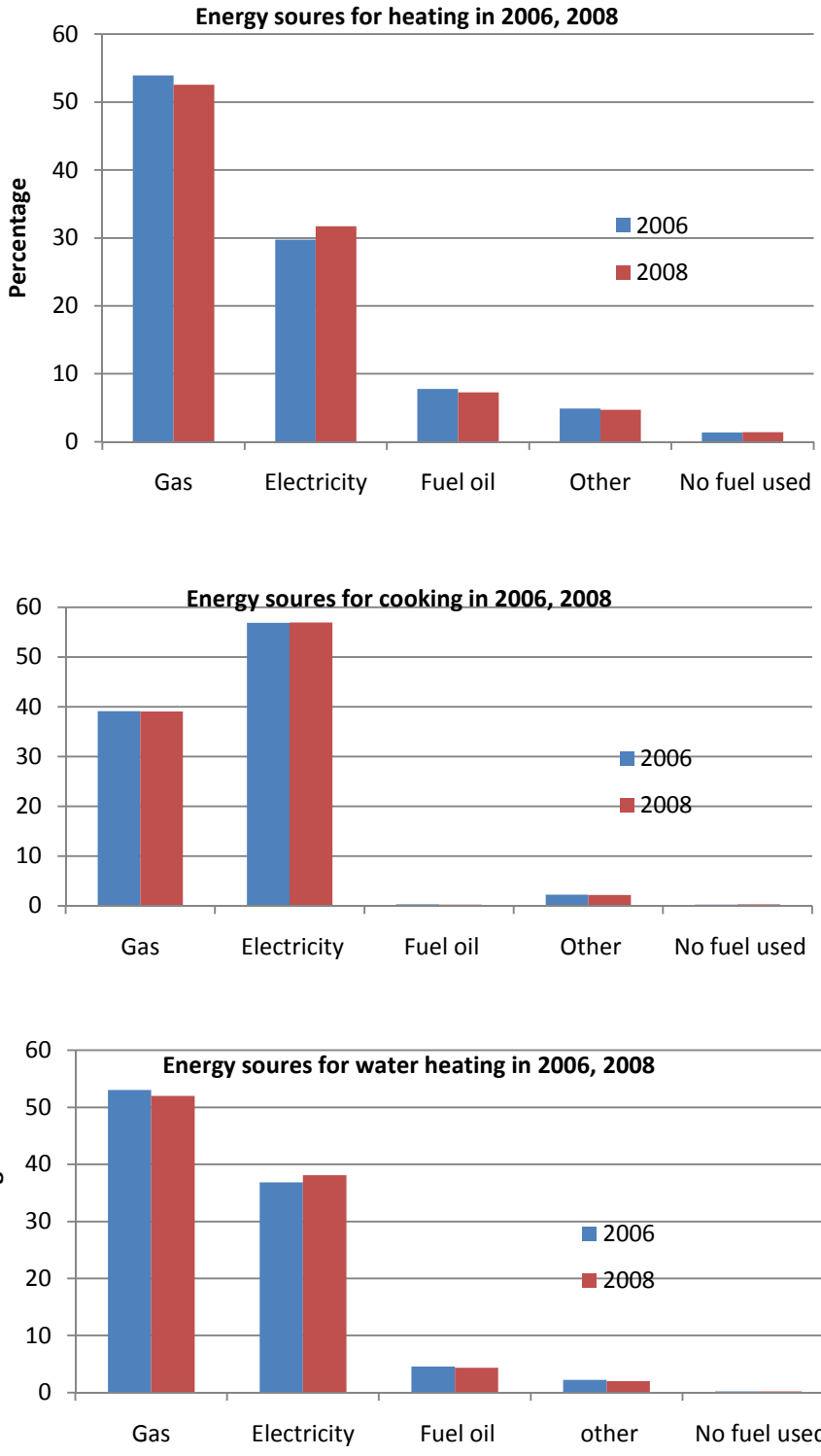

Fig. 3: Energy sources for major residential activities.
Sources: Consumer Expenditure Survey (2006, 2008)

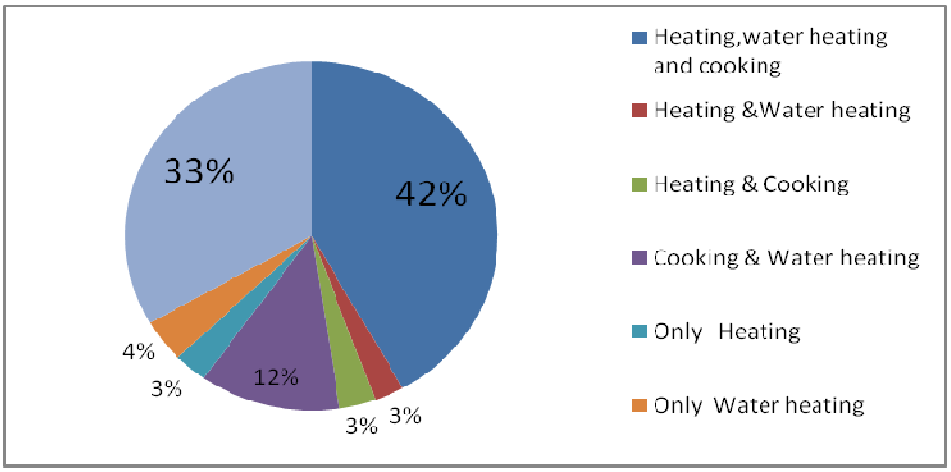

Fig. 4: Household Electricity Use Structure in 2008.
Sources: Consumer Expenditure Survey, 2008

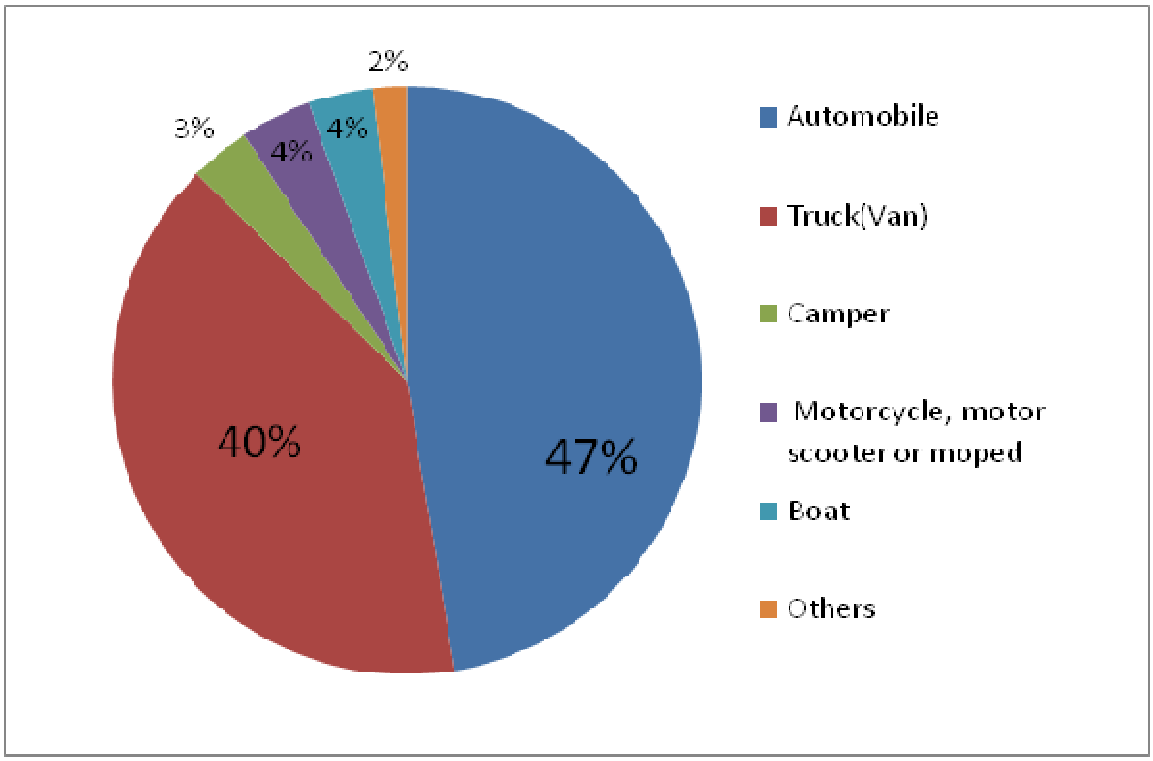

Fig.5 Household Vehicles Type in 2008.
Sources: Consumer Expenditure Survey, 2008

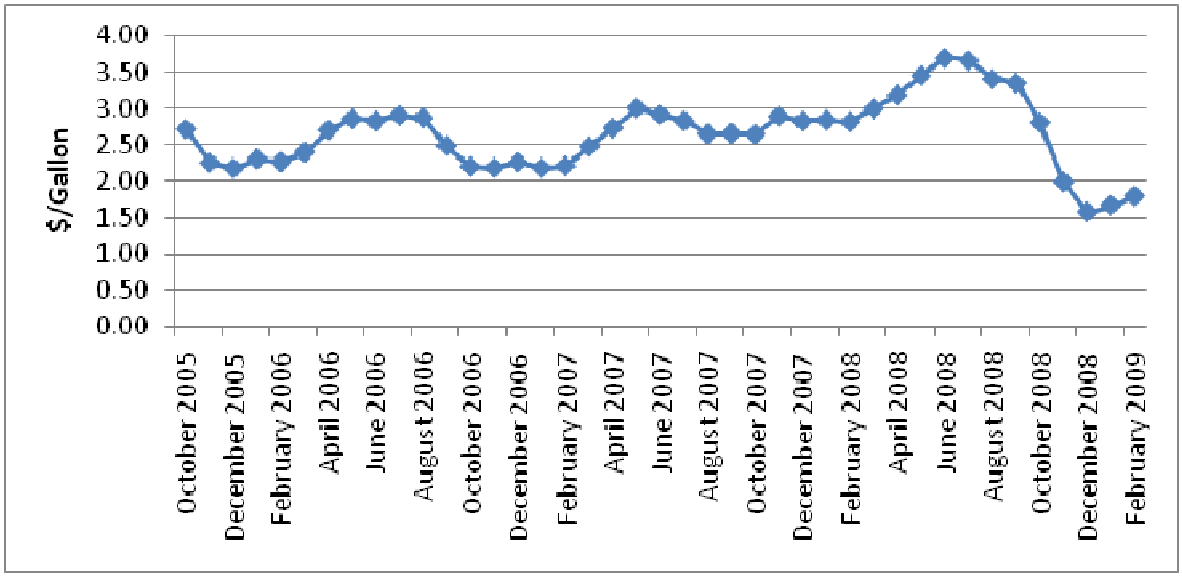

Fig.6 Real Motor Gasoline Price from 2005.10 to 2009.02(Base=October 2005).
Sources: Short-Term Energy Outlook, EIA (2010)

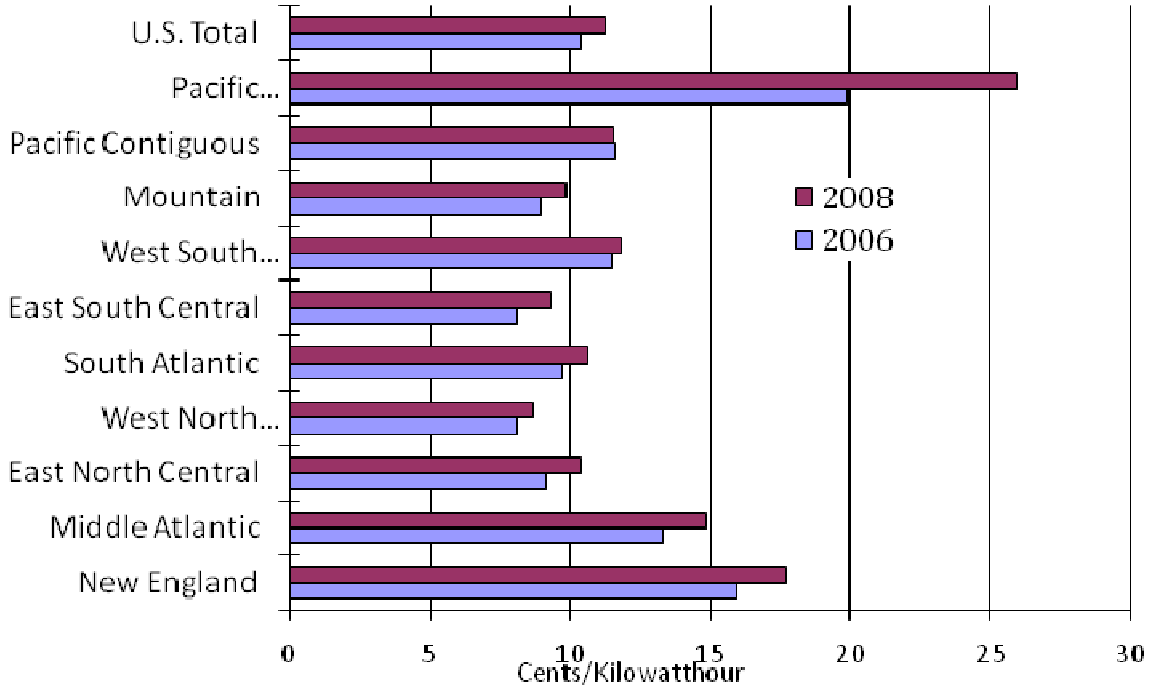

Fig. 7 Electricity Prices by Region in 2006, 2008.
Sources: Electric Power Monthly, EIA (2006, 2008)