Household Energy Use and Travel: Opportunities for Behavioral Change

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ABSTRACT:

While some studies have analyzed household energy use patterns, there is little data about the connections between such patterns and energy policy opinions. This study acquires and examines such data for the Austin metropolitan area and attempts to infer directions for fruitful energy policy. A sizeable majority of the population-corrected 856 respondents recognized global warming as a problem (95%) and agreed that lifestyle changes are needed to combat climate change (85%). Many also believe that climate change can be combated by application of tighter policies in vehicle technologies (68%), fuel economies (86%) and better home and building design strategies (85%). Current energy consumption trends suggest that savings in energy and major reductions in emissions are likely to come from fuel economy improvements, rebates offered on relatively fuel-efficient vehicles purchases, home heating and cooling practices, caps on maximum household energy use and long-term behavioral shifts.

INTRODUCTION

Rising energy prices, concerns about climate change, and national energy security are hot topics of debate, both globally and nationally. Reducing energy consumption directly addresses each of these issues. In the midst of such discussion, information regarding households' current energy consumption via travel and home use will no doubt be helpful in crafting local, regional, and national policies to address all three issues. To this end, a detailed survey of energy use, practices, and opinions on energy and transportation policies was developed and its over-1,200 responses are analyzed here.

Significant behavioral changes are often difficult to inspire and short-lived. Certain travel choices can be particularly resistant to change. King et al. (2009) found that "stated willingness to change behaviors is largely high. However, willingness to change transport behaviors is consistently lower than willingness to change non-transport (e.g. domestic) behaviors." In addition, people would rather make changes in trip chaining, tire inflation and speeds, and even destinations than mode choice (Bomberg and Kockelman, 2008; King et al., 2009).

Much of the choice behavior and attitudes toward transport and energy cannot be explained by demographic factors (King et al., 2009). This study attempts to better understand these attitudinal differences, specifically for the Austin metropolitan population.

DATA ACQUISITION

Questionnaire Design

In fall 2008, graduate students at the University of Texas at Austin (UT) designed a 10-page, 5-section self-completion questionnaire with five sections covering personal travel choices and opinions, vehicles owned, home design and energy use, opinions on energy policy, and basic demographics. They included ranking questions, multiple-choice questions, and stated and revealed preference questions.

The Transportation section focused on respondents' travel patterns – both short- and long-distance. It also asked questions to determine the stated response to both higher gas prices and lower transit fares. There were several questions on working from home and teleconferencing, asking if the respondent participated in either, and questions designed to better understand the reasons for such behaviors.

The Vehicles section asked for a listing of currently owned vehicles, annual vehicle-miles traveled (VMT) for each vehicle, and a ranking of key features in selecting a new vehicle. This section also asked a variety of questions to determine attitudes toward several different policies which encourage the purchase of energy-efficient vehicles.

In the Home Design and Energy Use section, questions emphasized household attributes, including monthly electric and natural gas consumption.

The Energy Policy section described a variety of policy scenarios and asked whether the respondent would support or oppose each. For example, it asked about household energy use caps and increased energy costs, as well as the use of bio-fuels, nuclear power plants, and carbon capture and sequestration for reducing greenhouse gas (GHG) emissions.

Finally, in the Demographics section, the survey sought basic information such as age, household size, and income.

Choice of Neighborhoods for Distribution

The survey was personally distributed across six neighborhoods in the Austin metropolitan region: Westlake, Far West, Hyde Park, East Austin, Sunset Valley, and Manor. Strategic cluster sampling of neighborhoods and streets was used in order to ensure a variety of household demographics. The six neighborhoods represent a valuable cross-section of the Austin metropolitan area in terms of ethnicity, wealth, population density, and transit access, while moderating data acquisition time and costs.

For example, Hyde Park enjoys high transit use, walking, and biking since it is dense (4,048 households/square mile), centrally located, and convenient to many bus routes and destinations. It also is home to many University of Texas (UT) students reside, so its average household size of 1.75 persons is rather low in comparison to Austin, Travis County, and the entire three-county metropolitan statistical area. East Austin also exhibits above average transit use due to its relatively high population density and bus availability (2.64 households/square mile). The area has relatively high proportions of low-income and minority households with lower vehicle ownership rates, who will be less likely to own and rely on personal vehicles as a primary means of transportation.

In contrast, Westlake households exhibit some of the highest rates of household energy usage in the metropolitan area. These residents rely on at least one personal vehicle for transportation, as the area has low density (297 households/square mile) and not a single bus stop. The area is also home to some of the highest income levels in Austin. In Manor it is likely that most residents rely primarily on the automobile for the majority of their travel, due to the very low density of development (46 households/square mile) and bus stops (0.9 stops/square mile), which provides an interesting contrast to some of the other chosen neighborhoods. Sunset Valley and Far West are more "average" neighborhoods than the other four, with moderate availability of bus alternatives (35.6 and 17.3 stops/square mile, respectively) and relatively average incomes. Residents of these areas will most likely have access to personal vehicles, but may supplement these with occasional public transit, bicycle, or walking trips. Far West, in particular, is expected to have a significant level of public transit trips due to its location along one of the UT shuttle lines. Also, Sunset Valley's high density of retail employment (977 jobs/square mile) makes it an unusual suburban setting, though land use mix is not high. Sampling all these neighborhoods implies a complete analysis of Austin area households.

Demographic data was obtained from the Capital Area Metropolitan Planning Organization's (CAMPO's) 2005 estimates. For each neighborhood, lists of apartment complexes to survey were developed; these apartment managers were contacted ahead of time in order to obtain permission to visit and distribute surveys.

Survey Distribution

A variety of techniques were used to distribute the survey to Austin-area residents. The most time-intensive technique consisted of canvassing homes across the six neighborhoods to distribute paper questionnaires, which was accomplished by three pairs of students over the course of two sequential weekends.

The survey was also available online (www.energysurvey.co.nr) in order to reach a wider audience. In addition to canvassing neighborhoods, the team created flyers with tear-off tabs containing the survey's URL. These flyers were posted in apartment laundry rooms, on community bulletin boards, and on campus information poles. The team also handed out surveys in front of Central Market Grocery Store's North Lamar location in an attempt to reach people outside of the University realm and outside the sampled neighborhoods. Additionally, the team created small cards with a short description of the survey and its URL and left these in public places, as well as with those who were too busy to take the paper survey immediately. Students with ties to the Austin community handed out surveys to friends and family. Finally, the team enlisted the help of 160 community organizations, from the regional transit agency and the University of Texas to the lesser-known Austin Pug Club and Heart of Texas Orchid Society, to distribute the survey's URL through their networks.

DATA DESCRIPTION

Weighting

Sampling weights were assigned to each record according to each respondent's demographic representation in the dataset, versus in the 3-county population. All records were weighted, though some records did not have all desired demographic information to weight properly. The initial sample size was 1,200, but only 856 could be assigned weights. In other words, 344 records were lacking some of the demographic information used to compute the weights (due to item non-response) and hence left out.

The sample set was divided into 720 categories (in a multi-dimensional space) based on gender (male, female), age (six categories), worker status (worker, non-worker), student status (student, non-student), household size (1,2,3,4,5+) and household income categories (low [<$30,000 per year], medium [$30,000 to $75,000] and high income [>$75,000] households) using the Census 2000's 5% Public Use Microdata Sample (PUMS). Cells housing zero counts (in either the sample or PUMS data sets) were merged with adjacent cells. Ratios of census-to-sample counts were then normalized, resulting in 856 usable records for data analysis. Workers were under-represented in the sample data, and students over-represented (due to use of student email lists in some of the response solicitations, as shown in Table 1). With respect to other demographic attributes, like gender and age, the sample averages are similar to the PUMS data set.

Geo-coding

Once all of the questionnaires were received, respondents' addresses were geo-coded using TransCAD and matched to Austin's database of traffic analysis zones (TAZs). The questionnaire requested home addresses, but not all respondents provided usable location information. Presumably to preserve privacy, some respondents provided only zip codes, which could not be linked to a particular TAZ. Others left the question entirely blank.

Addresses along relatively new streets could not be found using TransCAD. Due to non-response, response error, and other matching issues, only 717 (84% of the 856 weighted records) were geo-coded to a TAZ. Supplementary datasets were prepared for the three-county Austin region using CAMPO land use data for the year 2000 and CAMPO's 1997 road network. These datasets provide variables like household and population counts, developed land (in acres), household, population, and neighborhood densities, employment counts (by industry sector), land values, and improvement value (per developed acre), and network distances to the region's Central Business District (CBD), the UT campus, and Austin airport at the TAZ level of resolution. Based on this data, each geo-coded survey record could be assigned land use attributes for the respondent's home location.

RESULTS

General Observations

This section of the report presents descriptive statistics (using sample weights) for responses to several important questions. It also presents some preliminary investigation into the characteristics of the respondents. The mean values from the surveyed population, along with values from Census 2000 for Austin and the National Household Travel Survey, are reported below.

Table 1: Summary of Household Characteristics

Variable	Minimum	Maximum	Average	Standard Deviation	Census 2000 Average
Number of vehicles	0	5	1.461	0.820	2.06
"Own house" indicator	0	1	0.652	0.477	0.448
Number of persons per household	1	26	2.538	2.018	2.40
Number of workers per household	0	20	1.577	1.450	1.33
Age	20	70	38.83	14.80	32.34
Female indicator	0	1	0.497	0.500	0.51
Income ($/year)	5,000	200,000	82,056	53,9	47,212

Gender proportions of the sample are in line with the Census estimates of Austin's population. There were certainly more students in the sample than the overall population, which is expected as the internet sample was somewhat more heavily targeted towards the student groups. The sample is also biased towards more educated people, with 70% of the respondents holding a bachelor's degree or higher. This is also reflected in the sample's very high mean income as compared to the mean income according to the 2000 Census. The average number of vehicles per household in the sample is 1.46, which is slightly lower than the national average of 2.06 (NHTS 2001). The number of persons in a household and number of workers per household are also similar to the Census estimates.

Figure 1 provides a summary of weighted responses to the survey question of actions the respondent thinks the government and public should take to control greenhouse gas emissions.[1] Most people (84%) agreed that lifestyle changes are necessary to combat the problems of global warming and climate change. The second most popular response (69%) is the belief that research and development will provide solutions to this problem. Fewer people (16%) were willing to live with restrictions on their own greenhouse gas emissions, underscoring the inertia present in individuals when changes in personal behavior are involved (Gärling and Axhausen, 2003; Kitamura and van der Hoon, 1987). Very few believe that global warming is not a problem (5%) or that nothing should be done (3%).

[1] Respondents could provide more than one answer.

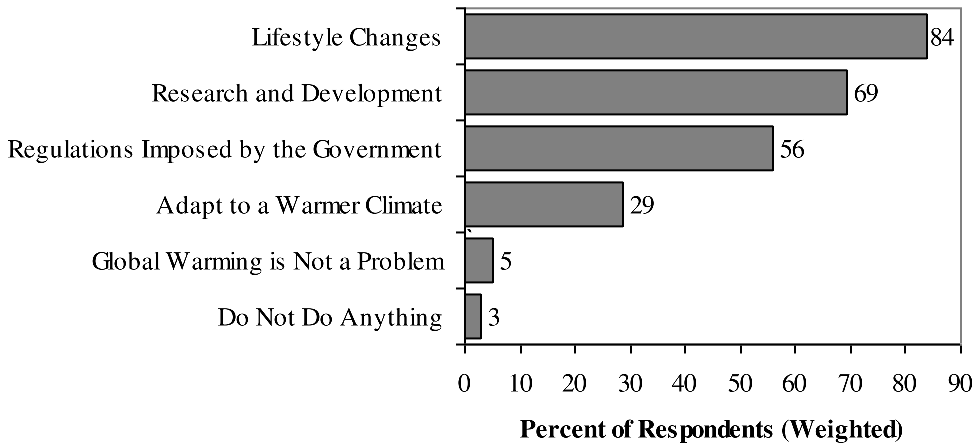

Figure 1: What Should We Do?

Figure 2 shows responses to questions regarding perceptions about climate change, willingness to accept personal responsibility for this change, and opinions on regulating options. These results are generally consistent with earlier findings of Curry et al. (2007), who found that there is a rise in awareness over time of the global warming problem in the U.S., as 49% of respondents consider it to be one of the top two most important problems as compared to only 21% in 2003. These results are also very consistent with Resource Systems Group's findings that 46% of the individuals believe "carbon emissions from my vehicle contribute to climate change" (Resource Systems Group, 2009). In this survey, a majority (95%) of the respondents agreed with the fact that it is everyone's responsibility to do their part to reduce greenhouse emissions. Also, many individuals seem to believe that current levels of consumption are changing the environment rapidly.

Two possible actions that could be taken to combat climate change – direct taxation of or a cap on energy use – were introduced in this survey. As Figure 2 shows, 48% of respondents agreed at some level with taxing energy use, while only 41% agreed with caps on energy use.

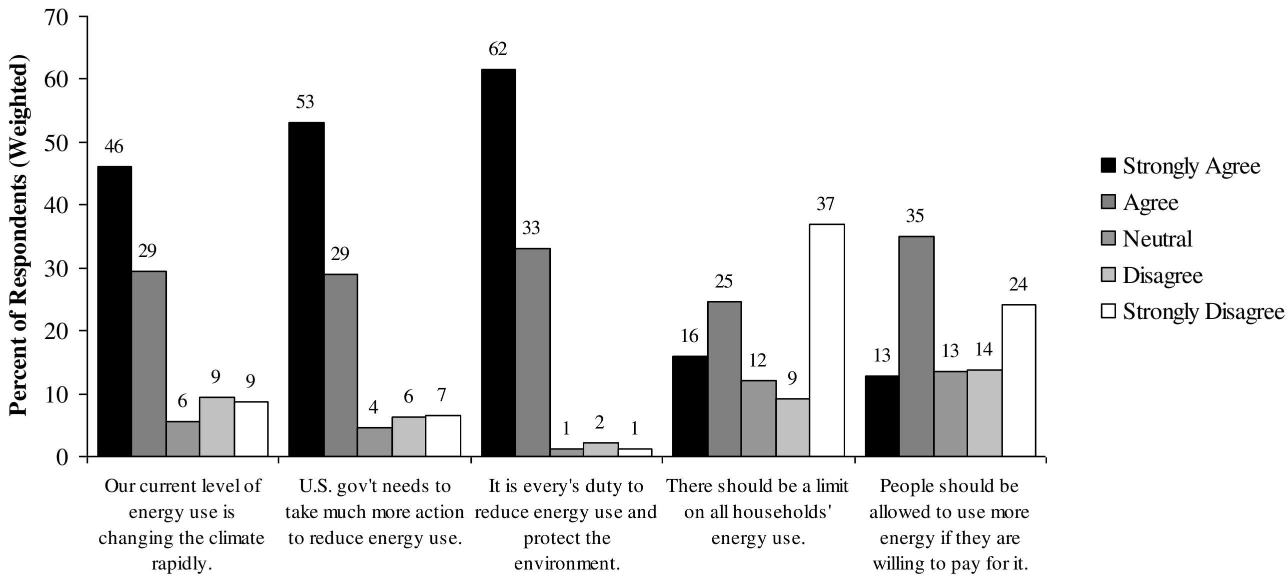

Figure 2: Opinions on Responsibility and Regulation

Table 2 shows the level of support for different policies to combat climate change. The most strongly supported policy measure (the measure with the lowest average score) is an increase fuel economy standards. Stricter appliance and building efficiency standards are also relatively favored. These may be popular because they do not involve any direct impact on individual lifestyles.

Table 2: Statistics on Support for Policies to Combat Climate Change (Weighted)

Policy Measure	Average Response (1=Strongly Support)	Standard Deviation of Response Values
Stricter vehicle fuel economy standards (example: 40 mpg fleet average)	1.60	1.03
Require strict energy efficiency standards on virtually all new buildings	1.66	0.98
Offer rebates to consumers for purchasing very fuel efficient vehicles (like hybrid & plug-in hybrid vehicles)	1.73	1.05
Require Energy Star™ standards on all household appliances	1.74	1.02
Carbon capture & sequestration (where GHG emissions are stored, rather than allowed to enter the atmosphere)	2.32	1.04
Impose a limit on GHG emissions and allow trading of purchased emission credits	2.34	1.17
Energy taxes (example: $50 per ton of GHG produced by electricity generation and motor fuel use)	2.40	1.21
Triple nation’s production of biofuels	2.73	1.24
Build 5+ nuclear power plants	2.74	1.37
Increase motor fuel taxes by $1 per gallon	2.94	1.49

Note: 1 indicates “strongly support,” 2 indicates “somewhat support,” 3 indicates “neutral,” 4 indicates “somewhat oppose,” and 5 indicates “strongly oppose.

Interestingly, the least popular policy option is a motor fuel tax increase. The lack of increase in this tax has pushed the Highway Trust Fund to a zero balance recently (fall 2008). Many have found that gas price has relatively little impact on bahavior (Small and van Dender, 2007; Puller and Greening, 1999) and many argue for increased fuel efficiency standards (Greene et al., 1999; Goldberg 1998; Thorpe 1997). The European Union’s current new sale fleet average is at 42 mpg and Japan averages 47 mpg

(An and Sauer 2004). Also relatively unpopular are nuclear power plants and biofuels. The true long-term carbon implications of both these energy sources have recently been questioned in technical and some non-technical literature (Searchinger et al., 2008, Clayton, 2007).

Requirement of stricter energy efficiency standards on new buildings was the least controversial policy option, with a response standard deviation of 0.98, and requiring Energy Star standards on household appliances was very close behind at 1.02. Both of these options require minimal effort or cost to the respondents, resulting in their populatity. On the other hand, increasing motor fuel taxes by $1/gallon was the most controversial option, with a standard deviation of 1.49. The significant impact this option would have on individuals and families causes the general population to be divided as to its importance.

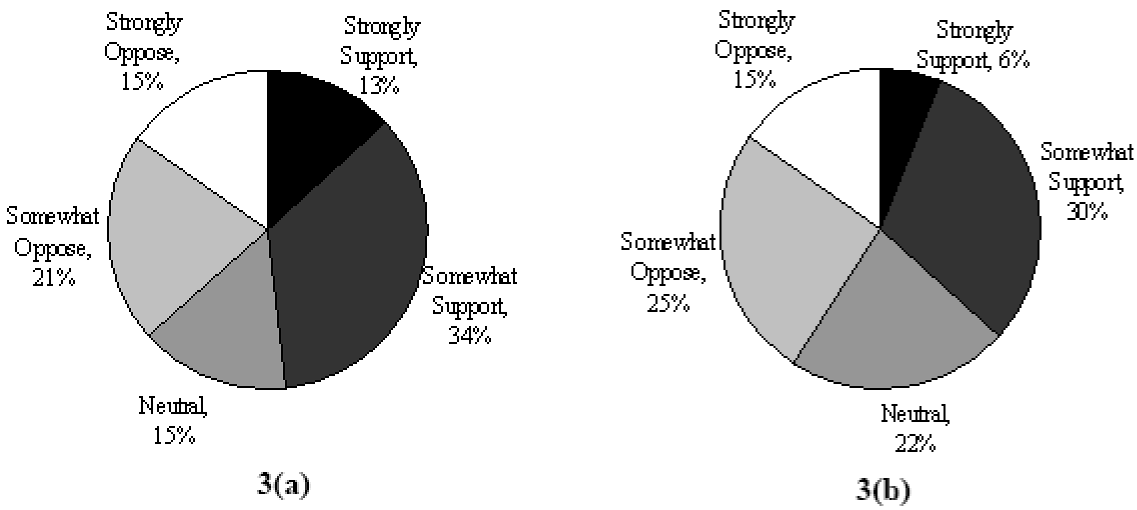

Figure 3 (a) Response for Capping Household Energy Consumed & (b) Response for Taxing all Energy Use

The above pie charts show the distribution of responses for the two proposed policies. In general, respondents tend to favor caps more than taxes. This may be because people with a high income who can afford such expenditures are not in favor of making lifestyle changes imposed by the capping policy. A correlation of 0.17 exists between the two ordered responses.

MODELS

Several models were run on the sample data. Summary statistics of all independent variables used can be seen in Table 3. Models included weighted least square analyses for annual fuel use and VMT per person, home size, and average monthly electricity use. A Poisson regression was used to estimate number of vehicles in a household, opinions about actions to take regarding climate change were analyzed with a binary probit, and a bivariate ordered probit model was used to analyze opinions on different regulation options.

Table 3: Summary Statistics

Variables	Minimum Value	Maximum Value	Average Value	Standard Deviation
Dependent Variables				
Yearly fuel usage per person (gallons/year)	0	3,408.3	423.25	393.26
Annual VMT per person (miles)	0	62,500	7,662.1	6,801.1
Home size (square feet)	500	5,000	1,685.9	855.91
Monthly electricity consumption (kWh)	200	15,542	1,770.6	1,486.9

Vehicles per household	0	5	1.461	0.820
Independent Variables				
Location Variables				
Distance to CBD (from centroid of home TAZ to Austin's CBD in network miles)	0	33.3	5.731	5.271
Population density (persons per acre in home TAZ)	0	29.67	4.295	3.68
Population density with distance to CBD greater than 6 miles	0	205.32	1.296	6.615
Job density (jobs per acre in household's TAZ)	1.821E-03	152.1	7.582	20.77
Household density (households per acre in TAZ)	0	78.95	1.170	2.955
Median income of zone	0	169,634	41,347	26,347
Number of transit stops in home TAZ	0	72,545	260.79	3,506
Individual Variables				
Age of respondent (years)	20	70	38.83	14.80
College-educated (has attained Bachelor's degree or higher)	0	1	0.734	0.442
Worker status (indicator variable for whether or not the respondent is employed)	0	1	0.37	0.49
Household Variables				
Household size	1	26	2.538	2.018
Number of children	0	4	0.4	0.821
Number of adults	1	26	2.178	1.997
Number of workers	0	20	1.577	1.450
Income of household ($1,000)	5	200	82.056	53.949
Income per person (household income / household size, $1,000)	1.25	175	37.585	25.945
Number of vehicles	0	5	1.461	0.820
Annual VMT per household member	0	62,500	7,662.1	6,801.1
Own home (household owns home or is paying off mortgage, rather than renting)	0	1	0.652	0.477
House Variables				
Home size (square feet)	500	5,000	1,686	855.9
Age of home (years)	0	59	32.25	17.90
Two- & three-story detached house indicator	0	1	0.249	0.433
Rooms in home	1	14	5.013	2.314

Annual Fuel Use

A least squares regression for fuel use per household member was run using sample weights. The dependent variable was calculated by dividing the vehicle miles traveled for each household vehicle by its fuel economy (to estimate annual fuel use by vehicle). These values were summed across household vehicles and then divided by the household size. Independent variables include demographic and location attributes, as shown in Table 4.

Table 4: Yearly Fuel Usage per person

Variable	Coefficient	T-statistic	Mean Elasticity
Constant	388.18	6.42	-
Population density with distance to CBD greater than 6 miles	-11.043	-1.51	-0.022
Distance to CBD	16.6	5.08	0.218
Number of transit stops in a TAZ	-1.17	-2.43	-0.069
College-educated	-101.18	-3	-0.170
Income per person	9.25E-04	1.3	0.080
Number of children in a house	-71.17	-4.6	-0.065
Age of respondent	1.58	1.5	0.140
R^2	0.1263		
Adjusted R^2	0.1169		

Note: Weighted least squares regression was used;
y=gallons per year per household member; n=717

The number of children in a household has a negative effect on fuel consumed per person in a household. Interestingly, as the educational qualifications of a household increase, the fuel consumption increases, but as the educational level increases, fuel consumption is reduced. As a person's age increases, the amount of vehicular travel he/she does is increased. Increased distance to the CBD leads to increased fuel consumption; this is predictable, as many of these individuals will live in the suburbs and generally require longer trips to work and other destinations. Also, as the number of transit stops in the residential area increase, the fuel consumption per person is predicted to fall. These results are consistent with the findings of Bhat et al. (2008) regarding the significance of land use variables on household vehicle holdings and usage.

Annual VMT per Person

A weighted least squares regression was run to predict annual vehicle miles traveled (VMT) per household member. The results of this model are shown in Table 5.

Table 5: Annual VMT per person

Variable	Coefficient	T-statistic	Mean Elasticity
Constant	5903	5.30	-
Population density with distance to CBD greater than 6 miles	-209.49	-1.68	-0.023
Population density	124.6	1.71	0.069
Distance to CBD	314.4	5.42	0.231
Number of transit stops in a TAZ	-16.34	-2.18	-0.054
College-educated	-1437	-2.67	-0.135
Income per person	0.0203	1.77	0.099
Number of children in a house	-1385	-5.48	-0.071
Age of respondent	25.46	1.46	0.127
R^2	0.1289		
Adjusted R^2	0.1191		

Interestingly, as the income per person increases, VMT per person is estimated to fall, but VMT is expected to increase as the education level of the household increases. As the age of the respondent increases, VMT predictions increase. As the distance to the CBD increases, many trip lengths go up, increasing a household's fuel consumption and VMT. According to this model and many others that have been analyzed [Feng et al. (2005), Kurani and Turrentine (2004), Gallagher and Muehlegger (2007), Mohammadian and Miller (2003)], auto dependence needs to be reduced in order to successfully tackle pollution and emissions.

Home Size and Monthly Electricity Consumption

A weighted least squares regression was used to predict the size and monthly electricity demands of a home. Table 6's dependent variables are the total square footage of the dwelling unit and the monthly kWh (average of summer and winter months) consumed by a household.

Table 6: Model Results for Home Size and Monthly Electricity Consumption

	Square Footage			Monthly Electricity		
Independent Variables	**Coefficient**	**T-statistic**	**Mean Elasticity**	**Coefficient**	**T-statistic**	**Mean Elasticity**
Constant	1006	8.28	-	701.9	4.15	-
Household size	44.16	1.55	0.0669	77.30	2.95	0.1109
Worker status	143.1	1.80	0.0316	-	-	-
Income of household ($1,000)	3.9E-03	6.39	0.1897	1.164E-03	1.13	0.0540
College-educated	-221.8	-3.72	-0.097	-	-	-
Age of home	-9.09	-5.77	-0.1754	2.70	1.05	0.0491
Own home	424.5	5.41	0.1654	-186.7	-1.42	-0.0688
Number of vehicles	222.7	5.28	0.1946	-	-	-
Number of adults	65.15	1.98	0.0849	-	-	-
Job density	-1.718	-1.83	-0.0077	-	-	-
Population density	-21.19	-2.94	-0.0544	-25.05	-0.98	-0.0608
Two- & three-story detached home indicator	-	-	-	355.2	3.26	0.05
Home size	-	-	-	0.4918	6.46	0.4687
R^2	0.3646			0.1958		
Adjusted R^2	0.3542			0.1844		

The estimated effects of Table 6's explanatory variables on home size and electricity consumption follow expected trends. Average single-family home size has increased about 1% per year, on average, since 1978, from 1,750 to 2,500 square feet (NAHB, 2008). The trend shown in this model reflects this historical relationship because as the age of the home increases by one year, the size of the home is predicted to decrease by approximately seven square feet. Home ownership usually indicates that it is not a multi-family unit, and single family units and condos are typically larger than apartments (by 283 square feet, on average, here). In addition, as household size and income increases, square footage also increases. Each owned vehicle is also associated with a rise in home size.

The estimates of kWh obtained in the sample are not accurate enough to predict energy consumption. About 34% item non-response was found in the energy consumption question. The estimates are in line with the 2001 Residential Energy Consumption Survey (RECS) which includes data for 4,822 U.S. households. Regression models using the RECS data suggest that the addition of one household member or 100 square feet of space will increase average monthly household energy consumption by 104 kWh and 22 kWh, respectively. Results from this Austin sample suggest something similar, on the order of 90 kWh and 60 kWh, respectively. The mean U.S. values for kWh consumed per month and home size in the RECS data are 900 kWh and 2,100 square feet, respectively. Comparatively, these Austin data average 1,200 kWh and 1,645 square feet. Though Austin home sizes may be smaller, the hot summers result in higher-than-U.S.-average electricity demand.

Number of Vehicles Owned by a Household

To estimate vehicle ownership levels, a Poisson count model specification was used. Table 7 gives these results.

Table 7: Model Results for Number of Vehicles Owned by a Household

Independent Variables	Coefficient	T-statistic	Mean Elasticity
Constant	-0.1572	-1.29	-
Household Size	0.03949	2.75	0.1002
Income per person (total income/household size)	1.82 E-06	1.30	6.84 E-02
Age of respondent	2.50 E-03	1.17	9.70 E-02
Own home	0.3619	4.45	0.2360
Region Specific Variables			
Distance to CBD	9.50 E-03	1.68	5.44 E-02
Job density (jobs per acre in TAZ)	-4.00 E-03	-1.54	-3.03 E-02
Log Likelihood at Convergence	-946.9		
Pseudo R^2	0.03		

As income per person rises, ownership levels also rise – an intuitive result of increased disposable income. Households tend to own more number of vehicles when they also own their homes. As job density increases, vehicle holdings decline; additionally, as distance to the CBD increases, the number of vehicles increases at twice the rate of the decline due to job density. These results are consistent with the findings of Fang (2008). Prillwitz et al. (2008) also report that zonal characteristics and changes in demographic attributes affect travel behavior and vehicle ownership changes. Additionally, results obtained by Zhao and Kockelman (2000) complement the findings of the overall model. Finally, a negative binomial regression was estimated as an alternative to the poisson count model to check for the over dispersion in the dependent variable (vehicle ownership). But the LR test resulted in accepting the null hypothesis that there was no over dispersion in the dependent variable and the poisson count model was similar to the negative binomial model.

Opinions on What Should be Done about Climate Change

Binary probit models were used to illuminate respondents' opinions on whether the U.S. should impose regulations on all kinds of energy use and whether Americans should adapt to a warmer climate. Solid majorities of respondents agree that regulations need to be imposed on energy use and disagree that we should simply adapt to a warmer climate (72.5%). The correlation between the two responses is 0.08.

People who own more vehicles are less likely to favor regulations being imposed on energy use and tend to share the opinion that we need to adapt to a warmer climate. This may be because they are less willing to change their accustomed lifestyles, which, being vehicle-oriented, are also likely to be energy-intensive. Households with more disposable income per person are likely to support regulations being imposed perhaps because they can afford such kind of regulations like gasoline tax or higher electricity bills. Households located in high income zones are highly in favor of adapting to a warmer climate because they can afford high electricity utility bills by continuous usage of cooling systems or air conditioning units.

Those individuals who own larger homes, which imply greater levels of energy use, also tend to disagree with the idea of regulations on energy use. Model results (Table 8) indicate that women and younger persons are in support of having regulations imposed to curb energy use. This same difference in agreement on the paired statements is seen with men and workers. Potoglou and Kanaroglou (2007) explain that in stated choice experiments, respondents always appear to be highly sensitive to the environment, while in reality, their environmental sensitivity may be lower. Therefore, these model results are simply estimates of what might happen and not necessarily indicative of reality. Bivariate binary probit model was also estimated to check for correlation between the two responses but the covariance between the equations residuals was not significant at the 95% confidence level and hence the results are not presented.

Table 8: Model Results for Opinions on What Should Be Done about Climate Change

	Adapt to a Warmer Climate		**Regulations Should be Imposed**	
Explanatory Variables	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**
Constant	-1.842	-5.30	0.9243	3.43
Age of respondent	-	-	-0.1468	-3.63
Female	-0.5626	-5.26	0.2725	2.73
Worker status	0.2709	1.92	-0.3179	-2.11
Number of vehicles owned by household	0.3563	4.33	-0.1085	-1.42
Income per person (total income/household size)	-	-	4.20E-06	1.79
Square footage of home	-3.47E-04	-4.34	-2.03E-04	-3.18
Own home	0.4909	3.30	0.2267	1.70
Distance to CBD	-0.0293	-2.48	-0.0236	-2.23
Household density (households per acre in TAZ)	0.1097	3.25	0.1095	3.20
Median income of zone	8.48E-06	5.37	-	-
Log Likelihood at Convergence	-383.9		-449.9	
Pseudo R^2	0.1267		0.0895	

Note: Binary probit was used.

Capping Energy Use vs. Taxing All Energy Use

Climate change is one of the planet's top issues. The US contains 4% of the world's population but produces 25% of all GHG emissions (BBC 2002). Transportation is responsible for 32% of U.S. GHG contributions (EIA 2007), and energy demands by residences are responsible for another 21% (EIA 2007). The two prevailing options for abatement of carbon emissions discussed are either a cap-and-trade system or a carbon emissions tax.

In a cap-and-trade system, the "cap" refers to an upper limit on the amount of carbon dioxide emissions that may be emitted from the use of electricity, oil, natural gas, or food. "Trade" refers to the system in which households or firms can buy or sell the rights to emit carbon, called credits. Carbon tax, by contrast, is a less complex option that requires carbon emitters to pay a tax for every ton of carbon emissions they produce. The government would set a price per ton on carbon, which would translate to a tax on gasoline, diesel, natural gas, electricity and other sources. This would induce households and firms to reduce consumption and move towards more carbon efficient means (for instance shifting to fuel efficient vehicles).

The correlation between the ordered responses is 0.17. As presented in Table 9, Only 2.8% of respondents completely support both of the policies. A majority of the respondents (21.9%) agreed that a cap should be placed on maximum energy use, but all energy used should not be taxed. Interestingly, a majority of respondents somewhat supporting the cap policy (36.70%) came from the somewhat support (11.40%) and somewhat oppose (11.20%) of the taxing policy.

Table 9: Comparison of Responses for Opinions on Capping Maximum Energy Use and Taxing Energy Use (Weighted Shares)

Comparison between the two policies		Tax on all energy use					
		Strongly Support	**Somewhat Support**	**Neutral**	**Somewhat Oppose**	**Strongly Oppose**	**Total**
Cap on maximum energy use	**Strongly Support**	23 2.80%	36 4.30%	18 2.20%	25 3.00%	24 2.90%	126 15.20%
	Somewhat Support	24 2.90%	95 11.40%	53 6.40%	93 11.20%	40 4.80%	305 36.70%
	Neutral	7 0.80%	29 3.50%	67 8.10%	25 3.00%	9 1.10%	137 16.50%
	Somewhat Oppose	3 0.40%	49 5.90%	17 2.00%	56 6.70%	13 1.60%	138 16.60%
	Strongly Oppose	9 1.10%	22 2.60%	19 2.30%	21 2.50%	54 6.50%	125 15.00%
	Total	66 7.90%	231 27.80%	174 20.90%	220 26.50%	140 16.80%	831 100.00%

Ordered probit and bivariate ordered probit models were used to analyze whether a cap should be placed on maximum energy use or whether all energy used should be taxed. The bivariate ordered probit model was estimated in STATA using the Sajaia's (2005) code. The standard errors are lower in the bivariate model, as expected, providing efficient estimates. Table 10 presents the estimated results. Results show that concerns about climate change tends to be higher among younger respondents than older respondents because age has a positive coefficient for both the dependent variables. This is consistent with the results of Bannon et al. (2007). As number of vehicles increases people tend to support the idea of having a cap on maximum energy use rather than taxing all energy use, which is expected because more vehicles available for use imply more travel and hence more energy use, resulting in greater potential taxes. This is contrary to the results obtained by Curry et al. (2007) which showed a positive correlation between higher energy use (higher electric bills) and willingness to pay for carbon taxes.

Table 10's model results indicate that men and workers are more unlikely to support energy taxes. Model results show that as the number of people in a household increase, which results in greater energy usage and hence a tendency to support taxes. Income per household member has a negative coefficient on capping maximum energy use, which is expected, since households with less disposable income per person are likely to be against greater rates of taxation. This result is coherent with the findings of Bannon et al. (2007). People who live in older homes tend to not support a cap or tax. Though the two dependent variables represent opinions on two distinct policies, the correlation coefficient is positive (0.1792) and significant at the 95% confidence level, suggesting that the more environmentally- or energy-conscious respondents favor both strategies in order to reduce energy consumption and CO_2 emissions.

Table 10: Model Results for Opinions on Capping Maximum Energy Use and Taxing All Energy Use

	Cap on Maximum Energy Use		Taxing all Energy Use	
Explanatory Variables	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**
Number of vehicles owned by household	-0.1174	-2.37	0.0772	1.39
Age of respondent	-	-	0.2137	7.14
Female	0.1739	2.36	-0.1587	-2.11
Worker status	-	-	0.2591	2.38
Income per person (total income/household size)	-3.47E-06	-2.13	-	-
Household size	0.0338	1.74	-0.0319	-1.54
Own home	-	-	-0.2032	-2.02
Age of home	-3.52E-03	-1.84	-6.13E-03	-2.99
Square footage of home	-	-	2.39E-04	4.64
Threshold 1	-1.786	-12.49	-0.1828	0.97
Threshold 2	-0.5681	-4.30	0.9261	4.89
Threshold 3	0.0223	0.17	1.352	7.07
Threshold 4	0.8272	6.23	2.122	10.78
Log Likelihood at Convergence	-2430			
Log Likelihood at Constants	-2467			
Covariance across equations' residuals	0.1792	4.63	-	

Note: Bivariate ordered probit was used.

CONCLUSIONS

Household energy use is a critical, yet complex, topic. This survey investigated household energy use patterns and energy policy opinions in the Austin metropolitan area. Very little research has been done on the connections between these patterns and opinions, despite the implications for future local, state, and national energy policies. Using a combination of revealed and stated preference questions, respondents provided insight into their daily energy use and their feelings about climate change and energy regulations. Through a variety of analytical model types, a great deal of information was obtained from the sample.

Most Austinites' (95% of the population corrected sample to represent Austin) appear to agree that climate change is a concern, but most (40%) also are unwilling to change their own behavior. Energy caps and taxes are generally supported by those who would not feel the direct impact of such policies (e.g., families with larger homes are less likely to support energy caps, which may have a direct impact on the energy used in their home), with greater support for caps than taxation. Despite the potential impacts such policies would have on their lives, 32% and 43% of (population-corrected) respondents are indifferent to direct taxation and capping of energy consumption, respectively. Support for energy caps and energy taxes is highly correlated, confirming the notion that individuals who are more environmentally-conscious also feel positively about a variety of energy-reduction measures.

Women, younger persons and high income households are in agreement to taxing energy use and regulations being imposed to reduce energy consumption. Household status variables age, household size, income and number of cars owned in the household had a strong impact on energy consumed and type of residential unit by the household.

There are significant opportunities for further research in this field. Additional information about opinions on energy policy from a variety of metropolitan areas can provide policy-makers with a vital source of information about preferred directions for the U.S. to take. Moreover, further analysis of the energy usage behavior of households could provide insights into practical methods to reduce the energy required for daily activities. The results of this survey and future research are particularly important in light of current global warming and climate change policies being considered by all levels of government.

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